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Closing the loop: Increasing fashion circularity in California

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While reading the report, please keep in mind that our quantitative analyses are based on the primary and secondary data sources cited throughout the report. We also note key assumptions behind calculations. All quantified values are illustrative, indicating a direction or trend, rather than a definitive data point.

Contents

Executive summary

The fashion value chain is predominantly linear and global. It has put the apparel industry on an unsustainable path.

In 2020, Californians bought and wore 510,000-530,000 tons of clothing.[i] Some 500,000 of those tons will eventually enter landfills —– covering an area about 3.5 times the size of the City of Los Angeles.[ii] More than 97 percent of the textiles used in this clothing are virgin materials. Less than 1 percent of the materials worn today will resurface in clothing manufactured tomorrow.[iii]

Such waste requires transformative change. The key lies in circularity —– specifically, in building a closed loop for recycling materials back into the manufacturing process, reducing both waste and reliance on natural resources.

To date, California has seen relatively little investment in (or research into the benefits of) closed-loop recycling of apparel, so progress on building collection, sorting, and recycling capacity to execute this process has remained limited. We launched this research to understand what effort building a closed-loop system in California will require, what stakeholders need to participate, and what initial impact the effort may have.

Our research shows that the effort promises to be very worthwhile.

California consumers want closed-loop recycling. Our survey results revealed the following:

Among surveyed consumers, 54 percent anticipate buying more clothes made with recycled materials.[iv]

— Younger Californians (18-24-years-old) report a willingness-to-pay premium of almost 15 percent for clothes made with recycled materials.[v]

— 92 percent of surveyed consumers would participate in a brand-sponsored apparel recycling program, if offered the opportunity.[vi]

A fully closed-loop apparel recycling system in California could potentially achieve a total holistic impact (economic, environmental, and social benefits) of $7-9 billion a year, based on our estimate of total holistic impact of approximately $3.5-4.5 billion from closed-loop recycling of polyester, which represents nearly 50 percent of apparel textile fibers thrown away by Californians.[vii] That translates into holistic impact of $2.70 for every $1.00 spent.[viii] Scaled up across the US, closed-loop apparel recycling could achieve a total holistic impact of $50-70 billion.[ix]

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i Sum of all imported finished apparel and apparel manufactured in-state, less the quantities exported or lost throughout the production and retail process (see Chapter 2, Exhibit 5 in the main report for a further breakdown and assumptions): Sources: "Crop production annual summary," US Department of Agriculture Economics, Statistics, and Market Information System, January 12, 2022; interviews with fashion / circularity experts (October-December 2021); "Preferred fiber and materials market report 2021," Textile Exchange, August 2021; "The lifecycle of secondhand clothing," Simple Recycling, October 2014;, 2022; "Textiles: Material-specific data," US Environmental Protection Agency, last updated July 2, 2021; "Textiles and apparel," US International Trade Commission, 2018, accessed 2021; American Chemistry Council, "2020 guide to the business of chemistry," December 2020, accessed 2022.

ii Assumes about 85-90 percent, or about 455,000 tons, of apparel sold to and worn by Californians ends up in landfills through curbside municipal solid waste (MSW) collection. An estimated 25,000 tons of production losses and 15,000 tons of deadstock also end up in landfills through curbside MSW collection. Of the remaining tons of apparel used by Californians and collected through other channels (i.e., donation centers, consignment stores, drop-off containers, mailed-collection programs, curbside textile collection programs, and in-store take-back programs), about 5 percent, or 5,000 tons, is ultimately landfilled. See Chapter 2, Exhibit 5 in the main report for a further breakdown and assumptions. Average weight of, and average m2 of fabric required to manufacture, a t-shirt and pair of jeans used to convert estimate of weight of apparel eventually landfilled to surface area: Sources: Interviews with fashion / circularity experts (October-December 2021); "The lifecycle of secondhand clothing," October 2014; "Textiles: Material-specific data," July 2, 2021 ; What Things Weigh, "How much does a pair of jeans weigh?," n.d., accessed 2021; Silver Bobbin, "How much does a t-shirt weigh (with examples)," n.d., accessed 2022; Venus Zine, "How many yards to make a pair of pants?," January 27, 2022; Leonard M. Pitt, "Los Angeles, California, United States," Encyclopedia Britannica, March 10, 2022.

iii "A new textiles economy: Redesigning fashion's future," Ellen MacArthur Foundation, January 12, 2017.

iv McKinsey 2021 California Fashion Circularity Survey (conducted in October 2021).

v Ibid.

vi Ibid.

vii Holistic impact includes environmental, social, and economic benefits: CO2e emissions abatement, water-use reduction, land-use reduction, chemical-use reduction, job creation, GDP growth from job creation, revenue growth, and cost savings. The $50-70 billion potential holistic impact for the US is based on sizing for the polyester use case in California. Since pure and blended polyester apparel accounts for an estimated 49 percent of all apparel, an estimated multiplier of two can be used to roughly size the total holistic impact for California of switching from virgin to recycled apparel for all fiber types (e.g., polyester, cotton, man-made cellulosic fibers), which would be an estimated $7-9 billion. Additional detail on an initiative-by-initiative level is available in the main report: Sources: Reverse Resources, "How much does garment industry actually waste?," February 1, 2021; Interviews with fashion / circularity experts (October-December 2021); "Preferred fiber and materials market report 2021," Textile Exchange, August 2021.

viii Capital expenditure (CapEx) and operating expenditure (OpEx) estimates were calculated at a high level for each individual initiative and were based on public data inputs and cost estimates from experts in the apparel and textile waste management industries. Additional detail on an initiative-by-initiative level is available in the main report.

ix Since California's retail industry accounts for approximately 13 percent of US GDP, an estimated multiplier of seven to eight can be used to roughly size the holistic impact for the US from switching to recycled apparel from virgin for all fiber types: Source: "Gross domestic product (GDP) by state," US Bureau of Economic Analysis, October 1, 2022, accessed November 2021.

Closed-loop recycling of polyester... translates into holistic impact of $2.70 for every $1.00 spent

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$7-9 billion

Total holistic impact - economic, environmental, and social benefits - from creating a closed-loop apparel recycling system in California (scaled up across the US, closed loop recycling could achieve a total holistic impact of $50-70 billion)

We identified eight core initiatives that could significantly advance fashion circularity for apparel made with polyester (100 percent or blended) in California and help unlock this holistic impact. Future efforts could build on these initiatives to address other textile materials:

— **Purchase recycled polyester to replace virgin polyester in apparel**, probably at a premium, but with few other switching costs involved.

— **Promote and sell recycled apparel to shoppers**, touting clothing “made with recycled polyester”.

— **Partner with apparel manufacturers to collect pre-consumer polyester waste**, such as scraps and rejected apparel that manufacturers discard.

— **Partner with retail stores to collect pre-consumer polyester waste**, such as unsold garments that are typically thrown away if not diverted for low-cost resale or donation to employees.

— **Partner with existing collectors, such as donation or consignment stores, to divert post-consumer polyester waste** that would otherwise be downcycled or sent abroad.

— **Introduce and scale curbside textile collection in Los Angeles, San Francisco, and select Bay Area counties** because the high cost of curbside collection makes it most viable in densely populated metropolitan areas.

— **Build a highly automated facility to sort and deconstruct polyester textiles** because the inability of recycling processes to handle more than one type of textile waste and the potential for unsorted waste to introduce contamination make sorting necessary.

— **Build a chemical recycling facility to process polyester textiles** because chemical recycling is critical to sustaining the quality of textile fiber over many iterations.

But any effort to build closed-loop recycling capacity faces a “catch 22” —— the disconnect between the supply of and the demand for recycled materials. While benefits outweigh costs system-wide, both benefits and costs are distributed unevenly among stakeholders across the value chain. Unlocking the total holistic impact will require actions to level the playing field, such as forging public-private partnerships, enacting recycling-friendly policies, and encouraging vertical integration in the apparel industry.

The California apparel industry can start building closed-loop recycling capacity today to reduce waste and reliance on limited natural resources. We hope that this report will establish the opportunity at stake for textile circularity in California as well as the actions stakeholders across the fashion industry can take to capture it. Furthermore, we hope this report can serve as the foundation for further research and action across other materials and geographies, catalyzing even more positive economic, environmental, and social benefits.

Chapter 1

Introduction to fashion circularity

In its current form, the fashion industry is on a path to consuming more and more resources and generating more and more waste. In 2018, the global fashion industry generated about 4 percent of all greenhouse gas emissions globally.[1] Less than 1 percent of clothing purchased today is eventually recycled back into new clothing.[2] The industry faces an existential decision — degrade the habitat where its consumers live or completely reinvent operations and capture new value, meeting customer expectations for sustainable action by businesses.

Circularity could anchor the fashion industry's reinvented operations. Building a more circular value chain could address environmental issues and also improve social and economic indicators by creating new jobs and opportunities for economic expansion.

Circularity has three dimensions that would reshape the typical fashion lifecycle:[3]

Reduce. How can we design and manufacture products that use more safe, recycled, or renewable textile materials (e.g., organic cotton)?

Reuse. How can we keep products in use longer (e.g., increase accessibility to resale or secondhand markets)?

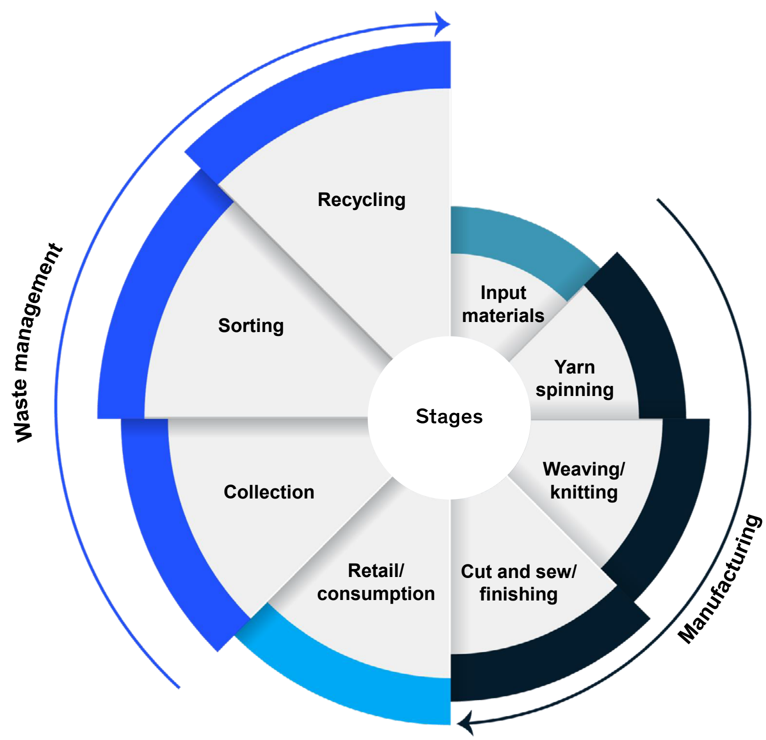
Recycle. How can we turn used textile materials that have reached the end of their useful life into new, high-quality materials that can re-enter the fashion value chain?

While all three dimensions are critical to building a circular economy, this report focuses on the challenges and opportunities involved in recycling materials back into the apparel manufacturing process and building a closed-loop fashion lifecycle in California.

The closed-loop fashion lifecycle

The closed-loop fashion lifecycle consists of eight major stages (Exhibit 1). In today's value chain, most economic activity happens in the front half of the lifecycle, from input materials to manufacturing to retail / consumption. As detailed below, a global network of companies produces raw fibers, yarns, and fabrics for assembly into clothes sold in retail stores. But the industry has little infrastructure to support the three stages of textile waste management — collection, sorting, and recycling — that are critical to closing the loop in the fashion lifecycle.

Exhibit 1
Stages of the closed-loop fashion lifecycle



Achieving full circularity requires a local, rather than a global, model, given the inherently local nature of the collection stage of the lifecycle. In the context of textile-to-textile recycling, conducting these activities within a given region could have incremental impact (e.g., CO2e, emissions abated, water saved) vs. the costs, while creating local jobs and encouraging economic mobility.

But the industry is very far from having a viable local model for circularity. The fashion value chain is predominantly linear and global. More than 97 percent of the materials used in fashion products are virgin materials —— derived from natural resources extracted in raw form, e.g., petroleum used for polyester fiber.[4] Approximately 70 percent of yarn is made in and exported by China, India, Vietnam, and the US, and almost two-thirds of the total finished apparel is exported from China, the EU, and Bangladesh.[5] Many countries participate in the production of clothes made from cotton and synthetic materials (Exhibit 2).

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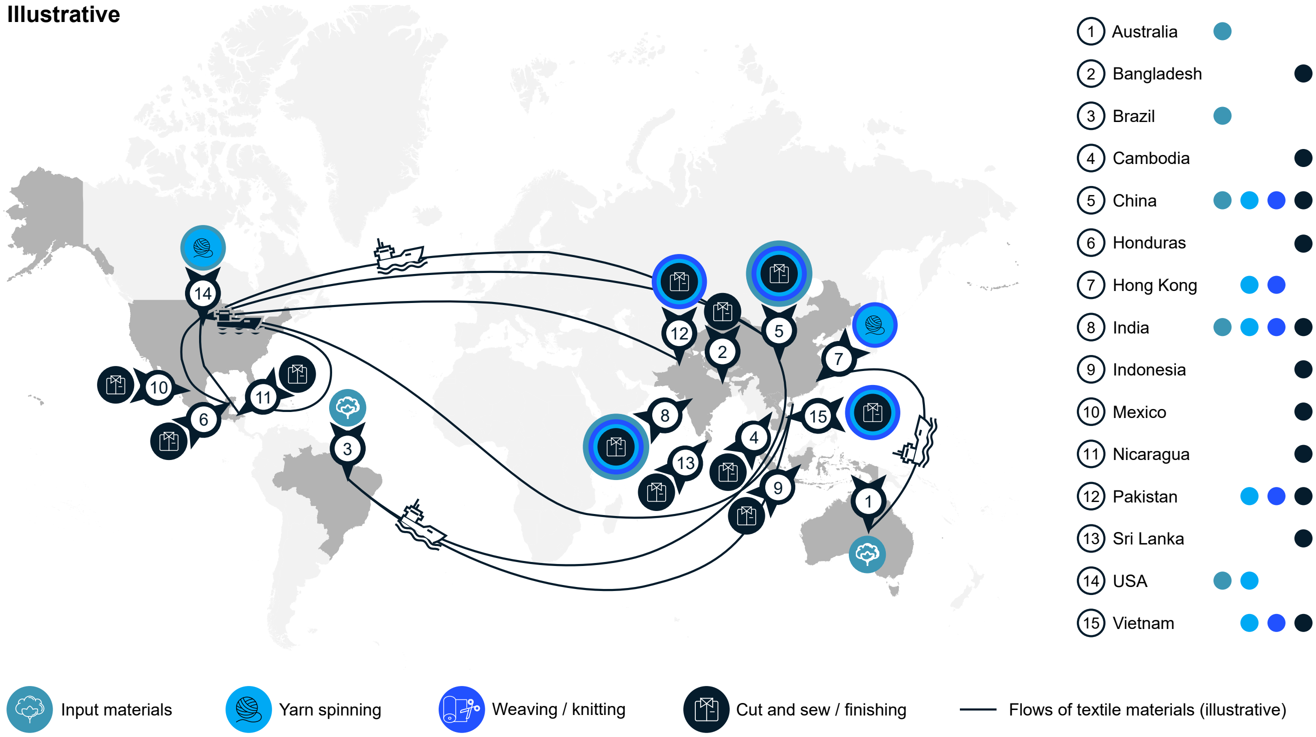
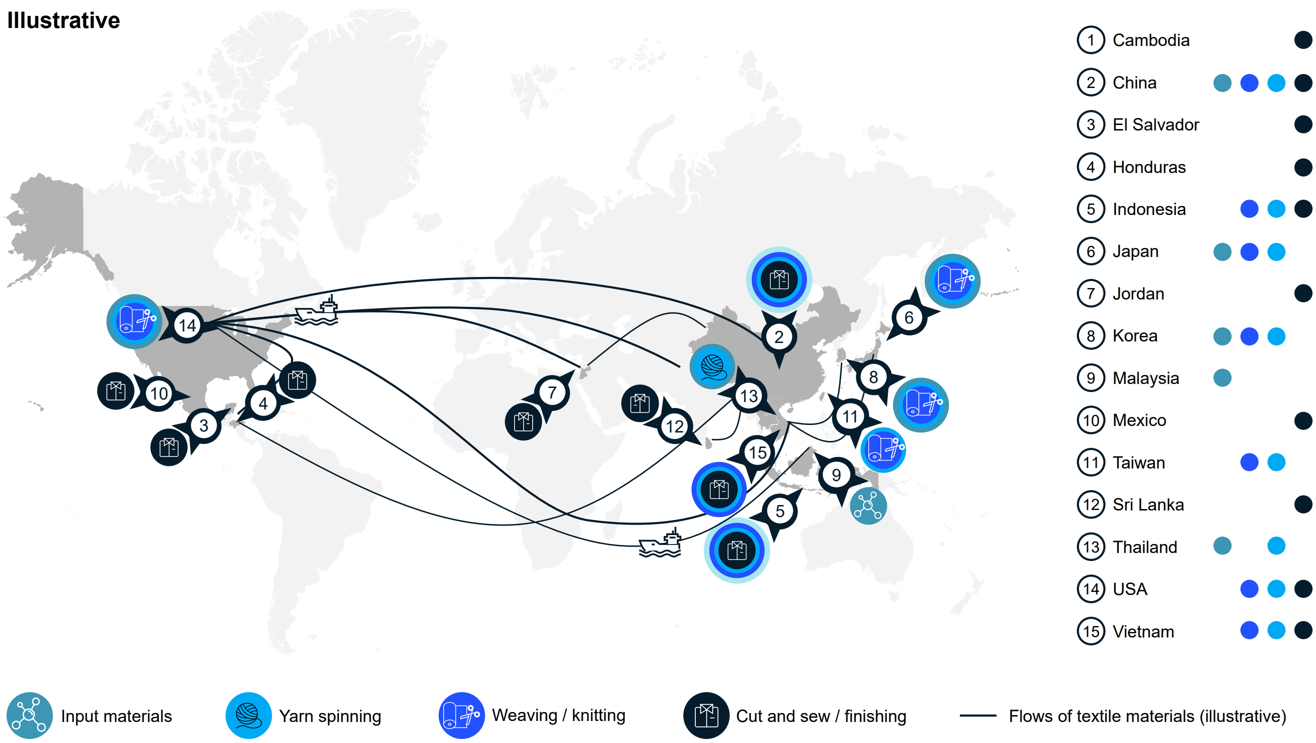
Exhibit 2

The fashion value chain is global

Mapping of primary origins and pathways for a typical cotton garment worn in the US



Mapping of primary origins and pathways for a typical synthetic garment worn in the US



Note: All countries identified above account for 80%+ of trade for output materials of the relevant lifecycle stage (as indicated by the color coding). The size of circle for each country is not meant to reflect relative volumes. This analysis only examines trade data for materials that ultimately end up in a cotton / synthetic garment worn in the US; it is not meant to represent a view of the holistic sourcing potential of the country for any synthetic garment.
Source: OTEXA, UNCOMTRADE data, WITS

Consider the environmental impact of producing a standard t-shirt (Exhibit 3). A t-shirt made exclusively from polyester emits ~11 kilograms of CO2e, consumes ~380 liters of water, leverages ~1+ pounds of chemicals, and uses 2-7 m2 of land during production.[6]

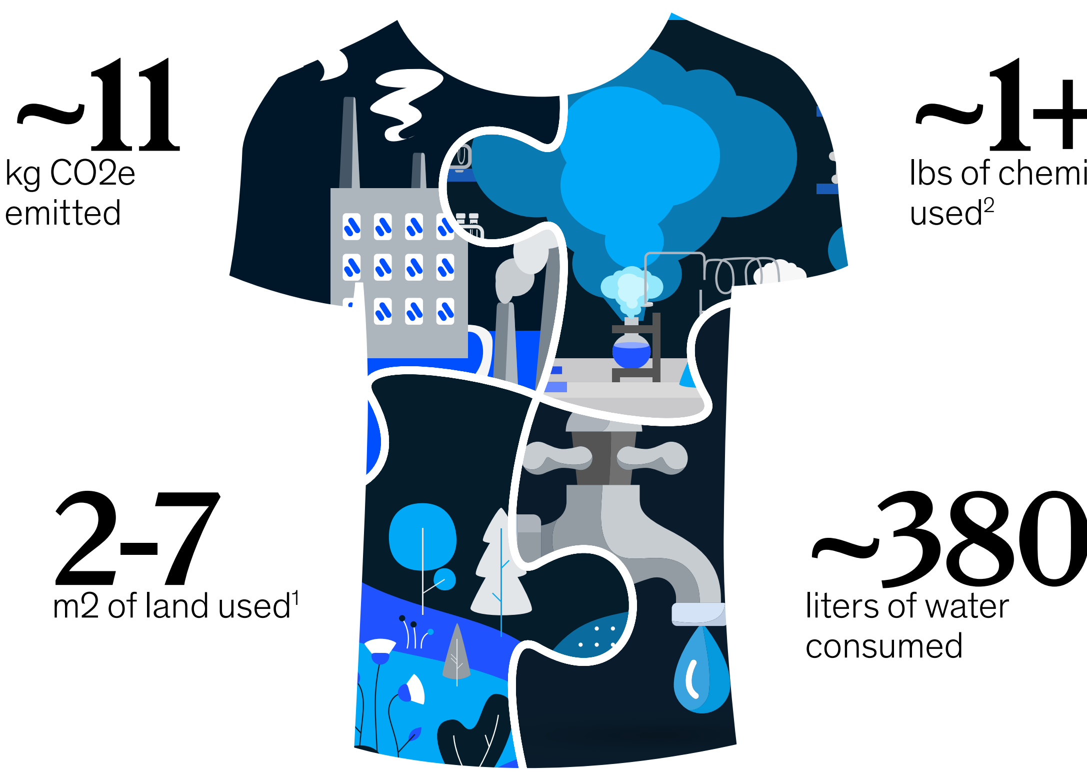
The activities at the front end of the apparel value chain cause most of this environmental impact (Exhibit 4). Raw material production, processing, and garment manufacturing account for the lion's share of a typical garment's impact —– 70-75 percent of the fashion industry's emissions.[7] Spinning and weaving generate 22 percent of the holistic climate impact, including impact on water and land, across the global apparel value chain; cut and sew / finishing generates 41 percent of the impact.[8]

Significantly reducing this impact would require tailored actions not only in managing pre- and post-consumer apparel waste, but also in sourcing and manufacturing. Circularity includes many of the steps needed to decrease the environmental impact of apparel across its lifecycle.

Exhibit 3

Producing a garment can be resource-intensive

Estimated impact of producing one t-shirt made from polyester



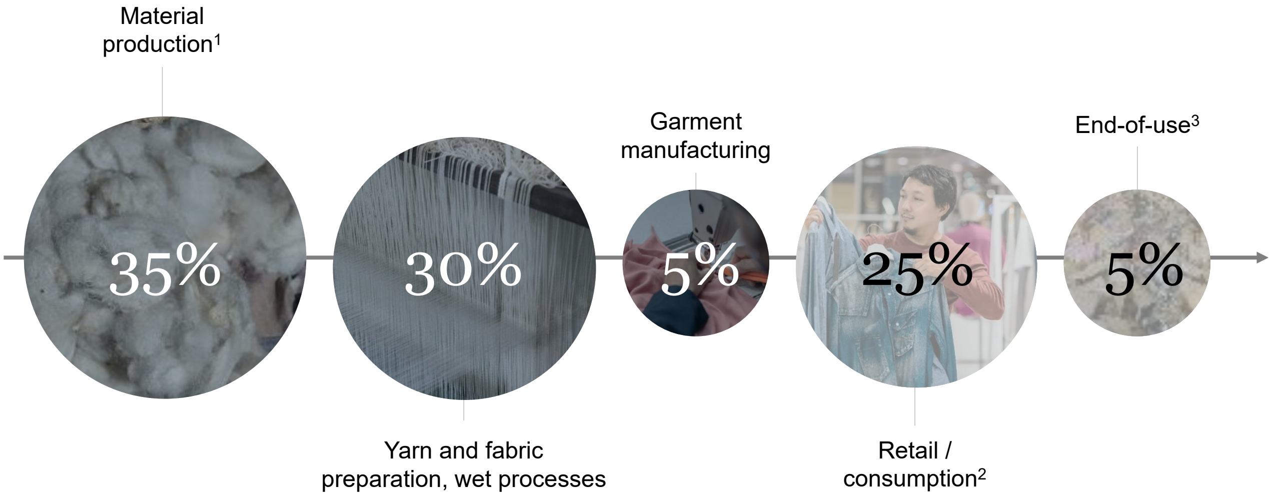
1. Assumes virgin polyester uses ~1.8 hectares (~4.44 acres, or ~1,800 m2) per ton of polyester, or 9 m2 per pound of virgin polyester. It also assumes the average t-shirt weighs 0.25-0.45 pounds and a raw material production loss of 12-30% from fiber to t-shirt, resulting in 0.3-0.7 lbs of virgin polyester used in the average t-shirt.
2. Only accounts for total ethylene glycol and terephthalic acid used in the production of polyester from crude oil (~1.5 lbs per lb of polyester) and assumes 1 t-shirt weighs ~0.3 lbs.

Source: Aviva Dallas, How much does a t-shirt weigh; IHS Markit PEP Yearbook, Terephthalic acid required to produce PET pellets; Interviews with fashion / circularity experts (October-December 2021); Organic Chemical Process Industry, AP-42, Ch. 6.6.2: Poly(ethylene terephthalate); Christian Schindler, Today's challenges for the global textile industry with a special focus on spinning; Zequan Wu, Haode evaluating the lifecycle environmental impacts of polyester sports t-shirts

Exhibit 4

Material production creates the greatest climate impact across the fashion lifecycle

Relative climate impact across the major steps of the fashion lifecycle



1. Final output of the material production process is textile fiber.
2. Impact of microplastics is not considered in this impact sizing.
3. This does not include energy use in the recycling processes.

Source: McKinsey and Global Fashion Agenda, Fashion on climate full report

Input materials

Textile production employs many input materials, but full circularity would require using only 100 percent textile-to-textile recycled materials. That said, recycled materials are not inherently carbon-neutral or chemical-free. Energy and chemicals (depending on the recycling process employed) are still required to recycle end-of-life textiles into new fibers, albeit less of these resources than producing new textile materials from scratch. Various types of new and used input materials can help reduce the carbon or water footprint associated with a particular garment. These materials could vary by type and origin, as described below:

Example input materials, by type:[9]

— **Carbon-neutral or negative**. Material releases net zero carbon emissions or captures carbon during production (e.g., carbon-neutral merino wool)

— **Organic or regenerative organic.** Material sourced in a way that meets standards for soil health, animal welfare, and farmworker fairness (e.g., regenerative organic cotton, organic linen)

— **FSC-certified.** Material comes from forests that meet sustainable forestry certification standards (e.g., FSC natural rubber)

— **Responsibly / sustainably sourced.** Material selected and sourced in a way that reduces environmental impact (e.g., cotton sourced through sustainable practices that conserve water)

— **Non-renewable**. Material selected and sourced without regard for environmental impact or secondary input intensity required

Example input materials, by origin:[10]

— **Renewable.** Material from a source that replenishes naturally (e.g., cotton, renewable sugarcane)

— **Recycled**. Material made from waste (e.g., recycled polyester from PET bottles)

— **Virgin**. Material made from previously unused resources (e.g., polyester from petroleum)

Manufacturing
Apparel manufacturing involves three main stages: spinning to turn input materials into yarn, weaving or knitting to turn yarn into fabric, and cut and sew / finishing to turn fabric into apparel. Improvements in operational efficiency across the three stages can reduce carbon emissions and use of water or chemicals. But applying circularity can reduce environmental impact even further, in addition to delivering social and economic benefits.

Achieving full circularity in the manufacturing process would likely require:

— Making infrastructure and process improvements so manufacturing can better handle recycled textile materials

— Addressing all manufacturing waste (12-30 percent of total textiles used in the garment manufacturing process annually), such as deadstock —— any unsellable and unused inventory, including damaged or incorrectly produced items —— and samples, by improving collection and recycling of these materials.[11]

Waste management
Managing end-of-life textile waste is the key to capitalizing on circularity in the fashion industry. Success requires applying circular principles to collecting, sorting, and recycling waste.

Collecting. Recycling requires the ability to collect end-of-life products. Today, the US collects less than 15 percent of apparel and footwear for recycling.[12] Moving toward circularity, the fashion industry can aspire to get as close to 100 percent collection as possible, but channels and capacity are too few and too small to approach this goal at present. The industry would likely need to create new collection strategies, including take-back programs, mail-back programs, and curbside pickup, to reduce barriers to consumer recycling and apparel- and footwear-specific waste drop-off / pickup locations for large, industrial, and pre-consumer sources of fashion waste.

Sorting. Effective waste management also requires strong sorting capabilities. Ideally, a fully operationalized, automatic sorting center could handle high volumes and diverse textile materials, including complicated fabric blends and items like shoes. Building such a center would require developing advanced automatic sorting technology and scaling up sorting capacity. Capitalizing on the benefits of a local model for recycling and building a network of centers to minimize transportation and maximize access to recycled outputs could also require some standardized sorting guidelines and establishment of predictable supply and demand to enable efficient operations.

Recycling. Full circularity would recycle 100 percent of eligible materials back into apparel and footwear manufacturing and downcycle all materials that are ineligible for textile-to-textile recycling, e.g., cannot be cleaned. This would require significant investment to scale capacity and recycling technology, especially in chemical recycling. Current mechanical recycling processes have higher capacity than chemical recycling processes, but chemical recycling is better suited to maintaining high quality over many iterations.[13]

The potential economic, environmental, and social impact of circularity in fashion makes committing to local circular operations critical. But achieving full circularity in any geography would require addressing a number of significant challenges. Making the right choices would require careful analysis of location-specific factors and development of standardized ways to compare the actions that might enable circularity (e.g., comparing the impact of each investment with the dollars invested).

The following chapters explore the current and predicted states of the apparel industry in California, including the end-of-life challenges to achieving circularity, and consumer perspectives on circularity, including the price elasticity of fashion products made with recycled materials. Finally, using apparel made from polyester as a case example, because it is the most-used textile fiber in the world today (accounts for 52 percent of the world textile market),[14] the final chapter outlines the major initiatives required to achieve circularity in California and offers a tool for analyzing the tangible and intangible benefits of these initiatives.

While this report focuses on polyester-made apparel worn in California, its purpose is to provide a blueprint for evaluating the current state and potential benefits of closing the loop for other materials and geographies around the world.

Chapter 2

California's current fashion lifecycle

Like the global fashion value chain, California's fashion value chain is primarily linear and global. As a result of this structure, of the 510,000-530,000 tons of apparel sold to and worn by Californians today, 490,000-510,000 tons will end up in landfills (covering an area about 3.5 times the size of the City of Los Angeles).[15] Only about 5,000 tons — less than 1 percent of total apparel textiles worn — will be recycled into textiles used in apparel tomorrow. This chapter examines the flows and volumes of apparel in California, from input materials to final disposal of pre- and post-consumer textile waste (Exhibit 5).

Input materials and imported finished apparel

The apparel value chain in California starts with about 1.1 million tons of material.[16] Most is apparel imported into the state as finished goods; but some, about 30 percent, is input textile material produced in California; and an even smaller portion, about 15 percent, is input textile material imported into the state.

The input materials used in the California value chain, both those imported for apparel manufacturing and those used in imported finished apparel, consist overwhelmingly (97 percent) of virgin input materials, with 2 percent recycled materials from non-textile sources and less than 1 percent textile-to-textile recycled materials.[17] This is consistent with fashion value chains around the world.

California also produces some of its own input materials. In 2020, California produced about 350,000 tons of cotton and polyester.[18] Most of the input materials produced in California do not stay in the state for apparel manufacturing. Approximately 80 percent, or about 280,000 tons, is exported, leaving some 70,000 tons for use in California apparel manufacturing.[19] Along with the input materials imported into the state, net re-exports, California apparel manufacturing has about 205,000 tons of input materials available for use each year.

The input materials / manufacturing portion of California's value chain is relatively small compared with the volume of finished apparel imported into the state. In 2020, California imported about 600,000-660,000 tons of finished apparel, mostly from Southeastern Asia.[20] A portion of the imported apparel was re-exported out of the state, leaving approximately 500,000 tons of finished apparel for sale in California.

Manufacturing and deadstock, overstock, and samples

The manufacturing stage of the fashion lifecycle produces significant pre-consumer waste. Of the approximately 205,000 tons of input materials used in California apparel manufacturing, about 20,000-30,000 tons is discarded during the apparel production process (due to reasons like cutting away extra fabric to match the desired shape of a garment or removing damaged input materials).[21] Much of this waste ends up in landfills.

Some 80 percent of the finished apparel made in California goes out of state for sale elsewhere.[22] Of the remaining finished apparel, 5-15 percent never reaches retail stores — it is instead used as samples or relegated to deadstock (including overstock).[23] This means that, of the finished apparel manufactured in the state, about 20 percent is sold directly to Californians. But most, about 75 percent, of the samples and deadstock still gets into the hands of Californians through such channels as direct gifts to apparel retail associates or donations and reuse.[24] Some imported finished apparel also winds up as samples or deadstock.

Whether manufactured in state or imported, approximately 510,000-530,000 tons of apparel are sold to and worn by Californians every year.[25]

490,000-510,000 tons

Total apparel sold to and worn by Californians today that will eventually end up in the landfill

While apparel sold in 2020 will not enter the waste management system for several years, apparel sold in past years has entered or will soon enter the system. On average, an item of clothing has a lifespan of four years or less.[26] Socks last about two and a half years, while items like jackets can last more than six years.[27]

Collecting, sorting, and recycling waste

Given the vast volumes of clothing being sold and approaching end-of-life, California has a tremendous amount of apparel that has been or is about to be discarded. Californians use many channels to dispose of clothing. Curbside solid waste collection, which goes straight to the landfill, is by far the largest. It accounts for 85-90 percent of apparel waste each year, including waste from industrial and residential sources —– about 495,000 tons in 2020.[28]

Several other collection methods divert the remaining 10-15 percent of end-of-life apparel from the landfill in California:[29]

— Donation centers and consignment stores. People bring clothes they no longer want for sale in these stores, both large donation centers and smaller boutique consignment stores. This channel collects 4-7 percent of end-of-life apparel.

— Drop-off containers. These decentralized containers belonging to collection organizations collect 4-7 percent of end-of-life apparel.

— Mailed collection programs. Consumers ship their end-of-life clothing to a collector. These programs collect 0-2 percent of end-of-life apparel.

— Curbside textile collection programs. Separate from the typical waste management service, these programs collect <1 percent of end-of-life apparel.

— In-store take-back programs. These brand-specific programs collect 0-2 percent of end-of-life apparel.

Donation centers and drop-off containers account for the lion's share of collection. Each handles some 25,000 tons of apparel a year. In contrast, mailed collection and in-store take-back programs each handle about 5,000 tons a year, while curbside textile collection handles less than 3,000 tons.

After collection, clothes are sorted to determine what is suitable for selling secondhand, either locally or internationally, for downcycling (or recycling, although today less than 1 percent of textile waste enters true closed-loop recycling), or for sending to the landfill. Donation centers and consignment stores tend to sort on-site in California; the other methods rely on central sorting facilities. Each step of the process adds a small percentage, about 5 percent in total, to the amount of apparel landfilled.[30]

Of the 65,000-70,000 tons of apparel initially diverted from the landfill, about 35,000 tons are sold secondhand; about 25,000 tons are downcycled; about 5,000 tons end up being landfilled; only about 5,000 tons are recycled into feedstock to produce new apparel.[31]

Without changes to apparel lifespans, apparel demand growth, and the path from input materials to final disposal, even more end-of-life apparel will end up in California's landfills. 2020 saw sales of about 2.6 billion units of apparel in California.[32] Based on a projected 1.3 percent CAGR in total units of apparel sold through 2026, apparel sales will reach about 2.8 billion units in 2025.[33] If the landfill rate stays at 85-90 percent, landfilled apparel will reach about 2.5 billion units.

Increasing the collection rate for channels other than curbside solid waste collection or introducing new collection channels would divert more apparel from the landfill. It could also replace demand for apparel made with virgin fibers with demand for apparel made with recycled fibers —– a scenario explored later in this report.

The emissions associated with increasing apparel will also continue to grow. Through 2030, annual emissions growth for synthetics, including polyester and man-made cellulosic fibers, is estimated at 5 percent, and annual emissions growth for cotton and other natural fibers is estimated at 1 percent. These growth rates contribute to keeping our planet well above the emissions levels needed to hold warming at 1.5 degrees Celsius.[34]

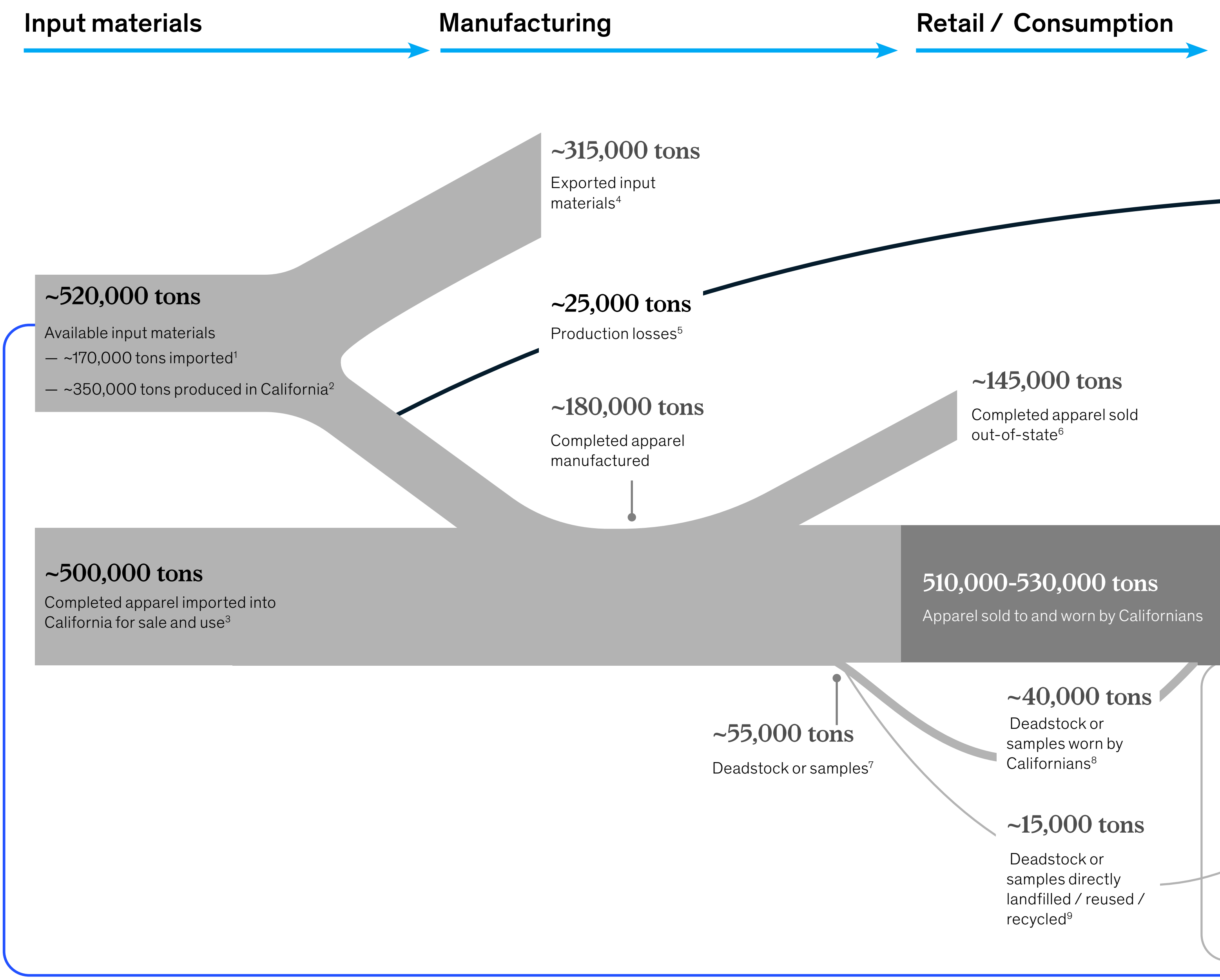
Implications for closed-loop recycling of textiles in California

Increasing collection capacity for pre- and post-consumer waste, combined with increasing recycling capacity, could improve circularity throughout the fashion lifecycle.

Exhibit 5

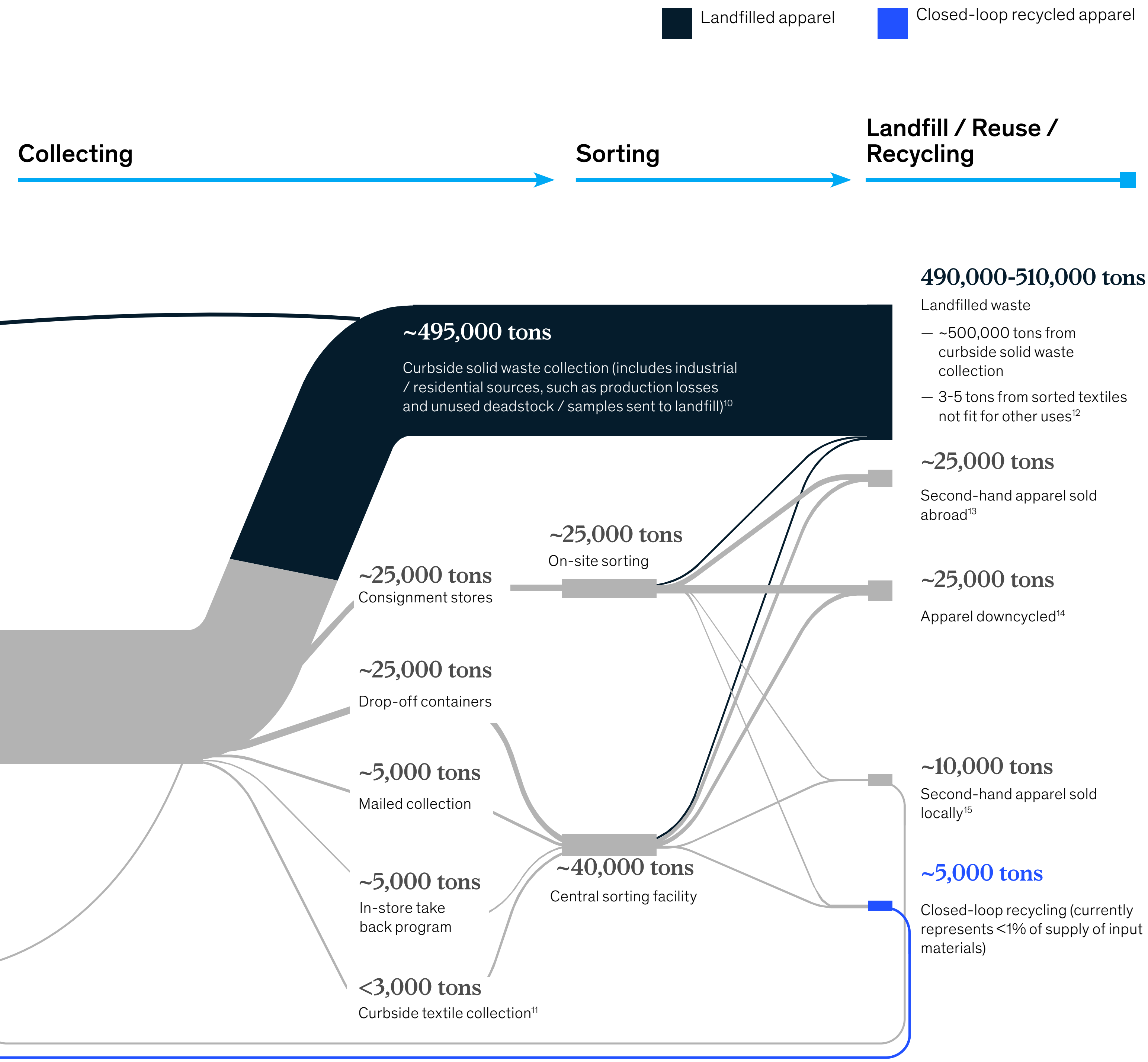
490,000-510,000 tons of apparel used by Californians today could be eventually landfilled; only 5,000 tons are closed-loop recycled

Estimated 2020 California apparel textile inflows and outflows



Note: Width of bars in diagram sized based on volume of apparel flows.

1. Assumes that total materials used to manufacture apparel in California are derived by applying California GDP / US GDP proportion to total US textile fiber imports in 2020 (estimated 65-75% of total textile fiber output is used in apparel) and that 100% of textile material imports are fabrics.
2. Input material production in this case is assumed to be cotton and polyester only. Cotton and polyester made up ~76% of the fiber market in 2020. Remaining input materials production in California is assumed to be negligible. ~605,000 bales of cotton were produced in California in 2020, at an assumed ~480 pounds of cotton per bale; this converts to kilotons to get ~145. US polyester fiber production in 2019 was ~1,275 metric kilotons, and we assume similar production for 2020. A ~2,205 pounds per metric ton conversion helps us reach ~1,405 kilotons US production and ~200 kilotons California polyester production after applying the California GDP / US GDP proportion.
3. Assumes ~600,000-660,000 tons of initially imported completed apparel by applying California GDP / US GDP proportion to total US apparel imports in 2020, then applying the 2019 US textiles and apparel re-export rate of ~20% to get to imported completed apparel that remains for sale to and use by Californians.
4. Assumes ~20% of total imported input materials and ~80% of total input materials produced in California are exported to other geographies, based on the 2019 US textiles and apparel domestic exports rate.
5. Materials lost during production based on global estimate of ~12%.
6. Assumes ~80% of completed apparel produced in California is exported to other geographies, based on the 2019 US textiles and apparel domestic exports rate.
7. Assumes 5-15% of finished apparel imported into or manufactured in California is deadstock (e.g., unsellable and unused inventory, including damaged or incorrectly produced items)or samples, based on interviews with fashion / circularity experts (October-December 2021).



8. Of the ~55,000 tons of deadstock or samples, assumes ~75% are given to employees or donated to be worn, based on interviews with fashion / circularity experts (October-December 2021).
9. Of the ~55,000 tons of deadstock or samples, assumes ~25% are sent directly to collection channels to be landfilled, reused, or recycled, based on interviews with fashion / circularity experts (October-December 2021).
10. Assumes 100% of production losses (i.e., industrial solid waste) and 85-90% of post-consumer used apparel (i.e., residential solid waste) are sent directly to landfills through curbside solid waste collection. Remaining used apparel units are collected via other channels (i.e., consignment stores: ~5%, drop-off containers: ~5%, mailed collection: ~1%, in-store take-back programs: ~1%, curbside textile collection: <1%)
11. Separate from curbside solid waste collection, curbside textile collection programs specifically collect post-consumer textile waste to be eventually recycled, reused, or landfilled.
12. Assumes ~5% of collected apparel units are sent to landfill or incineration.
13. Assumes 50-60% of collected apparel units are wearable and resold as secondhand; assumes 65-70% of that is sold overseas.
14. Assumes 40-45% of collected apparel units are downcycled, a process of recycling that yields a product of lower value or functionality than the original item, such as recycling apparel into insulation or mattress stuffing (i.e., not textile-to-textile recycled).
15. Assumes 50-60% of collected apparel units are wearable and resold as secondhand; assumes 30-35% of that is sold locally.

Source: American Chemistry Council, 2020 guide to the business of chemistry; Ellen MacArthur Foundation, A new textiles economy: Redesigning fashion's future; Interviews with fashion / circularity experts (October-December 2021); Simple Recycling, The lifecycle of secondhand clothing; Textile Exchange, Preferred fiber and materials market report; US Department of Agriculture Economics, Statistics, and Market Information System; US EPA; USDA ERS; US International Trade Commission

Increasing collection of manufacturing waste and deadstock diverts less material from the landfill but faces fewer challenges to collecting, sorting, and recycling the material, thanks to its higher reliability as an input source and general profile as clean textile scraps.

Increasing collection of end-of-life apparel has the potential to divert more material from the landfill but faces significant challenges, including the difficulty of accounting for fragmented and unpredictable flows.

Capturing both opportunities to divert more material from the landfill would require increasing awareness of and access to collection locations, building broader understanding of the types of apparel accepted, and establishing partnerships between industrial sources of waste and recyclers.

Increasing the capacity and ability to handle complex inputs offers additional opportunities to improve circularity. These opportunities involve both the sorters who receive apparel after its diversion from the landfill and prepare it for recycling and the recyclers. Increasing collection does little good if downstream operations cannot use the collected materials. This opportunity faces two challenges — the manual-labor-intensive nature of sorting and the nascent state of gold-standard closed-loop textile recycling technologies, such as chemical textile-to-textile recycling.

Chapter 3 discusses the status quo of textile waste management across the US and in California.

Only about 5,000 tons—less than 1% of total apparel textiles worn—will be recycled into textiles to be used in apparel tomorrow

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Chapter 3

State of closed-loop recycling of apparel in the US and California today

Together, the collection, sorting, and recycling stages of waste management could catalyze the transition from a linear to a circular fashion lifecycle. This chapter explores the activities that happen in each of these stages across the US and then examines California's textile and non-textile waste management infrastructure.

Textile waste management across the US

Textile waste comes from both pre-consumer and post-consumer sources. Pre-consumer waste, which accounts for 30 percent of total textile waste, consists of materials that never go home with consumers because they are lost in the production process (e.g., scraps, samples, and rejected apparel). Post-consumer waste, which accounts for the remaining 70 percent, consists of garments bought, worn, and then discarded or donated by consumers.[35]

Collecting waste

Apparel manufacturing facilities, distribution centers, and retail sites that serve major fashion brands often generate pre-consumer waste. Since most apparel manufacturing takes place in Southeast Asia, pre-consumer waste lost in the production process is typically generated outside of the US.[36] But fabric scraps and deadstock in the US also end up as pre-consumer waste when they cannot be sold, even at a steep discount. Because sorting is expensive and recycling capacity is limited, fashion brands often pay a premium to divert their waste from the landfill.

Curbside solid waste collection and free donation channels typically handle post-consumer apparel waste. As discussed in Chapter 2, curbside solid waste collection is by far the most common channel, with 85-90 percent of textile waste ending up in the landfill.[37]

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Across pre- and post-consumer waste collection, increasing the percentage of used apparel collected and diverted from the landfill is critical to scaling fashion circularity. By comparison, US diversion rates for aluminum and cardboard — some of the most valuable commoditized recyclables — are about 50 percent for aluminum cans, 90 percent for aluminum used in building and automotive materials, and 90 percent for old, corrugated cardboard.[38] The last chapter of this report explores major obstacles to closed-loop textile recycling in greater detail, including potential drivers of low apparel diversion rates.

Sorting waste

Sorting is possible only for waste collected through channels that avoid the landfill, such as donation centers, drop-off containers, mailed collection programs, curbside textile collection programs, and in-store take-back programs. Unfortunately, little apparel that enters traditional solid waste or single-stream recycling gets sorted because the items are too damaged to salvage.

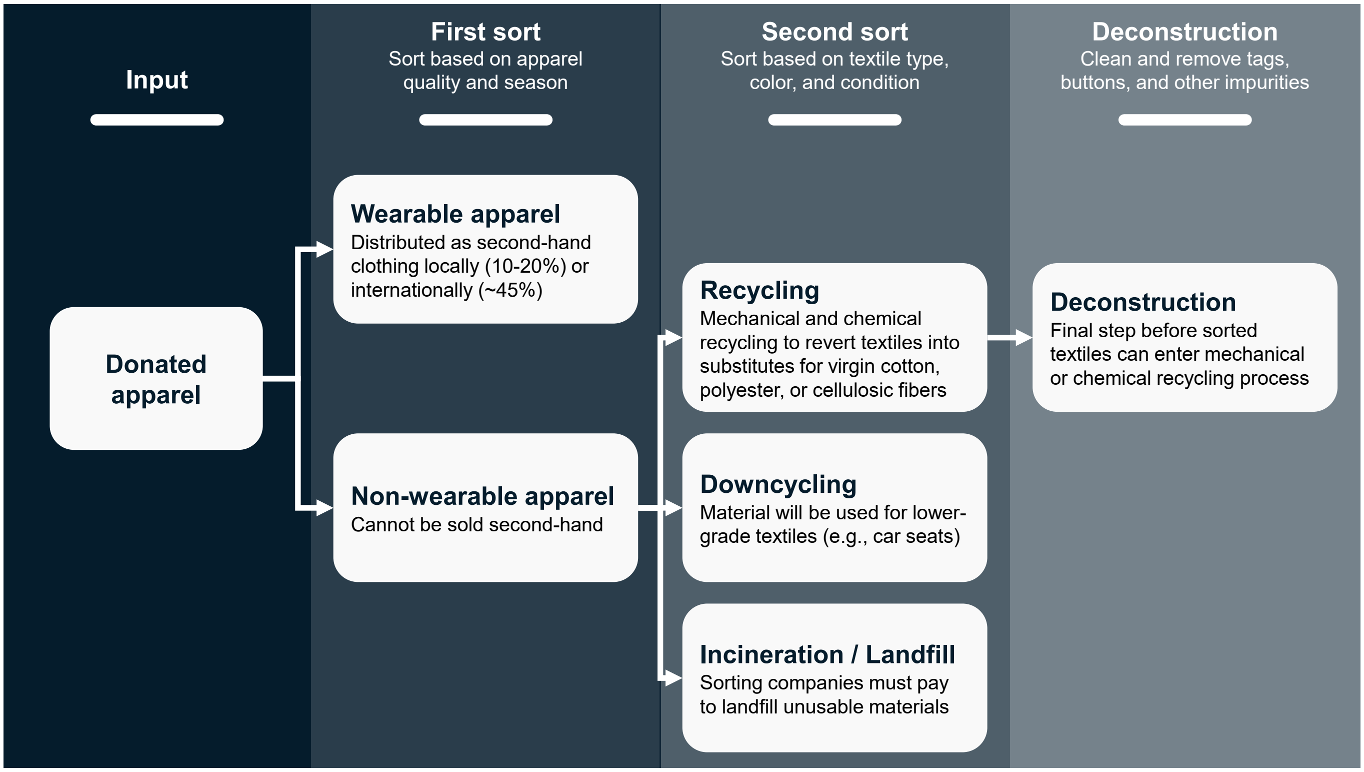
Currently, textile sorting is very labor-intensive. Sorting typically happens at donation centers / consignment stores or central sorting and / or distribution facilities operated by textile waste collectors. Closed-loop recycling requires first sort, second sort, and deconstruction processes (Exhibit 6). (Note: Both pre- and post-consumer waste must be sorted and deconstructed before recycling. But some pre-consumer waste can skip the first or second sorting process if the collection method did not mix the waste with other apparel or textile types, such as a large shipment of all-white, 100 percent cotton scraps.)

First sort. The first sort focuses on apparel quality and seasonality. Employees or volunteers examine each garment to determine whether it is wearable and then set aside the best items for sale by local or online secondhand retailers. They may sort garments that are wearable but unlikely to sell off the rack in the US by seasonality for sale to international wholesalers (e.g., summer clothes for hotter climates). Finally, items deemed non-wearable may be sorted out for lower-end uses, most often wiping rags or shredded stuffing.[39]

Exhibit 6

Sorting is highly labor-intensive and conducted primarily in donation centers / consignment stores or large central facilities

Key sorting stages to extract full value of collected used garments



Source: Interviews with fashion / circularity experts (October-December 2021); Reverse Resources, How much does garment industry actually waste?; Simple Recycling, The lifecycle of secondhand clothing

Second sort. Focused on textile type and color, the second sort is critical for textile-to-textile recycling, as it limits contaminants and ensures making the purest form of feedstock available to recyclers. Existing recycling technologies can handle 80-100 percent cotton or polyester garments (plus some cotton-polyester blends).[40] An effective second sort process would recognize these textile types, sort them by color as needed, and divert them for textile-to-textile recycling.

But the second sort rarely happens in the US today due to high cost and lack of demand from recyclers still operating at pilot scale. Instead, about half of collected clothing is deemed non-wearable and downcycled for lower-end use. Less than 1 percent of all used apparel is sorted successfully for textile-to-textile recycling.

The second sort varies from completely manual to heavily automated. In a manual sorting facility, employees examine and sort garments by fiber type based on tag information. The process is inefficient and prone to human error. At most, an employee can sort 10-20 pounds of clothing per hour (equivalent to one or two loads in a standard top-load washing machine).[41]

An automated sorting facility uses high-powered camera technology to examine and sort garments by fiber type and color. Automation is more efficient and accurate than manual sorting. But it also requires more capital investment and energy to power the conveyor belts, camera technology, electrical and control systems, and compressed air and de-dusting systems.[42] Industry experts generally agree that, while manual sorting can be employed as closed-loop recycling develops, the greater capacity, efficiency, and accuracy of automation make it the future of textile waste sorting.[43]

Case study

Automated sorting in Sweden

Today, the world has few large-scale textile sorting facilities, and most of them employ hundreds of people to sort through materials manually.

In 2021, the world's first fully automated sorting facility for textile waste began operating in Malmö, Sweden. The facility is the product of a partnership among multiple private stakeholders, including the plant designer and builder, Stadler of Germany; plant operator, Sysav Industri AB of Sweden; and producer of Autosort technology, Tomra of Norway.[44] The government-funded Swedish Innovation Platform for Textile Sorting (SIPTex) project was involved in financing the investment.[45]

The industrial-scale facility, which has a maximum capacity of 4.5 tons per hour per line, opened after years of testing in a smaller pilot plant built in 2017. The facility receives pre- and post-consumer waste in bales that weigh about half a ton and can process textiles ranging from yarn and fabric scraps to rejected garments and used apparel. On a day-to-day basis, the facility requires employees only to start and stop the machines, feed textiles into the line, and remove the sorted bales at the end of the line.

A central control and dosing system manages the entire operation. Conveyor belts carry textiles through the facility for examination by Tomra's Autosort optical sorting technology that is maintained by a compressed air and de-dusting system. At the end of each line, a baling machine packages textiles that are sorted by fiber type and color.


© Mikael Vaisanen / Getty Images

Deconstruction. Once separated from the rest of the apparel waste, recyclable textiles (predominantly cotton and polyester) require deconstruction, which involves removing tags, buttons, zippers, and other non-fabric materials from the textiles. Sometimes, even the thread used in seams needs to be removed before the sorted textiles go to the recycler. The process is labor-intensive, and to date no automated deconstruction technologies have been deployed at scale. Deconstruction can happen during the manual second sort or at the end of the line in an automated sorting facility.

Recycling waste

The waste management system sends pre- and post-consumer textiles to four common end-of-life destinations: landfill or incinerator, downcycling, textile-to-textile recycling, and secondhand or discount resale. This report focuses on opportunities to intervene when used textiles go to end-of-life destinations that offer lower value than textile-to-textile recycling. These are opportunities for closed-loop recycling of apparel otherwise landfilled, incinerated, or downcycled.

Landfill or incinerator. Diversion from the landfill or incinerator is by far the largest opportunity for more effective recycling of pre- and post-consumer waste. Americans send about 17 million tons of textile waste to the landfill each year.[46] That's equivalent to dumping two solid waste trucks full of textile waste every minute. In addition, secondhand clothing sold to international markets often ends up in the landfill or incinerator.

Once in the landfill, synthetic fibers like polyester can take at least 200 years to decompose. As they decompose, natural fibers like cotton or wool also generate methane — a greenhouse gas 25 times more potent than carbon dioxide at trapping heat in the atmosphere.[47]

Downcycling. Today, about half of all donated clothing is downcycled, not sold secondhand.[48] Downcyclers include companies that repurpose garments as wiping rags or shred them for lower-end uses like home insulation, carpet fiber, and stuffing for mattresses or car seats. Unlike textile-to-textile recyclers, downcyclers can intake textiles that vary widely in type, quality, and impurity — offering a convenient and cheap option for collectors looking to discard a large volume of used textiles that are not suitable for secondhand sale.

But separating recyclable garments (e.g., cotton and polyester) from the waste sent to downcyclers might open a window for circularity. Recycling these sorted garments could produce new clothing at a lower environmental and social cost than virgin input materials involve.

Textile-to-textile recycling. Commercially viable technologies to produce recycled polyester, cotton, and man-made cellulose exist. Innovations in textile-to-textile recycling offer an opportunity not only to reduce the waste piling up in landfills, but also to conserve the energy, water, chemicals, and land required to produce virgin input materials (e.g., farming virgin cotton or manufacturing polyester).

Textile-to-textile recycling takes two forms:

— **Mechanical recycling** transforms textile waste into reusable yarn without altering its basic chemical structure. This process typically shreds textiles (e.g., cotton) and pulls the shreds apart into fibers for re-spinning. Because the fibers get shorter in each cycle, the process is not fully circular. Recycling a textile by mechanical means can work only a finite number of times.[49]

— **Chemical recycling** uses a series of chemical reactions to break down used textiles into molecular building blocks called monomers. The process can reconstruct the monomers into recycled fibers (e.g., polyester or viscose) that are chemically identical to their virgin counterparts. This is the advantage of chemical recycling. Because quality does not diminish with each cycle, the process can approach full circularity. Apparel made with chemically recycled yarn can have the same tactile quality and performance as apparel made with virgin input materials, and textiles can be recycled ad infinitum.[50]

Today, five recycling technologies constitute the core of a more circular fashion system. Most mechanical and chemical technologies work with 80–100 percent pure cotton and polyester waste, but some methods tested at pilot scale can recycle man-made cellulosic textiles and blended fabrics (usually cotton-polyester blends).[51] For details, see “Five core recycling technologies” sidebar.

Americans send about 17 million tons of textile waste to the landfill each year. That’s equivalent to dumping two solid waste trucks full of textile waste every minute.

Five core recycling technologies

1. **Mechanical cotton recycling** operates at commercial scale today, but several limitations prevent it from being a complete closed-loop recycling solution.

   First, the process requires almost 100 percent cotton fabric inputs and outputs a lower-quality, rougher fabric than virgin cotton (due to the shortening of fibers during shredding).[52] To address this problem, some producers mix virgin and recycled cotton fibers to produce yarn more similar to virgin cotton in texture and quality.[53]

   Second, the process is not fully circular, because the loss of quality during each cycle means that cotton can be recycled back into apparel only a finite number of times.

   Third, only recycled cotton made with pure white cotton inputs can produce true white or bright colors.

   Despite these limitations, cotton recycling is a better end use than downcycling or landfilling, making it a component of a more circular economy for textiles.

2. **Mechanical polyester recycling** typically uses PET bottles or packaging as an input to produce recycled polyester fabric (the technology can also use polyester apparel textiles). Similarly, mechanical nylon recycling typically uses nylon items like fishnets to produce recycled nylon fabric. Therefore, the mechanical recycling of synthetic fibers is not a fully closed-loop textile-to-textile solution.

   We include this recycling method because most recycled polyester and nylon today comes from mechanical recycling. The technology operates at scale, and demand for the output is increasing as fashion brands seek to reduce their environmental impact. But the shedding of microplastics remains an issue with all polyester and nylon fabrics.[54]

3. **Chemical polyester recycling** typically requires more than 80 percent polyester yarn or fabric feedstock.[55] The process uses chemicals to break down the yarn or fabric into monomers, then builds the monomers back up into recycled polyester of the same quality as virgin polyester.[56] The process is fully circular, but the recycled polyester produces microplastics that are a key sustainability concern.

   Still, the industry has acknowledged the need to scale chemical polyester recycling. Over 70 fashion brands have signed on to the Textile Exchange's "2025 Recycled Polyester Challenge." The challenge states that "chemical recycling…is a key part of the solution" to accomplish the goal of increasing recycled polyester use from 14 percent today to 45 percent by 2025.[57]

   While promising technologies have been tested at pilot scale, industry dynamics have created a catch 22. The lack of sorted feedstock and guaranteed demand for output poses major risks to scaling, but without scale the cost of recycled outputs is much higher than virgin input materials, limiting demand.

4. **Chemical cellulose recycling** faces a similar catch 22. The process, which inputs more than 80 percent cotton or man-made cellulosic fibers, does not operate at scale today. But recycled man-made cellulose (e.g., rayon) has commercial potential. When solvents are used to dissolve the fibers down to a liquid pulp, the recycled man-made cellulosic fibers that are output can have the same quality as their virgin counterparts. The process can even manipulate man-made cellulosic fibers to achieve a cotton-like touch and feel.

5. **Chemical blended fabric** recycling is nascent but represents a significant opportunity for a textile industry that produced $35 billion of blended fabrics in 2016 alone.[58] Some technologies are attempting to recycle blended fabrics (which make up at least 50 percent of total apparel waste), but most are operating at laboratory or pilot scale.[59]

   The most successful technologies appear to work with cotton-polyester blends, which account for about 20 percent of all blended fabrics.[60] The recycled output has two components — man-made cellulosic fibers (made from the cotton in the blend) and polyester fabric or PET pellets (made from the polyester in the blend).

   Blended fabrics present an additional challenge for textile-to-textile recycling. Separating fibers and impurities is difficult, and efficiency is limited, as is the ability to sell both output fibers.[61]

Secondhand or discount resale. Wearable clothing suitable for secondhand sale is not a target source of feedstock for recycling. When consumers are willing to purchase and wear a used garment, reuse is preferable to recycling. But approximately half of the clothing collected by secondhand retailers in the US is sent abroad or downcycled instead.[62] Therefore, understanding how apparel ends up in secondhand or discount resale channels in the first place is important.

— **Secondhand resale.** In the US, donation centers and consignment stores (online and brick-and-mortar) sell post-consumer apparel deemed sufficiently high-quality. An estimated 10-20 percent of donated clothing is sold locally, while an additional ~35 percent is sold abroad.[63]

— **Discount resale.** Discount resellers typically purchase order cancellations, overstock, end-of-season, and post-clearance garments from apparel manufacturers or retailers. The business model relies on buying pre-consumer garments in bulk, at a steep discount, and then reselling them to consumers at a relatively cheap price.

Textile-to-textile recycling technologies
Chemical and mechanical recycling technologies have the potential to unlock the future of textile circularity if the industry can overcome the challenges and risks of scaling.

Across the US, waste management of fashion textiles remains in its infancy, with very few textile-to-textile recyclers, all operating at pilot scale (Exhibit 7).[64]

Textile waste management in California

Textile circularity in California faces challenges across the waste management lifecycle. The largest bottleneck is the lack of sorting and recycling capacity. Even if that infrastructure existed, without improvements in collection, most apparel waste would likely never enter a channel that could lead to textile-to-textile recycling. Today, most textile waste is simply thrown away, and once it enters the traditional solid waste or recycling streams, sorting it out is nearly impossible.[65] The materials are effectively damaged and beyond recycling.[66]

The sections that follow review key waste management practices in California and outline potential partnerships with incumbent waste management stakeholders. California's waste management industry manages 40 million tons of organic waste, recyclable materials, and solid waste every year and employs more than 40,000 people across the collection, sorting, and recycling stages.[67]

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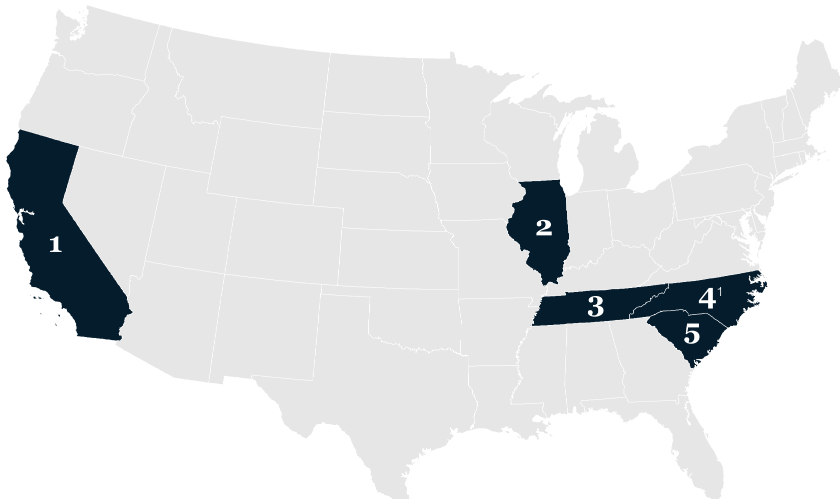
Exhibit 7

Few US-based textile recycling facilities can convert used apparel textiles into recycled fibers for new apparel

Location and description of identified textile recycling facilities in the US



	Facility operator	Current technology	Input types	Output types
1	Ambercycle	Chemical polyester recycling	Pure and blended polyester	Recycled polyester
2	Natural Fiber Welding	CLARUS technology converts cotton into longer fibers to engineer performance recycled cotton	Cotton, man-made leather	Recycled cotton, man-made leather
3	Eastman Chemical Company	Chemical polyester recycling	Pure and blended polyester	Recycled polyester intermediates
4	Evrnu	Chemical polyester recycling	Pure cotton, pure polyester, blended cotton-polyester	Recycled polyester; recycled man-made cellulosic fibers
5	Circ	Chemical polyester and cellulosic recycling	Pure cotton, pure polyester, blended cotton-polyester	Recycled polyester; recycled man-made cellulosic fibers

Note: The five companies in the exhibit reflect the landscape at time of writing identified through outside-in research and interviews with fashion / circularity experts (October-December 2021); these companies may not be all of the players operating in the US.

1. Evrnu's pilot plant is in South Carolina, but it also has headquarters and a chemical lab in Seattle, Washington, and an extrusion line in New Jersey.

Source: Ambercycle, Circ, Eastman, Evrnu, and Natural Fiber Welding websites; Interviews with fashion / circularity experts (October-December 2021)

Collecting waste

California municipalities typically franchise collection of residential and commercial waste to haulers in exclusive zones. These haulers collect solid waste, recyclables, and green waste from homes and businesses curbside. Dozens of waste haulers operate in California; 20 percent are publicly owned, and 80 percent are private companies.[68] The state has no large-scale curbside textile recycling programs.[69]

In addition, some private and non-profit companies collect donated clothing from households. Households donate most clothing through donation centers or drop-off containers concentrated in urban areas (Exhibit 8). Several fashion brands that have a retail footprint in California (e.g., Madewell with their denim program) have launched in-store take-back programs to collect used clothing for reuse / repair or recycling.[70]

For each zip code, the maps show the number of collection locations per 10,000 residents. Even after accounting for differences in population density, the major players have very few collection locations outside the major metropolitan areas surrounding San Francisco and Los Angeles.[71] (Note: The lightest color on the maps indicates zero collection facilities.)

Sorting waste

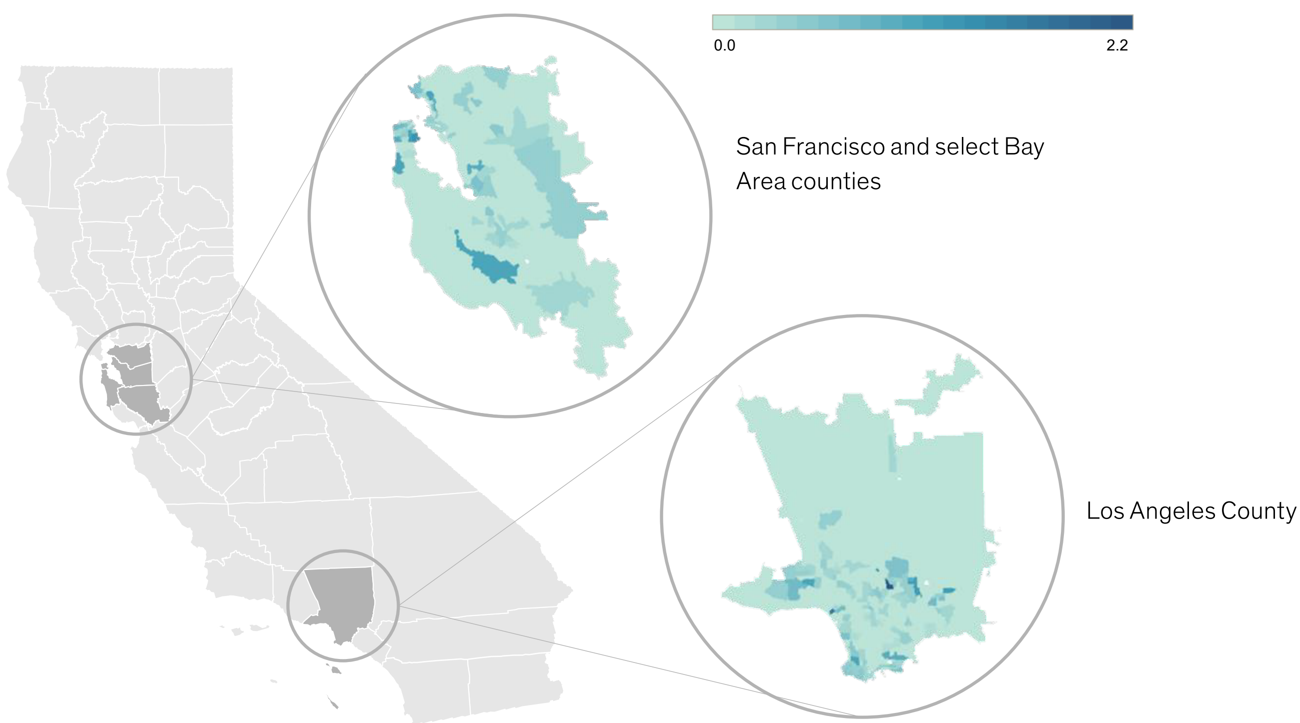
Municipal solid waste (MSW) typically goes to a transfer station for consolidation into larger loads, without any sorting, before transportation to one of California's ~175 landfills or a waste-to-energy facilities.[72]

Meanwhile, single-stream recycling waste goes to a materials recovery facility (MRF) for sorting into categories of recyclable materials (e.g., paper, glass, and plastic) and non-recyclable materials. Sorted recyclable materials are packaged into bales and sold wholesale to recyclers who pay for and process commodities like aluminum, paper, and certain plastics. Because each recycler typically handles specific materials, the industry is fragmented, but waste haulers and recyclers have strong established relationships.[73]

Exhibit 8

Current collection sites are concentrated in Los Angeles, San Francisco, and select Bay Area counties

Collection sites in each area per 10,000 residents (by zip code)



Source: AMVETS Thrift Stores; Goodwill of Southern California; Out of the Closet; TEXgreen; The Salvation Army; USAgain

California has fewer than 100 large MRFs, and none of them sort textile waste.[74] In fact, textiles that are mistakenly thrown in the recycling containers can get caught and damage the sorting equipment, because traditional MRFs are not designed to process textile waste.

Still, California may be able to leverage existing transfer stations or MRFs to aggregate textiles for sorting. For example, a textile sorter could partner with a major waste hauler to aggregate pre- or post-consumer textile waste at a transfer station already used to manage traditional MSW and recycling waste. By enhancing this transfer station with textile sorting capacity, the partners could leverage existing infrastructure for new operations that enable circularity.

Recycling waste

Textile recycling can aspire to reach a state of commercialization similar to other recycled products like aluminum and certain plastics. For example, waste haulers could play a crucial match-making role between fashion brands or consumers and textile-to-textile recyclers who need feedstock. Waste haulers could also provide waste storage, logistics, and transportation support to recyclers. Because of their size and scale, waste haulers could even partner with textile recyclers to define and disseminate clear industry standards for sorting textile waste (i.e., standards that match recyclers' feedstock specifications).[75]

California waste management landscape

California's waste management regulators and municipalities might play a critical role in advancing circularity. The Department of Resources Recycling and Recovery (CalRecycle) is responsible for enacting state-wide waste management policies and convening stakeholders, including municipalities, residents, and waste management companies.[76] Individual municipalities are responsible for funding and execution. Each municipality manages its own waste management services, often through contracts with private waste haulers.[77]

California has no state-wide policies or programs that explicitly address textile waste recovery.[78] But two broader waste management initiatives could affect textiles:

— **Statute SB1383** set a state-wide goal of diverting 75 percent of all organic waste (including textiles) by 2025.[79] Passed in September 2016, SB1383 defined requirements for individual municipalities to divert organic waste (e.g., adopt a standard three-bin system to collect residential green waste, recyclables, and MSW) and might encourage textile waste recovery as municipalities work to comply with the requirements.[80] According to CalRecycle, SB1383 can help meet California's targets for reducing greenhouse gas emissions, because organic waste in landfills contributes over 20 percent of the state's methane emissions.[81]

— **Recycling Market Development Zone Loan Program** exists to help finance organizations or businesses located in California that prevent, reduce, or recycle waste through value-added processing or manufacturing. Eligible facilities can apply for loans to cover 75 percent of their total project costs, up to $2 million. Facilities must be located in a designated Recycling Market Development Zone and use waste feedstock generated in California.[82]

Finally, some municipalities have piloted initiatives like monthly curbside textile collection and partnerships with clothing donation locations. But sustaining or scaling the initiatives has proven challenging, and many residential curbside pilots have ended due to high costs, lack of participation, or difficulty keeping textiles clean and segregated from other waste.[83]

This chapter reviewed the status quo of waste management across the US and in California today. Chapter 4 looks at a final key stakeholder in the ecosystem — the California consumer — because any efforts to build a more circular fashion economy must take consumer habits and attitudes toward sustainable apparel into account.

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Chapter 4

Californians' perspectives on sustainability and circularity in fashion

Determining how to accelerate circularity requires understanding consumers' perspectives on and experiences with sustainability and circularity. To develop that understanding and identify opportunities for advancing toward circularity, we surveyed California consumers.[84] We acknowledge that consumer surveys, especially when investigating virtuous behavior, are prone to respondent bias.

This chapter discusses the survey results and their implications for efforts to accelerate circularity. We have organized the discussion in four sections —— general attitudes toward sustainability, current and future purchasing habits, willingness to pay for recycled materials, and treatment of end-of-life apparel.

General attitudes toward sustainability in fashion

Californians are mindful of sustainability in making fashion choices. This has important implications for the feasibility of circularity.

Californians express overwhelming support for "green" causes and admit their impact on purchasing decisions. Among the survey respondents, 80 percent call sustainability important when selecting a fashion brand to buy; 81 percent say it is important that the fashion brands they buy use sustainably sourced materials; and 72 percent are more loyal to brands that use sustainably sourced or recycled materials.

Californians who spend more on clothes or buy more clothes are even more inclined to make sustainability a factor in their purchase decisions. Of those Californians who spend $301-500 a month on clothes, 87 percent consider sustainability important vs. 75 percent of those who spend $0-100 on clothes.[85] The gap is similar between groups who buy more vs. fewer clothes; of those who buy 11-15 items a month, 91 percent consider sustainability important vs. 77 percent of those who buy 0-1 items a month.[86]

Not only do we see widespread consumer interest in sustainability in the fashion industry, but those consumers who make up a disproportionate share of the market are most likely to value and make decisions based on apparel sustainability.

Current and future purchasing habits

Consumers are also seeking ways to buy their clothes more sustainably. In aggregate, 61 percent of the survey respondents report at least sometimes buying clothing made with recycled materials. And, while 61 percent of Californians who buy an average of 0-1 articles of clothing per month report that they buy clothing made with recycled materials, this number increases steadily as the amount of clothing purchased increases. 93 percent of those who buy 11-15 items a month state that they buy clothing made with recycled materials. California has room to grow the purchase rates of clothes made with recycled materials but already enjoys a high level of consumer engagement.

We asked consumers about their future intention to buy clothing made with recycled materials. Most anticipate buying more clothes made with recycled materials (54 percent); only 7 percent anticipate buying fewer clothes made with recycled materials.

The intention to purchase more clothes made with recycled materials grows with the amount of clothing purchased per month. Only 43 percent of respondents who buy 0-1 items per month intend to buy more clothes made with recycled materials over the next 1-3 years, while 83 percent of those who buy 11-15 items per month intend to buy more clothes made with recycled materials. Their commitment may reflect a general industry trend toward using more recycled materials, as well as strong consumer demand for recycled materials.

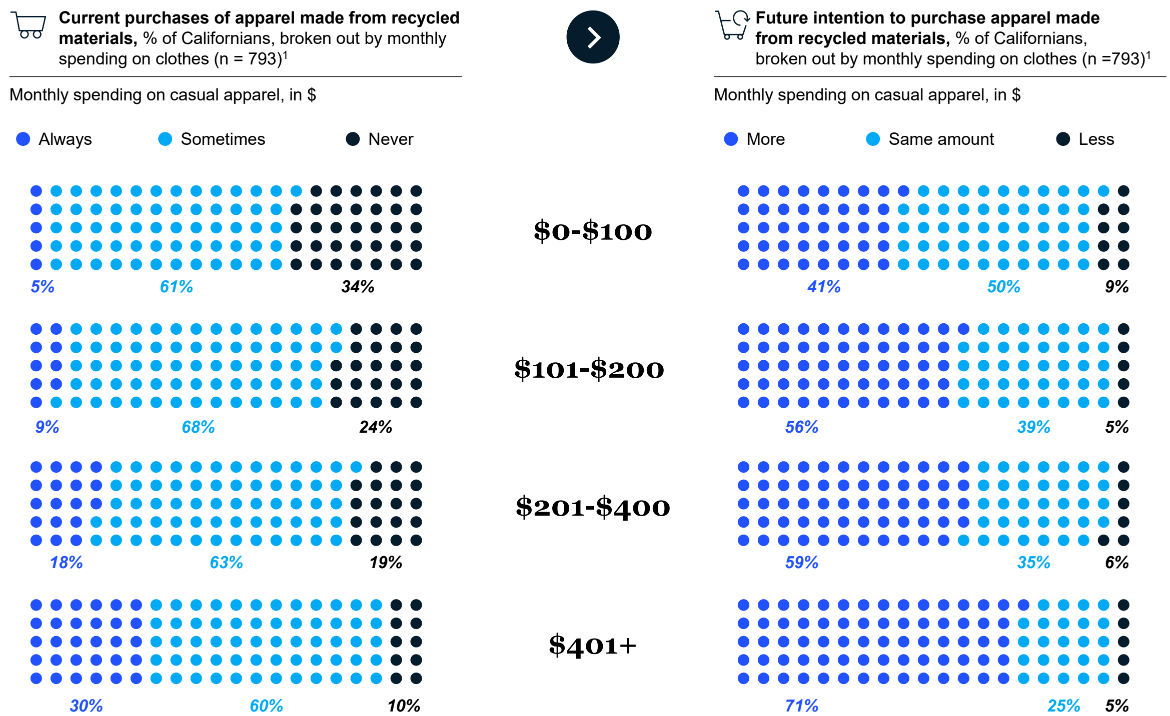
People who spend more on clothing are more likely to purchase clothing made with recycled materials in the future. Among consumers buying casual apparel, 41 percent of those who spend $0-100 per month anticipate buying more clothes made with recycled materials in the future vs. 75 percent of those who spend $401-500 and 63 percent of those who spend more than $500 (Exhibit 9). The fact that these consumers have stronger spending power in the industry creates incentives for brands to use more recycled materials in their products and communicate their commitment to doing so to consumers.

Willingness to pay for recycled materials

The survey explored what, if any, premium consumers say they would be willing to pay for apparel made with recycled materials.

Exhibit 9

Californians intend to buy more apparel made from recycled materials than they do today



1. Does not equal to 1,002 respondents, as only Californians who purchased casual apparel in the last month were asked this question.
Source: McKinsey 2021 California Fashion Circularity Survey, n = 1,002. Questions included: Do you currently buy clothing that is made from recycled materials? In the next one to three years, I anticipate buying [more / less / same amount of] apparel made from recycled materials than I do now. How much did you spend on casual apparel in the past month?

On average, younger Californians (18-34-years-old) report willingness to pay a premium for apparel made with recycled materials, while older Californians (55-65+) do not.[88] Those 18-24-years-old report willingness to pay almost 15 percent more for apparel made with recycled materials.[89] Reported willingness to pay a premium does not differ significantly by major metropolitan area or purchase volume.

This tracks other survey results. Younger consumers are more likely to consider sustainability important more often, such as selecting a fashion brand to buy or considering the origin of materials in clothing.

Several factors may account for the differences in willingness to pay:[90]

— Younger consumers may feel more strongly about promoting sustainability with their own actions.

— Older consumers may have more fixed buying habits and be less willing to experiment with different products.

Willingness-to-pay analysis

Willingness to pay has historically differed between survey responses and actions in the real world. Willingness to pay is often overstated when the purchase under discussion can be categorized as more virtuous than the baseline —— e.g., buying apparel made with recycled materials is more virtuous than buying traditional apparel.[87]

To minimize skew, we applied a randomized controlled trial question design. We asked 50 percent of respondents about the price they pay for the typical jeans they like and want to buy. We then asked the other 50 percent about the price they would be willing to pay for jeans made of recycled material. To determine the difference in willingness to pay, we calculated and compared the average prices that both groups would be willing to pay.

— Brands that market to older consumers may focus less on recycled materials, leaving these consumers less exposed to them.

Ensuring sustainable economics for circularity would require making one or a combination of changes to the current business model:

— Brands could charge a very slight premium for clothing made with recycled materials, which a majority of Californians seems to support.

— Companies across the value chain could invest to increase scale and purchasing power, reducing costs for recycled material inputs and thus making recycled products cost-competitive with virgin-produced products.

— The government could consider policy interventions, such as taxes or subsidies.

Together, these actions would significantly strengthen the business case for textile circularity.

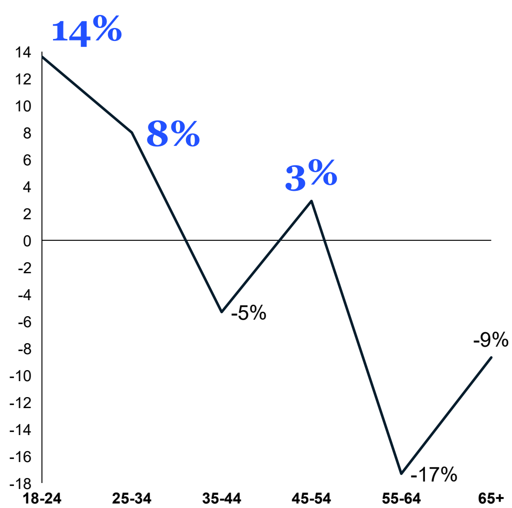
The willingness to pay a premium for apparel made with recycled materials differs by type of clothing. This has implications for efforts to accelerate circularity. Survey respondents who typically buy mass market clothing ($40-99) and value clothing (less than $40) are willing to pay a premium for recycled materials.[91] But those who buy "masstige" clothing ($100-249) are not willing to pay a premium, nor are those who typically buy luxury clothing (more than $250).[92]

Buyers of masstige and luxury clothing may associate recycled apparel with cheaper, lower-quality, used products. Educating consumers who are less willing to pay may require demonstrating that the positive environmental impact of recycled materials does not diminish quality and performance (Exhibit 10).

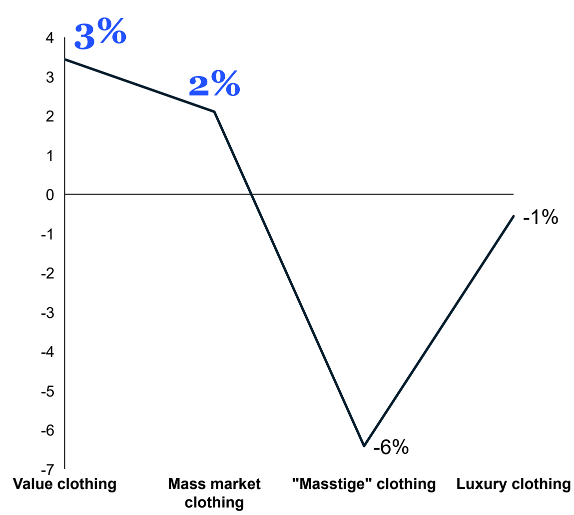
Exhibit 10

Younger Californians and Californians who purchase value or mass market apparel have a higher stated willingness to pay for apparel made from recycled materials

Premium willing to pay for a pair of recycled jeans broken out by age group
% of price per pair of jeans



Premium willing to pay for a pair of recycled jeans broken out by purchase type
% of price per pair of jeans



Source: McKinsey 2021 California Fashion Circularity Survey, n = 1,002. Questions included: If you are out shopping for a pair of jeans and find a pair of jeans that you like and want to buy, how much do you typically pay for them? If you are out shopping for a pair of jeans and find a pair made from a recycled polyester blend that you like and want to buy, how much would you be willing to pay for them?

Definitions

Value clothing (<$40): Apparel purchased from big box retailers

Mass market clothing ($40-99): Apparel purchased from fast fashion retailers or department stores

"Masstige" clothing ($100-249): Apparel purchased from higher-end retailers or department stores

Luxury clothing ($250+): Apparel purchased from designer brands

While fashion brands have opportunities to capitalize on some consumers' willingness to pay for recycled materials, they should also consider opportunities to change consumer preferences by educating those less willing to pay.

Consumer willingness to pay further differs by type of recycled or sustainably sourced material. Asked to select the materials for which they would be willing to pay more, survey respondents rank recycled cotton in the top three 36 percent of the time and recycled polyester (both textile and non-textile) in the top three 47 percent of the time, in aggregate (Exhibit 11).

In aggregate, recycled cotton and polyester inputs rank significantly higher — 47 percent for polyester across feedstocks (recycled plastic bottles, marine plastic, and textile-to-textile recycled polyester) — than recycled leather, wool, and linen, but recycled leather is much more popular than recycled wool or linen.

While the aggregate willingness to pay for polyester is higher than for other recycled materials, willingness to pay differs by type of recycled polyester feedstock. Recycled plastic bottles rank in the top three 20 percent of the time, recycled marine plastic 16 percent of the time, and textile-to-textile recycled polyester 12 percent of the time.

Because polyester is the most used fiber in the world, informing consumers about the importance of buying clothing made with recycled polyester will be important. The industry should do further research to understand whether consumers really prefer specific types of polyester feedstock, and if so, how they perceive the differing environmental impact of the feedstock.

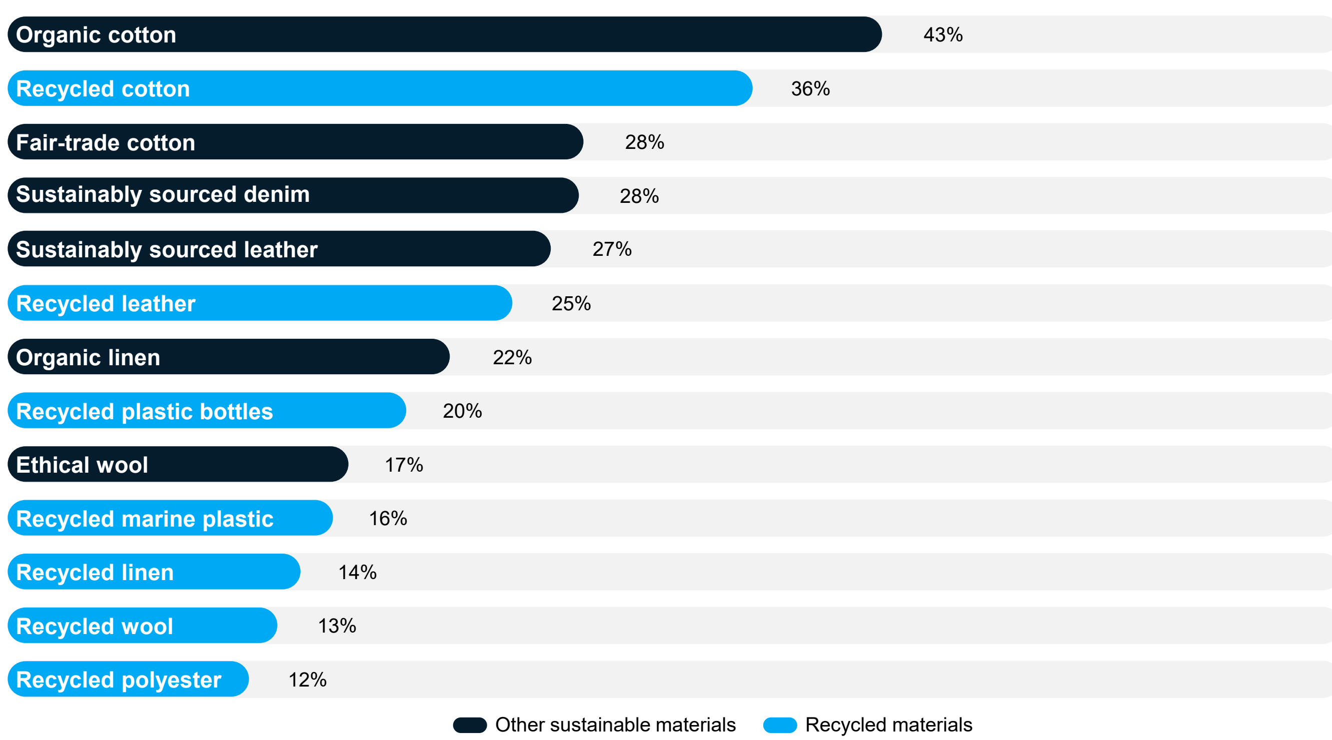
Recycled polyester comes from two sources — non-textile materials like reclaimed plastic converted into fibers and textile materials obtained through fiber-to-fiber recycling. The sources produce the same recycled polyester fiber output.

Efforts to reduce barriers to closed-loop recycling may need to communicate to consumers the benefits of textile-to-textile recycled polyester over non-textile recycled polyester like marine plastic and plastic bottles. In addition, scaling a source for

Exhibit 11

Willingness to pay a premium for apparel varies widely based on the type of material used

Percentage of respondents who ranked the material in the top three of materials they would pay more for in apparel



Source: McKinsey 2021 California Fashion Circularity Survey, n = 1,002. Question: Select the top materials you would be willing to pay more for in apparel, up to five. Rank the selected in order of willingness to pay more for in apparel recycled polyester feedstock that is separate from recycled plastic bottles may not only help to divert apparel from the landfill but also avoid potential price increases driven by competition from consumer goods companies for recycled polyethylene products (e.g., rPET).

Treatment of end-of-life apparel

Consumer opinions and actions on circularity at the end of the fashion lifecycle are critical. Today, 45 percent of Californians do not participate in an apparel recycling program, and 56 percent call donation their primary way to dispose of apparel. While 14 percent say that they primarily recycle their clothes via a textile recycling program, 11 percent admit that throwing clothes away is their primary method of disposal.

Exploring disposal methods for end-of-life apparel requires looking beyond the current habits of Californians in general to the habits of the Californians who generate the most end-of-life apparel. To this end, we divided the survey results on disposal of end-of-life apparel into groups based on the average number of items that respondents buy each month (Exhibit 12).[93]

In general, about the same percentages of respondents report throwing away their end-of-life apparel and recycling it. But this does not match the reality in California, where current landfill rates for clothes are 85-90 percent.[94] Various factors may account for these disparities. For example, respondents may have answered based on intent, rather than the default action of throwing away that happens when people get busy, or the receiving organizations may have sent some of the donated clothes to the landfill (about 5 percent of what these organizations collect today).[95]

Exhibit 12

Californians say that they primarily donate their end-of-life clothing

Primary method of disposal for end-of-life apparel, percentage of respondents

		Number of clothing items bought per month[1]			
	Average	0-1	2-5	6-10	11-15
Throw away	~20%	29	23	15	17
Recycle	~20%	7	11	26	45
Give to family/friends	~20%	10	15	19	14
Donate	~40%	55	50	40	24

1. Consumers who indicated they bought 16+ items per month were excluded based on small sample size.
Source: McKinsey 2021 California Fashion Circularity Survey, n = 1,002. Question: What do you do with your clothes when you are done with them?

Advancing circularity in California will require significant improvements. While only 14 percent of respondents report primarily recycling their clothes, 92 percent say that they would participate in a brand-sponsored apparel recycling program, if available (Exhibit 13). This willingness does not differ significantly with the type of apparel purchased (Exhibit 14).

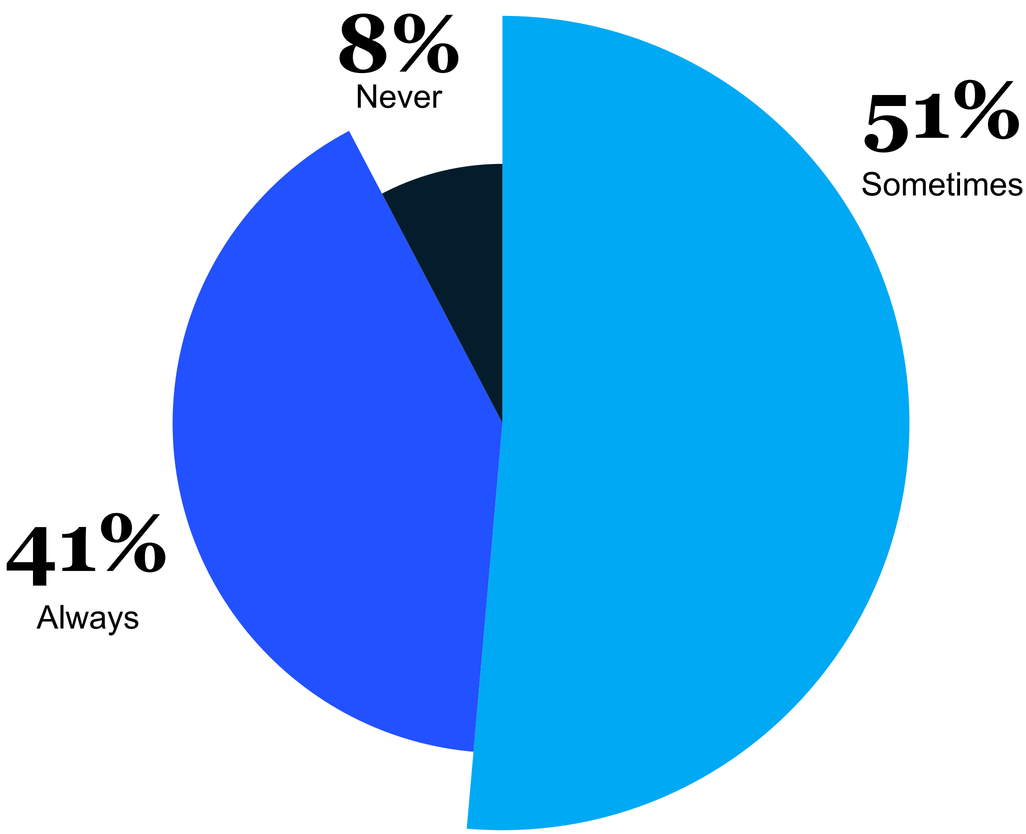
Given the consumer appetite for apparel recycling, the question is how to build the necessary collection and sorting capacity. While pre-consumer waste raises collection and sorting issues, the sheer volume of post-consumer waste calls for educating consumers about their apparel disposal options and reclaiming a higher percentage of end-of-life apparel.

To accelerate recycling and improve reuse and resale programs that can keep apparel out of the landfill, consumers need education on appropriate methods of disposal based on the condition of clothes. Asked the condition of any apparel they have discarded, 40 percent of respondents who primarily send their clothing to the landfill say clean; 43 percent say worn but wearable; 12 percent say wearable after repair; and more than 25 percent say like new (Exhibit 15).[96] Instead of going to the landfill, these clothes should go to others for reuse or to recycling facilities, creating a truly circular model for the apparel industry.

Exhibit 13

Californians indicate that they would participate in an apparel recycling program, if available

Willingness to participate in a brand-driven apparel recycling program, percentage of respondents

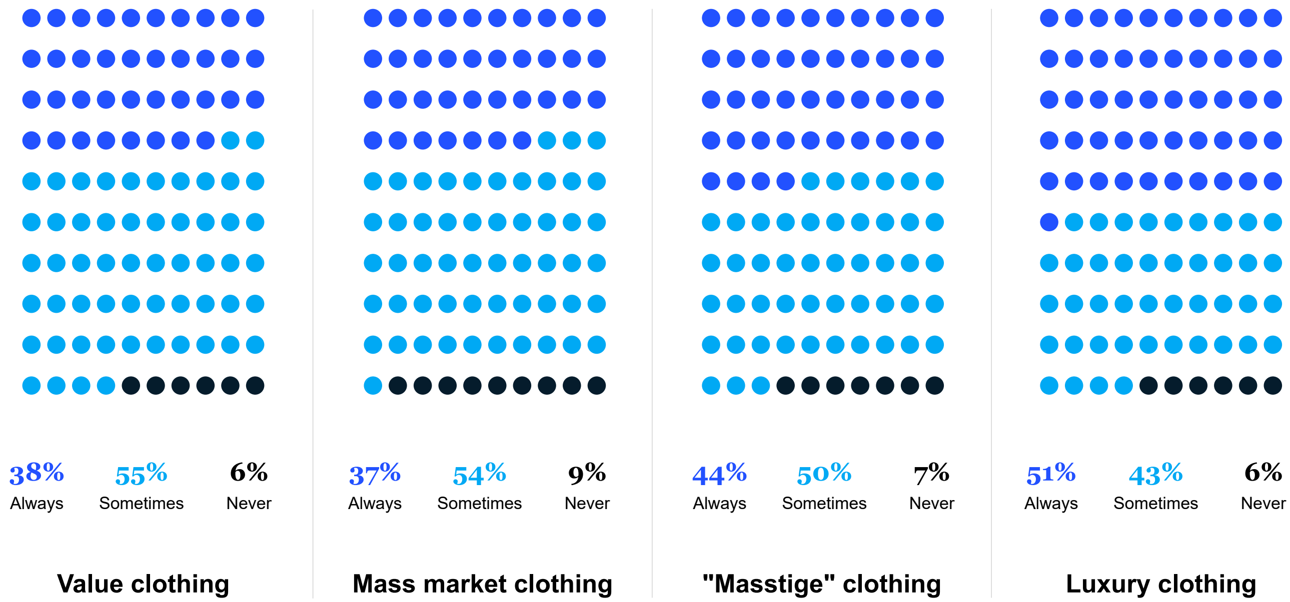


Source: McKinsey 2021 California Fashion Circularity Survey, n = 1,002. Question: Would you participate in an apparel or footwear recycling program if offered by one of the brands you currently purchase?

Exhibit 14

Willingness to participate in an apparel recycling program is similar across clothing types purchased

Willingness to participate in a brand-driven apparel recycling program by clothing type purchased, percentage of respondents



Source: McKinsey 2021 California Fashion Circularity Survey, n = 1,002. Question: Would you participate in an apparel recycling program if offered by one of the brands you currently purchase?

Efforts to establish new recycling programs should pay attention to consumers' program preferences. Today, 70 percent of Californians who recycle or donate items take them to a donation center like Goodwill; 35 percent put them in a drop-off container; 23 percent take them to a store for a take-back program; 20 percent participate in a curbside collection program; and 14 percent mail them via a collection service.[97]

But asked their preferred methods of recycling, 63 percent of respondents put drop-off containers in their top three, followed by 47 percent citing in-store take-back programs and 44 percent citing donation centers / consignment stores. Efforts to increase recycling participation can start by addressing this gap between the vision and current practices.

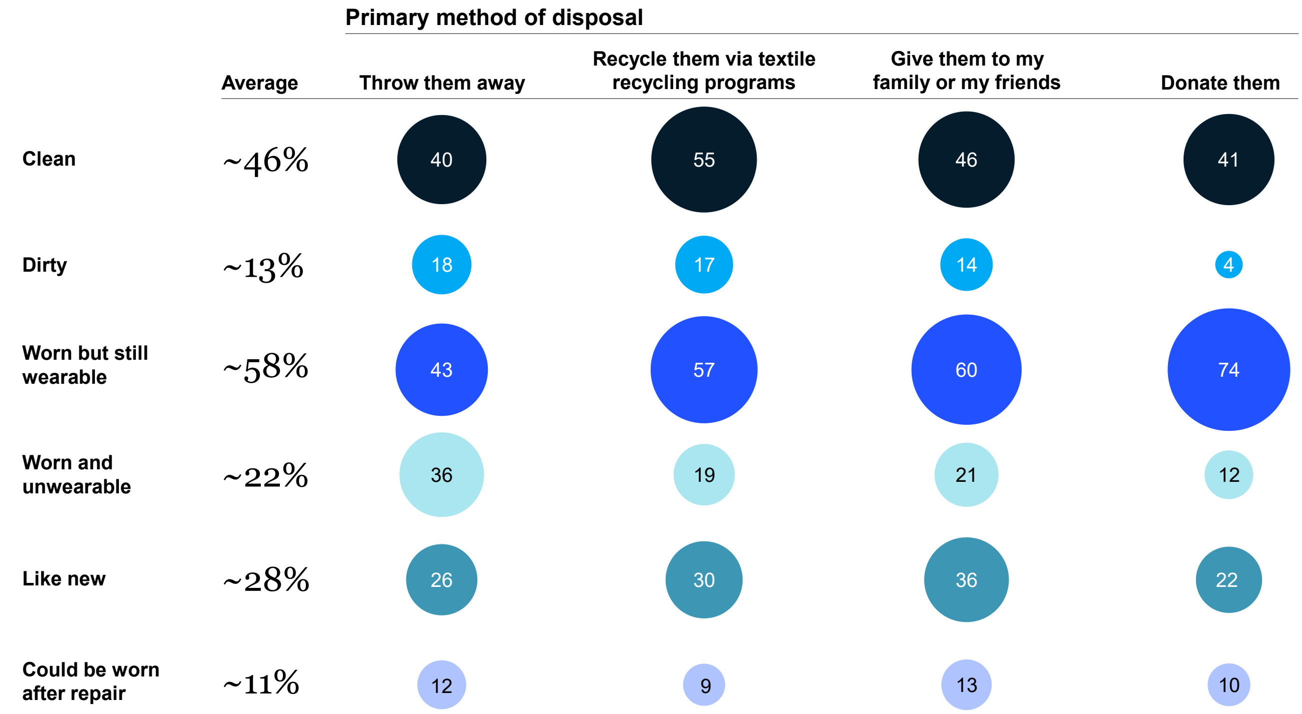
Just 31 percent of Californians consider their current apparel recycling methods very convenient, and 29 percent call their current methods inconvenient or only slightly convenient. This is a problem, as drop-off or shipping convenience is the most important factor in making respondents likely to participate in an apparel recycling program. 59 percent call it a top-three factor, along with knowing their positive impact on the environment (55 percent) and receiving discounts on new items (51 percent). This suggests that convenience outranks financial incentives in securing participation in a recycling program.

Against the background of opportunities, challenges, and consumer preferences, Chapter 5 discusses the total holistic impact that advancing textile circularity in California could have and specific initiatives that might move the needle.

Exhibit 15

Among Californians who primarily send their clothing to the landfill, more than 25 percent say the condition of the clothing they are disposing is “like new”

Condition of apparel when disposed of by primary method of disposal, percentage of respondents[1]



Note: Percentages represent total number of respondents who selected a particular answer, as respondents could select multiple answers (e.g., some apparel typically thrown away by a respondent could be “worn but still wearable,” while others are “clean”).
1. Analysis excluded consumers who indicated buying 16+ items per month due to small sample size.
Source: McKinsey 2021 California Fashion Circularity Survey, n = 1,002. Question: What condition are your clothes and footwear typically in when you discard them?

Chapter 5

Advancing fashion circularity in California

This chapter summarizes the key obstacles to establishing closed-loop textile recycling and analyzes 12 potential initiatives for advancing apparel circularity in California, including their total holistic impact (economic, environmental, and social benefits) and costs – based on a polyester use case. These initiatives could generate total holistic impact for the state estimated at $7-9 billion.[98] Expanding these initiatives to all other textile materials across the US fashion industry could generate total holistic impact estimated at $50-70 billion.[99]

Major obstacles to closed-loop recycling

Each stage of the fashion lifecycle includes significant obstacles to closed-loop recycling. Long term, the shift from a linear to a circular apparel economy would require addressing all these obstacles, but early interventions could target areas with the biggest infrastructure gaps today, especially collection, sorting, and recycling.

Collection obstacles

Collection channels that serve closed-loop recycling are highly fragmented and can accept only specific types of textiles (e.g., >80 percent white cotton, >80 percent polyester, or cotton-polyester blends) —— typically in small amounts.[100] Apparel manufacturers that generate pre-consumer waste would likely need to pay a premium for recycling relative to landfilling or downcycling end-of-life textiles, due primarily to the additional sorting and deconstruction activities required. Fashion brands committed to diverting textiles to their highest and best use often spend more time and effort navigating complex relationships with diverse stakeholders, including discount resellers, waste haulers, textile sorters, recyclers, and downcyclers.

While consumers can typically donate post-consumer waste for free (e.g., at a used clothing drop off), some survey respondents (29 percent) find existing collection options inconvenient or only slightly convenient. This is probably a key reason that they throw away most textile waste.[101]

Sorting obstacles

Sorting (including deconstruction activities) faces three major obstacles:[102]

- **Current sorters do not segregate by textile type**. Donation centers / consignment stores and central facilities that process used textiles often sort based on quality and seasonality to determine if clothing can sell secondhand, but they rarely sort by textile type (as closed-loop recycling requires). The only ways to mitigate this gap today are to be selective in which garments can enter a recycling channel (e.g., accept only items that are >80 percent polyester) or to have the recyclers sort garments upon receipt.
- **The textile-to-textile recycling industry lacks standardized sorting guidelines and feedstock specifications**, in part because the volume of textile recycling today remains small, minimizing the need for sophisticated sorting solutions at scale.
- **Deconstruction of fabrics destined for recycling rarely happens**. Only a few sub-scale start-ups support deconstruction, and the remaining clothes end up in the landfill. Removing tags, buttons, zippers, and other impurities is labor-intensive and inefficient and will not occur without consistent demand and willingness to pay for deconstructed garments.

$7-9 billion

Total holistic impact - economic, environmental, and social benefits - from creating a closed-loop apparel recycling system in California (scaled up across the US, this could generate total holistic impact estimated at $50-70 billion)

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Recycling obstacles

Closed-loop recycling also faces three obstacles:

— **Technical barriers restrict the inputs and outputs of recycling facilities**. All textile-to-textile recyclers have narrow specifications for fabrics they can handle (e.g., fiber type, color, and quality), and they cannot process buttons, zippers, trims, and other impurities. Beyond a few technologies that work primarily with cotton-polyester blended fabrics, most recyclers cannot intake the blended textiles estimated to represent more than 50 percent of today's fashion industry.[103] Only chemical recycling can achieve virgin-quality outputs, and these breakthrough processes have been tested only for polyester and man-made cellulosic outputs.[104]

— **The lack of collection and sorting infrastructure makes the availability and cost of feedstock for recycling uncertain**. This in turn poses a risk to scaling recycling capacity. Despite the large amount of textile waste generated, the volume of feedstock available for collection and sorting for recycling remains very uncertain. The textile recycling experts we interviewed consistently expressed uncertainty about prices for feedstock over the next decade. These prices can significantly affect costs since feedstock can account for ~30 percent of a recycler's total operating expenses.

— **The risk of insufficient demand may discourage textile recyclers from scaling**. Although fashion brands would like to procure more recycled input materials, textile recyclers still face challenges securing contracts with apparel manufacturers at a price that fits the economics of their business. Investing in a multi-million-dollar textile recycling facility is risky if recyclers need to secure customers as well as feedstock.

To evaluate the total potential benefits from addressing these obstacles by achieving closed-loop textile recycling, we developed a five-step methodology.

Our methodology for defining potential solutions to achieve closed-loop textile recycling and evaluating their collective holistic impact

To define potential solutions to the major obstacles to closed-loop textile recycling and determine the holistic impact they could create — i.e., the system-level financial and non-financial net impact (in this case, economic, environmental, and social impact) — we developed a five-step methodology to guide exploration:

1. **Define cost and holistic impact metrics to evaluate circularity**. The cost metrics include one-time capital expenses, such as buildings and equipment, and recurring annual operating expenses, such as utilities, labor, transportation, and feedstock. We defined eight holistic impact metrics across economic, environmental, and social dimensions.

   — **The economic metrics** include incremental revenue growth (e.g., from selling recycled polyester input materials or recycled polyester apparel at a premium) and cost savings (e.g., from process efficiencies).

   — **The environmental metrics** include reductions in CO_2e emissions, water use, land use, and chemical use, translated into dollar values based on California market values for the resource.[105] For example, we valued each unit of reduction in CO_2e emissions at $60 per metric ton of CO_2e, based on the average 2030 price for one carbon offset under California's cap-and-trade program.[106]

   Recognizing that replacing virgin with recycled polyester will likely conserve land and water used in lower-cost operations in countries such as Bangladesh (e.g., where virgin polyester is produced and / or used in manufacturing today), we estimated a lower-range dollar value based on the market value of land and water in those countries.

   — **The social metrics** include jobs created, based on the state's median wages for occupations where additional jobs were expected, and GDP growth from jobs, based on research by the Institute for Policy Studies on the contribution of US minimum wage growth to economic activity.[107]

2. **Define potential initiatives to address major obstacles and advance circularity in California**. Focusing on polyester as the use case, we identified core and enabling initiatives that could accelerate textile-to-textile recycling in California.

3. **Estimate the costs and benefits of each initiative**. Our top-down analysis of costs and benefits drew on diverse sources, including proprietary analyses, external research, and interviews with experts in apparel sales, textile collection, and chemical recycling.

   Given the distributed nature of environmental impact, we sized the total environmental impact of replacing virgin fiber input materials with recycled materials. Our methodology for sizing the total environmental impact of the closed-loop system is broadly consistent with the ISO 14040: 2006 methodology of the International Organization for Standardization.[108]

   Then, we allocated the total impact across initiatives relevant to the purchasing of recycled fibers and the collection, sorting, and recycling of textile waste, proportionate to their total annualized costs (i.e., run-rate operating costs and amortized capital costs).

   This approach to environmental impact allocation recognizes that the market prices for an item across various recycling stages are currently in flux. Once market prices for collected and sorted feedstock and recycled outputs were clear, the methodology could recalibrate to allocate total environmental impact across the closed-loop system based on market prices instead of total annualized costs.

4. **Compare costs and benefits for the set of initiatives**. We assessed the holistic impact potentially generated as a return on the capital expense and recurring operating expenses required to support closed-loop recycling. We also identified which initiatives could be economically viable (i.e., revenue exceeds costs) and which would require external funding or cost savings to scale.

5. **Develop a perspective on the total holistic impact of closed-loop recycling in California and the US**. Leveraging our estimate of total holistic impact from closed-loop recycling of polyester in California, we applied a multiplier to generate a rough estimate of the holistic impact of fashion circularity across California and the US, taking all fiber types into consideration.

12 potential initiatives to advance fashion circularity

The 12 initiatives represent opportunities across the fashion lifecycle to advance closed-loop recycling, with a focus on interventions relevant to polyester. They include:[109]

Input materials

— Purchase recycled polyester to replace virgin polyester in apparel

Manufacturing

— Modify product design to reduce the percentage of blended polyester apparel (i.e., contains other fiber types)

— Implement clothing digital product ID with detailed material composition information to improve tracking and sorting

Retail / consumption

— Promote and sell recycled apparel to shoppers

Collection

— Partner with apparel manufacturers to collect pre-consumer industrial polyester waste

— Partner with retail stores to collect pre-consumer polyester waste

— Partner with existing collectors to divert post-consumer polyester waste that would otherwise be downcycled or sent abroad

— Launch a public information campaign to encourage California residents to donate / recycle used apparel

— Offer incentives for consumers to participate in apparel take-back programs (e.g., store credit, discounts)

— Scale curbside textile collection in Los Angeles, San Francisco, and select Bay Area counties

Sorting

— Build a highly automated facility to sort and deconstruct polyester textiles

Recycling

— Build a chemical recycling facility to process polyester textiles

Rationale for focus on recycled polyester
While these initiatives focus on polyester as the use case, many are also relevant to other textile materials. We focused on recycled polyester because:

— **Polyester is the most used fiber in the world, and demand is growing.** Polyester accounts for ~50 percent of the global fiber market (vs. ~30 percent for cotton, the second most used fiber).[110] Demand for polyester is increasing at 3-5 percent, 2017-2030 (vs. 0-1 percent for cotton).[111]

— **More than 70 brands have committed to increase their use of recycled polyester.** These brands signed on to the Textile Exchange's 2025 Recycled Polyester Challenge that aims to increase recycled polyester use from 14 percent today to 45 percent by 2025.

— **The fashion industry faces increased competition for recycled polyester made from plastic water bottles (rPET)** because beverage and bottle manufacturers have also committed to using more recycled content in their products.[112] Rather than competing for increasingly cost-prohibitive rPET material downcycled from plastic bottles (instead of keeping it in a closed loop to produce new plastic bottles), apparel manufacturers could use polyester recycled from used textiles.

— **Polyester chemical recycling is one of the most promising textile-to-textile recycling technologies with scaling potential.** Depolymerization technologies have been commercialized successfully, and multiple chemical recyclers have developed processes to clean and purify polyester waste.[113] A few US chemical recyclers can process both 100 percent pure polyester and some blended textiles (e.g., cotton-polyester).

These factors make recycled polyester a compelling initial focus for scaling textile circularity in California, but microplastics pollution remains a key issue. Both virgin and recycled polyester sheds microplastics that pollute major water bodies and interfere with organic functions. These negative effects would require action to ensure net positive environmental impact in using recycled polyester.

Polyester is just one of the many fiber types that stand to play a role in closed-loop recycling. Future research should assess the costs and holistic impact of other fiber types, especially recycled cotton and certain man-made cellulosic fibers.

Focus on eight core initiatives

Of the 12 initiatives, the eight core initiatives described below offer the greatest potential for advancing fashion circularity in California. We identified these initiatives in consultation with more than 30 experts in the fashion and waste management industries.

Fashion circularity cannot happen without willingness to purchase recycled, instead of virgin, input materials and apparel and development of increased collection, sorting, and recycling capacity. The eight core initiatives meet these minimum requirements.

1. **Purchase recycled polyester to replace virgin polyester in apparel**. Fashion brands or apparel manufacturers might have to pay an incremental premium to procure recycled polyester input materials (potentially ~25 percent on the current price of ~$1,400 per ton of virgin polyester), but other switching costs would be minimal.[114]

   Fashion brands would need to design apparel for recycling. Recycled polyester input materials processed down to monomers behave like virgin polyester input materials through the rest of the manufacturing process (e.g., yarn spinning, weaving, or knitting).

2. **Promote and sell recycled apparel to shoppers**. Engaging consumers in fashion circularity could begin at the point of sale. Consumers should be able to see which clothing is "made with recycled polyester" and should have access to information about how fashion circularity works. Coining a new term for recycled polyester that meets high apparel standards (e.g., "re-poly" or "eco-polyester") could provide more formal recognition to the retailers who use it and help increase transparency and awareness for customers who are making purchase decisions.

   In fact, fashion brands could benefit from increased consumer awareness of fashion circularity. Our consumer survey suggests that value and mass market consumers in California (55-60 percent of survey respondents) might be willing to pay a premium of 2-3 percent for recycled clothing. Even if this stated consumer willingness to pay does not translate into actual behavior, other alternative or complementary levers (e.g., corporate investment and policy-driven interventions) have the potential to achieve the same impact.

3. **Partner with apparel manufacturers to collect pre-consumer polyester waste**. The manufacturing process generates waste, such as scraps and rejected apparel. According to industry sources, an estimated 12-30 percent of input materials are discarded during the production of garments.[115]

   Because pre-consumer waste is often cleaner and more homogenous than post-consumer waste, partnering with apparel manufacturers in California that could segregate and collect pre-consumer polyester waste for closed-loop recycling might be advantageous.[116] These partnerships could focus initial closed-loop recycling efforts, but the amount of available waste is relatively small (~20,000 tons of polyester, about 8 percent of estimated total polyester apparel waste generated in California).[117]

4. **Partner with retail stores to collect pre-consumer polyester waste**. Retail stores have unsold goods, such as overstock and returns that do not sell on clearance. This source of waste is relatively small (5,000-10,000 tons of polyester, about 2-4 percent of estimated total polyester apparel waste generated in California) because most garments are diverted for low-cost resale or donated to employees, rather than thrown away.[118] But after other channels have been exhausted, textile-to-textile recycling could offer an alternative end-of-life use.

5. **Partner with existing collectors to divert post-consumer polyester waste that would otherwise be downcycled or sent abroad**. Today, donation centers and drop-off containers collect most end-of-life garments that escape the landfill for resale and extension of their useful life. But 80-90 percent of these garments do not sell off the rack in local thrift shops, making these channels promising sources of post-consumer waste. In addition, some fashion brands have launched programs to collect used garments from end-consumers via retail stores and mail.[119]

6. **Scale curbside textile collection in Los Angeles, San Francisco, and select Bay Area counties**. Curbside textile collection is a convenient option for California residents that could bolster collection rates, increasing the scale of closed-

loop recycling. But curbside collection is one of the most expensive methods per ton. Therefore, it has the greatest potential in metropolitan areas like Los Angeles, San Francisco, and select Bay Area counties, which are nine times more densely populated than the average California county.[120]

7. **Build a highly automated facility to sort and deconstruct polyester textiles**. Sorting is necessary because each recycling process is designed to handle a specific type of textile waste (e.g., >80 percent polyester or cotton textiles). Textile recyclers cannot handle unsorted waste because even a small amount of contamination can damage the recycled output. Textile sorting in the US is not at scale today, and items are often not tagged with enough information to accurately determine their fiber type or blend. Therefore, a highly automated optical sorting facility offers the best way to meet the need for efficient, accurate, high-volume sorting.

   The sorting facility could use state-of-the-art optical technology to sort textiles by fiber type and color and would feed collected textiles onto conveyor belts, where items would be scanned by high-powered cameras and separated by fiber type.[121] We assume manual deconstruction of polyester materials destined for chemical recycling at the end of the sorting line.[122] Finally, a baling machine would package sorted and deconstructed textiles for purchase by textile recyclers.

8. **Build a chemical recycling facility to process polyester textiles**. Increasing chemical textile recycling capacity would be critical as it can produce virgin-quality recycled fibers over many iterations (unlike mechanical textile recycling). Chemical recycling would be necessary to achieve closed-loop textile recycling. The recycling facility would break down pure and blended polyester textile waste into monomers. Recyclers would remove impurities and reform the monomers into virgin-quality PET pellets or resin for sale to downstream spinners that would use the inputs to make polyester yarn.

Holistic impact of closed-loop recycling in California

We estimate closed-loop textile recycling in California could achieve total holistic impact of $7–9 billion a year (equal to 4–6 percent of the state's 2020 gross domestic product from retail).[123] This estimate rests on evaluation of the potential holistic impact of closed-loop recycling of pure and blended polyester apparel manufactured and / or worn in the state. This impact could reach $3.5–4.5 billion a year.[124]

Total holistic impact

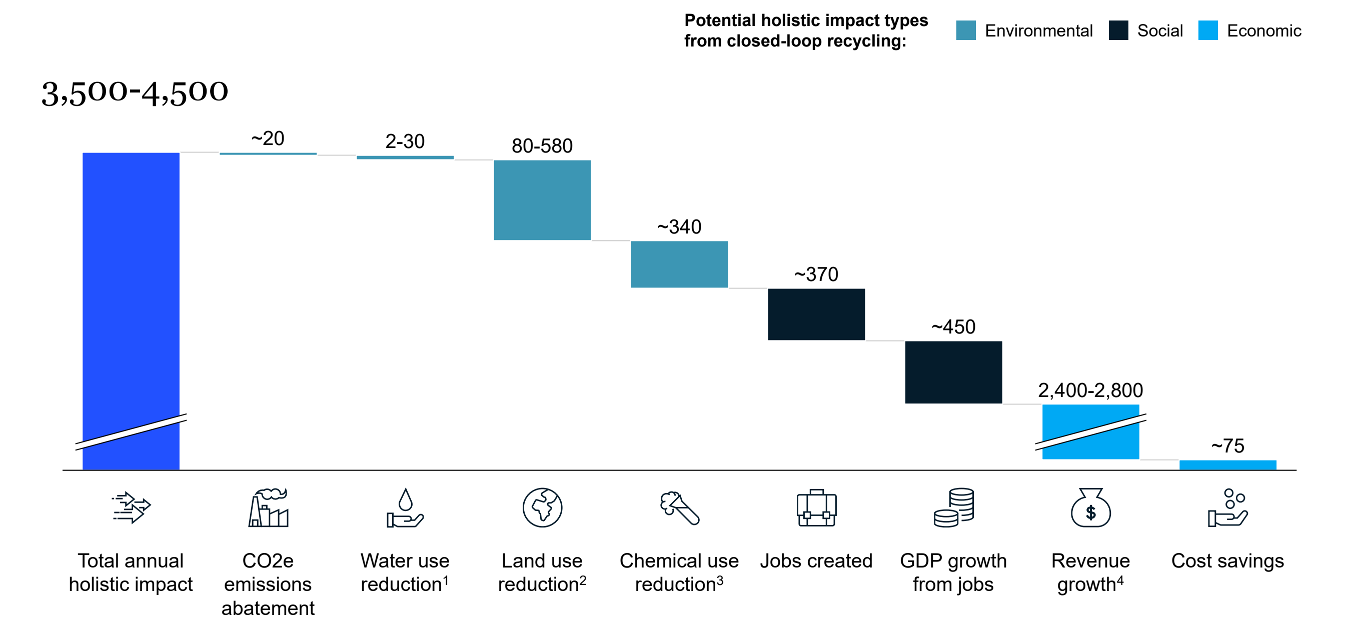
Our analysis assumes recycling 76 percent of the pure and blended polyester apparel consumed in California (~225,000 tons of polyester) by 2030.[125] We assume diverting 15 percent of end-of-life polyester textiles for repair or resale and collecting 89 percent of the remaining polyester textiles destined for the landfill (based on the 2020 recycling rate for used corrugated cardboard, a material that has achieved a "gold-standard" recycling rate).[126]

Reaching this target could unlock $3.5-4.5 billion of holistic impact (Exhibit 16). Environmental benefits like reducing CO2e emissions and water use and social benefits like creating jobs and growing GDP could account for 30-40 percent of the total impact.[127] The economic benefits of an at-scale circular economy with cost-neutral recycled inputs would deliver the remaining 60-70 percent of the impact for the private sector, primarily through consumers' willingness to pay, scale efficiencies, and policy-driven interventions across the activities involved in selling recycled polyester apparel, sorting feedstock, and using recycled input materials.

Exhibit 16

Advancing closed-loop recycling of polyester in California could have holistic impact of $3.5-4.5 billion of holistic impact

Total potential holistic impact by source of impact, USD millions



1. High end based on average water price in Bay Area of California (~$2.60 per m3); low end based on average water price in low-cost country (e.g., Dhaka, Bangladesh: ~$0.17 per m3).
2. High end based on average price for undeveloped land in California (~$8,500 per acre); low end based on average price for undeveloped land in low-cost country (e.g., Bangladesh: $1,100-1,200 per acre).
3. Includes ethylene glycol (MET) and terephthalic acid (TPA), the two main crude-oil-derived chemical components of polyester.
4. Within total revenue growth, $1.9-2.2 billion based on different scenarios for total economic benefit realizable from a combination of Californians' willingness to pay a premium, improvements in at-scale recycling processes that help achieve an input cost for recycled materials that is below virgin materials, and policy-driven interventions. We assumed that adoption would require margin improvement of at least 2-3% beyond cost neutrality. We assumed adoption by the 55% of Californians who say they would pay this margin as a premium for access to recycled products in the low scenario and for all Californians in the high scenario, accounting for wider adoption driven by technological, economic, and / or policy factors.

Source: Sarah Anderson, Wall Street bonuses and the minimum wage; bdnews24.com, Dhaka WASA raises water price by 24.97% for households; California Water Service, Non-residential metered service in 2021 in California Water Service's rates and tariffs; Tamma Carleton, Updating the United States government's social cost of carbon; Center for Climate and Energy Solutions, Policy Hub: California cap and trade; Nia Cherrett, Ecological footprint and water analysis of cotton, hemp and polyester; EcoCosy climate leadership white paper 2020; Fashion Industry Charter for Climate Action, Identifying low-carbon sources of cotton and polyester fibers; IHS Markit PEP Yearbook, Terephthalic acid required to produce PET pellets; Interviews with fashion / circularity experts (October-December 2021); McKinsey and Global Fashion Agenda, Fashion on climate full report; Organic Chemical Process Industry, AP-42, Ch. 6.6.2: Poly(ethylene terephthalate); Katherine Ricke, Country-level social cost of carbon; Gustav Sandin, Environmental impact of textile fibers – what we know and what we don't know: The fiber bible, part 2; Sustainable Business, California to boost solar and wind capacity to meet renewable goals; Textile Exchange, Material snapshot: Virgin polyester; US Department of Agriculture, Land values: 2021 summary

Environmental and social impact

The true environmental cost of polyester apparel production would decrease if recycled input materials replaced virgin input materials (Exhibit 17). Our calculations focus on resources used in the production of polyester input materials (e.g., up to PET pellets or resin sold to yarn spinners).

Recycled polyester eliminates the need to extract new crude oil and the energy-intensive steps (e.g., steam cracking) required to transform crude oil into the monomers that form polyester. Relative to virgin polyester, recycled polyester requires less:

— Carbon emissions[128]

— Water use[129]

— Land-use[130], and

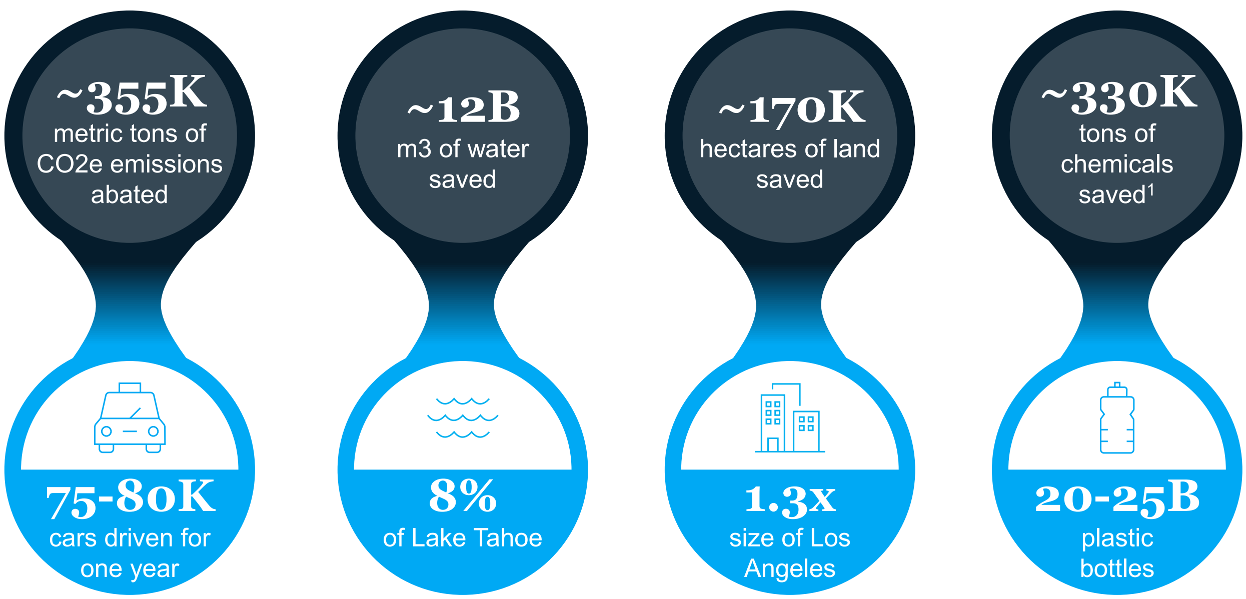
— Chemicals use[131]

Building an industry to produce recycled polyester in California could also create an estimated 8,500-9,000 collection, sorting, and recycling jobs.[132] If scaled up to produce all types of recycled apparel materials in California, it could create 17,000-18,000 collection, sorting, and recycling jobs, an estimated 35% increase in the total number of jobs affiliated with the waste management and remediation services sector in the state.[133]

Exhibit 17

Closed-loop recycling of polyester could have significant environmental impact

Total potential environmental impact from closed-loop recycling of polyester



1. Only accounts for ethylene glycol and terephthalic acid.

Source: IHS Markit PEP Yearbook, Terephthalic acid required to produce PET pellets; Interviews with fashion / circularity experts (October-December 2021) ; Organic Chemical Process Industry, AP-42, Ch. 6.6.2; Encyclopedia Britannica, Lake Tahoe, lake, United States; Pet Resin Association, Little known facts about PET plastics; Leonard Pitt, Los Angeles; Sustainable Business, California to boost solar and wind capacity to meet renewable goals; Textile Exchange, Material snapshot: Virgin polyester; UN Fashion Industry Charter for Climate Action; US Environmental Protection Agency, Greenhouse gas emissions from a typical passenger vehicle, EPA-420-F-18-008.

17,000-18,000

Total collection, sorting, and recycling jobs that could be created by producing all types of recycled apparel materials in California (an estimated 35% increase in the total number of jobs affiliated with the waste management and remediation services sector in the state)

Cost vs. holistic impact of each initiative

Unlocking the estimated $3.5-4.5 billion of annual holistic impact would involve new capital and operating expenses. We estimate that building an at-scale circular textiles economy for polyester textiles would require investing $1 billion in initial capital expenditures (CapEx) and allocating $1.5 billion annually to operating expenses (OpEx).[134] This investment could fund efforts to scale collection, sorting, and recycling capacity and to create awareness and incentives for Californians to participate in the new ecosystem.

Relative to the cost, a circular fashion ecosystem could create significant value. Every $1.00 spent could generate ~$2.70 of net holistic impact (Exhibit 18).[135]

While annual holistic impact would exceed annual run-rate operating expenses for each initiative, the initiatives would generate revenue and cost savings unevenly.[136] Only some stakeholders would profit in a nascent circular economy. For example, fashion brands might cover incremental procurement and marketing costs by selling recycled garments at a premium that reflects their environmental and social benefits. Similarly, chemical textile recycling at scale could turn a profit by securing feedstock and customers.

But, while recycling at scale might be profitable, current feedstock prices would not compensate waste haulers, collectors, and sorters for the costs of scaling their operations. This issue is critical because having sufficient feedstock for closed-loop recycling requires having ample collection and sorting capacity to handle textile waste.

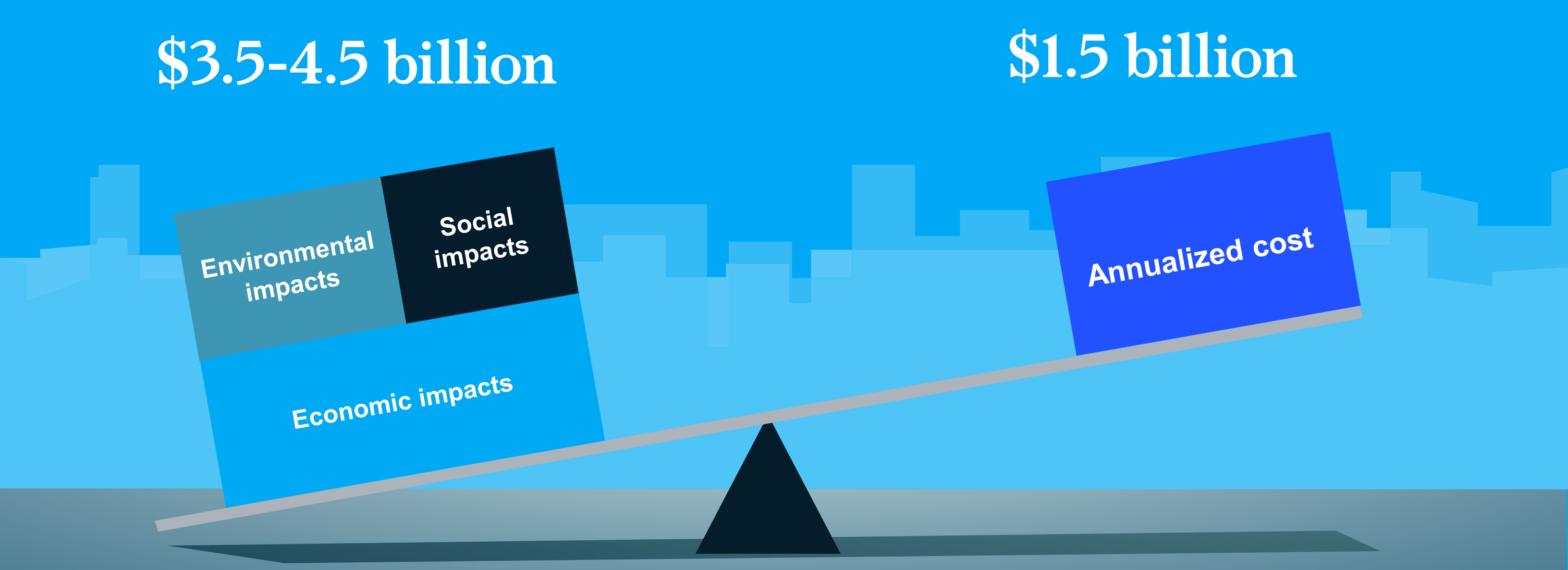
Cost implications for core initiatives

Three core initiatives (#1, 2, and 8) could be self-sustaining in the long term, but the other five (#3, 4, 5, 6, and 7) face challenges and would likely require additional external funding or incremental cost reduction to succeed (Exhibit 19).

Exhibit 18

Closed-loop recycling of polyester could generate almost 3x total potential holistic impact for each $1 spent

Total annual potential holistic impact from closed-loop recycling of polyester vs. annualized cost



1. Annualized cost is calculated as total capital expenses amortized linearly over the lifespan of the asset plus annual run-rate operating expenses.

Source: IHS Markit PEP Yearbook, Terephthalic acid required to produce PET pellets; Interviews with fashion / circularity experts (October-December 2021); Organic Chemical Process Industry, AP-42, Ch. 6.6.2; Sustainable Business, California to boost solar and wind capacity; Textile Exchange, Material snapshot: Virgin polyester; UN Fashion Industry Charter for Climate Action

Self-sustaining core initiatives

1. Purchase recycled polyester to replace virgin polyester in apparel. Fashion brands can expect to pay a premium for recycled polyester for the foreseeable future. Replacing ~225,000 tons of virgin polyester with recycled polyester could cost an additional $75-80 million a year.[137] While this initiative does not look profitable on its own, selling recycled apparel to shoppers at a premium could have net positive profit impact for brands, as the description of the next initiative details.

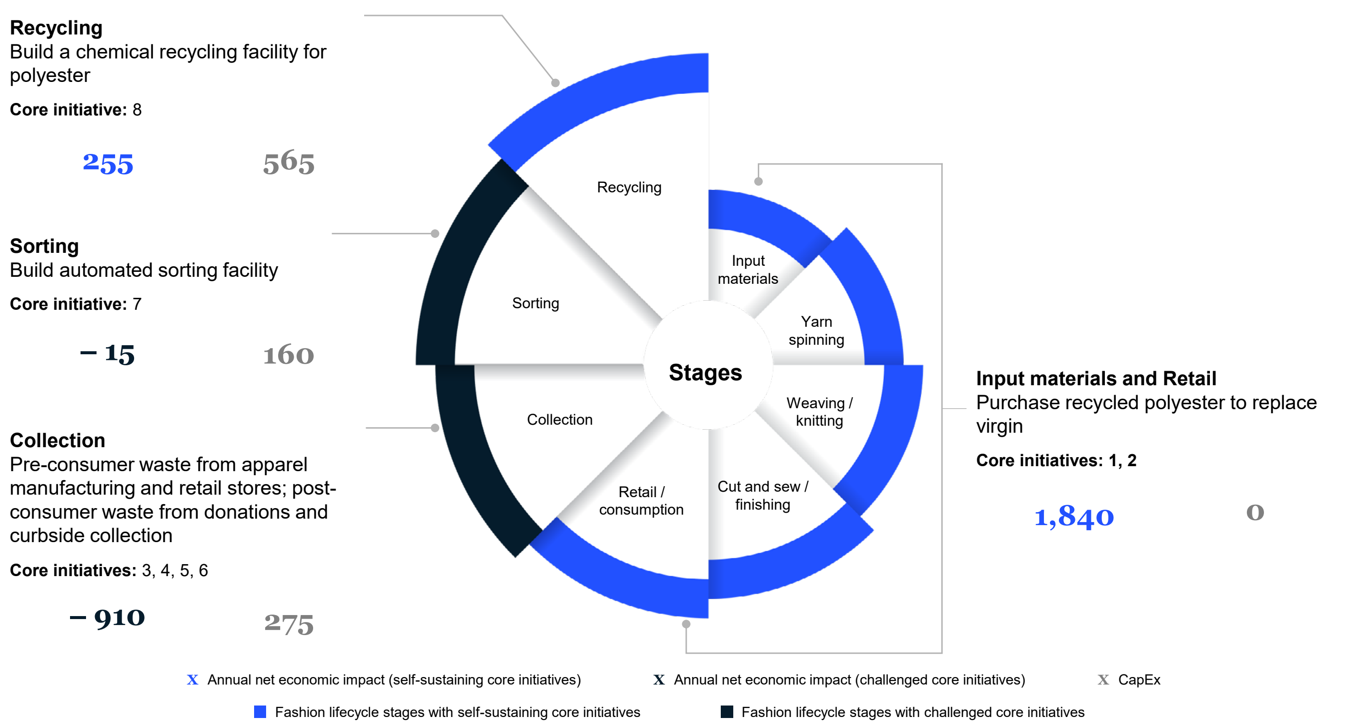
2. Promote and sell recycled apparel to shoppers. Fashion brands could promote closed-loop recycling to shoppers to encourage participation in the circular ecosystem. These marketing efforts could cost ~$135 million a year but could help capture at least some of the premium of 2-3 percent for recycled apparel reported in the willingness-to-pay section of our survey.[138] That premium, together with technological, economic, and policy factors, could generate incremental revenue of $1.9-2.2 billion that would more than compensate for additional procurement and marketing expenses, making the economic case for closing the loop.[139]

8. Build a chemical recycling facility in California to process polyester textiles. A large-scale (~225,000-ton throughput) chemical recycling facility might require total capital expenses of $560-570 million for the facilities and equipment needed to break down, purify, and reconstruct polyester. Operating expenses might total ~$135 million a year, including utilities, feedstock, labor, and other recurring expenses.[140] Compared with expected revenues of ~$390 million a year, large-scale facilities could be profitable, with relatively short payback periods (less than three years) for the upfront capital investment. But to achieve these economies of scale, investors and textile recyclers would require sufficient feedstock and secure demand for recycled outputs.

Exhibit 19

Some core initiatives will require support beyond initial capital costs for long-term success

Estimated 2030 annual net economic impact (annual revenue and cost savings vs. annual run-rate OpEx) and total CapEx by stage of fashion lifecycle, USD millions



Source: Interviews with fashion / circularity experts (October-December 2021)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Challenged core initiatives

3. Partner with apparel manufacturers to collect pre-consumer polyester waste and 4. Partner with retail stores to collect pre-consumer polyester waste. Annual run rate operating expenses for pre-consumer waste collection could be $6-7 million, including labor and transportation costs incurred to obtain ~11,000 tons of polyester waste from apparel manufacturers and ~4,000 tons of polyester from retail stores.[141] These costs would exceed the expected revenues of ~$2 million from selling collected textiles, based on current feedstock prices that textile recyclers are willing to pay.

Therefore, apparel manufacturers and retail stores might require additional incentives to collect pre-consumer waste — such as higher feedstock prices, externally funded transportation, or perceived brand value (e.g., an environment-friendly brand identity).

Initial recycling efforts might focus on pre-consumer collection because pre-consumer waste is often easier and thus more cost-effective to process than post-consumer waste. However, because pre-consumer waste accounts for only 10–12 percent of total textile waste, expanding post-consumer waste collection would also be necessary to achieve closed-loop recycling at scale in California.

5. Partner with existing collectors to divert post-consumer polyester waste that would otherwise be downcycled or sent abroad. Post-consumer textile waste is the largest source of feedstock in California. But the 10–15 percent of textile waste collected today is scattered across channels, with 85-90 percent going to the landfill, so alternative collection must ramp up dramatically to improve closed-loop recycling rates.

Annual operating expenses required to scale collection channels to ~135,000 tons a year might amount to $275 million a year.[142] This does not include additional capital expenses, but additional infrastructure might be needed to collect, haul, and pre-sort textile waste (e.g., waste hauling vehicles, collection locations, and distribution centers).

Current feedstock prices do not compensate for the labor and transportation required to collect post-consumer waste.[143] Selling collected textiles to downstream textile sorters and recyclers at current feedstock prices would generate estimated revenue of $35-40 million.[144] This implies a system-level revenue shortfall of $240-245 million just to break even on costs.

This shortfall might be even greater if collectors considered the potential opportunity costs of selling to a downcycler or textile recycler vs. an international wholesaler. If other stakeholders in the marketplace were willing to pay more for collected textiles, securing feedstock for closed-loop recycling might prove difficult.

6. Scale curbside textile collection in Los Angeles, San Francisco, and select Bay Area counties. The future circular ecosystem could tap multiple collection channels to consolidate textile waste. In addition to the collectors' channels used in California today, incremental curbside textile collection might offer convenience. Curbside collection would be most viable in densely populated urban areas because it requires significant scale to justify the costs of door-to-door collection.

New York City's Department of Sanitation, for example, launched a partnership with the non-profit Housing Works in 2011 to install bins for free curbside textile collection at commercial buildings, schools, and apartment buildings with ten or more units.[145] As of 2018, the program saw more than 13 million pounds of textile materials recycled.[146]

Two of California's most densely populated areas, Los Angeles, San Francisco, and select Bay Area counties, might be candidates for curbside textile recycling at scale.[147]

Potential revenues from selling collected textiles would not cover the costs of collection. The operating expenses for curbside textile collection available to the 5.9 million households in Los Angeles, San Francisco, and select Bay Area counties alone would be an estimated $310 million a year (collecting a maximum estimated volume of ~95,000 tons of waste per year, equal to 30-35 percent of all polyester apparel waste generated in California).[148]

In addition to operating expenses for labor and transportation, this initiative might involve a one-time cost of $275 million to provide textile-specific bins to participants. Capital expenses could increase further if additional waste hauling vehicles or transfer stations were needed to collect and consolidate textile waste. Potential revenues might reach $30 million, based on current feedstock prices.

7. Build a highly automated facility in California to sort and deconstruct polyester textiles. Building an automated sorting facility would require an initial capital investment of ~$160 million.[149] Because optical sorting is highly efficient, the annual operating expenses might be much lower — $20 million for sorting, plus $40 million for manual deconstruction.[150] But annual expected revenues of ~$45 million, based on estimated feedstock prices for sorted textiles, would be insufficient to justify the investment.[151]

Potential strategies to address challenged initiatives

If the five challenged initiatives did not receive external funding or find ways to reduce costs, the entire $3.5-4.5 billion of holistic impact from advancing polyester closed-loop recycling might be at risk.

We explored three potential ways to avoid this eventuality. Together, they could make the business model for closed-loop recycling work for collectors and sorters:

- **Consumer fees** — for example, having waste generators pay for recycling as a service that would generate revenue for collectors on top of the sale of collected materials; charging households and businesses for curbside recycling, similar to programs already in place for other materials like paper and plastic; collecting and sorting other recyclable materials in addition to textiles
- **Public funding or subsidies** — for example, accessing financial assistance, such as grants or other public incentives, to cover ongoing operating costs[152]
- **Business model innovation** — for example, integrating vertically with other players in the value chain to spread costs (e.g., collection and sorting entity); tapping volunteers to lower labor costs; leveraging existing supply trucks to consolidate waste at low incremental cost.[153]

Public funding or subsidies provided to the challenged initiatives could decline gradually, potentially without negative impact on the sector, as the market scaled and stabilized. For example, if mass market consumers were eventually willing to pay a premium for recycled apparel and / or at-scale recycling involved lower manufacturing cost than production of traditional virgin materials, the price difference might flow through the value chain to compensate collectors, sorters, and recyclers for their critical contributions to closed-loop recycling (similar to the fair-trade business used by some coffee producers).

Feedstock prices would probably increase, reflecting the value and end-of-life potential of textile waste.[154] In addition, likely learning rate efficiencies (typically 5-25 percent for each doubling of total cumulative production in manufacturing industries) would further reduce production costs as technologies and processes matured.[155]

Getting started

To start to unlock the total potential holistic impact of closed-loop recycling through the eight core initiatives that we have proposed, players across the apparel industry should act in tandem on three fronts:

— **Expand textile collection** to ensure convenient options for diverting pre- and post-consumer apparel waste from the landfill.

  Retailers could establish internal collection channels for pre-consumer waste —– textile scraps from manufacturing facilities and / or deadstock from distribution centers and retail stores. Retailers could expand the collection of post-consumer waste by encouraging and increasing the convenience of donating end-of-life garments (vs. relegating them to the landfill) —– for example, by offering exclusive promotions or take-back programs.

  Donation centers could divert used clothing from downcycling, and municipalities could provide textile-specific collection bins to homes and businesses. Once collected, textile waste would require efficient consolidation for downstream sorting and recycling.

— **Expand capacity to sort and deconstruct textiles** and, ultimately, produce high-quality recycling feedstock at scale. To enhance efficiency, apparel manufacturers could collaborate with textile collectors and sorters —– for example, tagging garments with digital product IDs (e.g., RFID or watermark) to identify their material composition, making sorting more accurate and efficient.

— **Scale chemical recycling capacity** to transform large amounts of textile waste into virgin-quality recycled input materials for manufacture into new apparel. Current technologies can chemically recycle polyester, man-made cellulosic fibers, and cotton —– fibers that account for over 80 percent of all apparel.[156]

Efforts to get started could follow multiple paths and forge various partnerships. Fashion brands, donation centers and consignment stores, municipalities, and California residents all have roles to play in textile collection.

Sorters could sort textiles manually until automated technologies scaled up. Waste haulers and reverse logistics platforms could partner in the new circular ecosystem to increase the capacity and efficiency of collecting end-of-life apparel.

Early buyers of recycled outputs might range from fashion brands designing new recycled apparel lines to makers of furniture or autos looking to incorporate more recycled input materials into their products (e.g., Audi, Ford, and others have expressed interest in using recycled materials in seats, carpeting, and floor mats in their vehicles).[157]

Apparel circularity is a multi-dimensional issue that warrants broader action and further study. While this report focuses on closed-loop recycling of polyester apparel, the fashion industry could add value by embracing other dimensions of circularity, such as reducing consumption, reusing and repairing garments, exploring additional products like footwear, and incorporating other fiber types.

This research rests on interviews, surveys, and theoretical estimates of costs and benefits, focused primarily on building a closed-loop recycling ecosystem for polyester apparel in California. Researchers could apply the methodology to other fiber types or geographies. Real-world data from pilot programs or field research could enhance the findings by providing granular insights into product-level demand signals, CapEx and OpEx data points (for evaluation across geographies), and examples of scale effects.

The sizing of holistic impact might expand to account for additional sources of environmental and social impact, such as reducing methane emissions from apparel waste in the landfill, increasing economic inclusion by creating equitable jobs, and retaining talent by building a purpose-driven California fashion industry.[158] Further efforts might refine the valuation of non-financial impact by doing more research to understand the true benefit to society.

Today's fashion industry is unsustainable. In California, more than 97 percent of the materials used in apparel manufacturing are virgin materials. Some 500,000 tons of textile waste go to the landfill, and that number will only grow as apparel demand increases.

Establishing a circular apparel industry in California by building closed-loop recycling capacity could unlock $7-9 billion in total economic, environmental, and social impact. California could realize $2.70 in holistic impact for every $1.00 spent.

But achieving such results would require developing collection, sorting, and recycling capacity to enable production of recycled input materials. The eight core initiatives described in this report would meet these minimum requirements and significantly advance fashion circularity in California.

While building a closed loop for apparel in California would take some external support and industry innovation, the effort promises tangible and intangible benefits that would have positive impact on all Californians. Success in California, and beyond, would require commitment to circularity, bold action, and resolve from stakeholders across the fashion lifecycle.

Success would ultimately require a commitment to circularity, bold action, and resolve from stakeholders across the fashion lifecycle.

Glossary

Blended textiles: Yarn or fabric manufactured with two or more fiber types combined together.[159]

Chemical cotton / cellulose recycling: Dissolving natural cotton or cellulosic textile with a solvent to break the textile down into a cellulose pulp and then regenerating the pulp into man-made cellulosic fibers via the viscose process.[160]

Chemical polyester recycling: Using chemically induced reactions to break down PET plastic or polyester textiles into building block molecules known as *monomers*, such as purified terephthalic acid and ethylene glycol, then using the purified PET monomers to make new PET pellets or resin.[161]

Chemical recycling: Method of recycling that uses chemical processes to break down pure and blended textiles (e.g., cotton, polyester) into their basic components and then repolymerizes them into virgin-quality recycled input materials.[162]

Circularity: Infrastructure and processes meant to ensure that inputs are safe (do not include toxic substances, recycled or renewable); products remain in use longer; products are recyclable and recycled into inputs for the value chain.[163]

Closed-loop recycling: Process that recycles pre- and post-consumer waste to supply materials used to manufacture new versions of the original items.[164] Closed-loop recycling differs from the broader sustainable manufacturing. Sustainability includes dimensions, such as low intensity of secondary input (power, water, chemicals) not included in closed-loop recycling.

Cotton: A natural fiber made from the tropical plants of the mallow family valued for its soft tactile feel and white color, which is easy to dye.[165]

Deadstock: Unsellable and unused inventory, including damaged or incorrectly produced items.[166] Overstock can be considered a subset of deadstock.

Downcycling: Also known as *cascading*, process of recycling that yields a product of lower value or functionality than the original item,[167] such as recycling apparel into insulation or mattress stuffing.

Man-made cellulosic fibers: Fibers made from the dissolved wood pulp, or cellulose, of trees or other plants.[168] Examples include viscose, lyocell, acetate, and modal.

Mechanical cotton recycling: Cutting, shredding, and pulling cotton apart into fibers, carding the fibers, and re-spinning them. Some virgin cotton is often added to improve quality.[169]

Mechanical polyester recycling: Shredding polyester into flakes, pressing them into PET pellets, and melting and then extruding the pellets to create recycled polyester fiber.[170]

Mechanical recycling: Method of recycling that transforms end-of-life materials into secondary materials without changing their basic chemical composition. Mechanical recycling is suitable only for pure fabrics, such as 100 percent cotton or 100 percent polyester apparel. Methods employed include shredding and carding of natural fabrics and shredding, melting, and extruding of plastic fibers.[171]

Overstock: An excessively large inventory of goods; more goods than demanded or needed.[172]

Polyester: Fiber derived from chemical reactions with crude oil, air, and water. Polyester input materials can be melted and reformed or broken down into basic chemical building blocks (monomers). Polyester is made by melting PET pellets and forcing the melted substance through small holes (extrusion) to create fibers.[173]

Polyethylene terephthalate (PET): The chemical name for polyester. PET is a clear, strong, lightweight plastic used in packaging or extruded to form synthetic polyester fibers.

Post-consumer industrial waste: Apparel waste that has been worn by consumers but is managed by businesses like hotels and hospitals; includes uniforms.

Post-consumer retail waste: Apparel waste that has been worn by consumers and disposed of at the household level.

Pre-consumer industrial waste: Apparel waste from manufacturers that has never been worn by consumers; includes trimmings as well as the output of overproduction or flawed production.

Pre-consumer retail waste: Apparel waste from retailers that has never been worn by consumers; includes returns, samples, and overstock / deadstock.

Pure textiles: Yarn or fabric manufactured with only one fiber type, such as 100 percent cotton or 100 percent polyester.[174]

Samples: Versions of a garment made to check fit, display in stores or photo shoots, run quality tests, etc. Garments cannot then be sold to consumers.[175]

Textile-to-textile recycling: Process of recovering materials from pre- and post-consumer textile waste and producing yarns for new fabrics.[176]

Upcycling: Process of recycling end-of-life materials that adds value, yielding a product of equal or higher value than the original item, such as processing factory scraps of polyester fabric back into polyester fiber used to make new garments.[177]

Virgin material: Previously unused input materials that require extracting new resources to produce, such as virgin polyester made from crude-oil derivatives.[178]

Endnotes

1 Achim Berg et al., “Fashion on climate: How the fashion industry can urgently act to reduce its greenhouse gas emissions,” McKinsey and Global Fashion Agenda, August 26, 2020.
2 “A new textiles economy: redesigning fashion’s future,” Ellen MacArthur Foundation, January 12, 2017.
3 Alvise Lisca et al., “The circular economy action agenda for textiles,” Platform for Accelerating the Circular Economy (PACE), February 2021.
4 “A new textiles economy,” 2017; “Sustainable facilities tool,” US General Services Administration, accessed 2021.
5 World Trade Organization, “World trade statistical review 2021,” accessed 2022.
6 This assumes raw material production losses are between 12-30 percent in the creation of the shirt. It also assumes virgin polyester uses ~1.8 hectares (~4.44 acres or ~1,800 m2) per ton of polyester or 9 m2 per pound of virgin polyester, the average t-shirt weighs 0.25-0.45 pounds, and a raw material production loss of 12-30 percent from fiber to t-shirt results in 0.3-0.7 lbs of virgin polyester used in the average t-shirt. This only accounts for total ethylene glycol and terephthalic acid used in the production of polyester from crude oil (~1.5 lbs per lb of polyester) and assumes one t-shirt weighs ~0.35 lbs: Sources: “How much does a t-shirt weigh,” Aviva Dallas, December 28, 2020; “AP-42, Ch. 6.6.2: Poly(ethylene terephthalate),” Organic Chemical Process Industry, US Environmental Protection Agency, November 19, 2018; IHS Markit PEP Yearbook, Terephthalic acid required to produce PET pellets, accessed October 2021. Zequan Wu, “Haode evaluating the lifecycle environmental impacts of polyester sports t-shirts,” *IOP Conference Series: Earth and Environmental Science,* Volume 474, Number 02217, May 15, 2020; Christian Schindler, “Today’s challenges for the global textile industry with a special focus on spinning,” International Textiles Manufacturers Federation (ITMF), Jaipur, India, November 17-19, 2016; Interviews with fashion / circularity experts (October-December 2021).
7 “Fashion on climate full report,” August 2020.
8 ”Sustainability and circularity in the textile value chain,” 2020.
9 Type refers to the type of production processes by which the material is produced; Material types based on postings from Patagonia, Allbirds, TENCEL, Levi’s and H&M websites.
10 Origin refers to the source from which the material is made.
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12 “Textiles: Material-specific data,” US Environmental Protection Agency, last updated July 2, 2021.
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14 “Preferred fiber and materials market report 2021,” Textile Exchange, August 2021.
15 Based on average weight of, and average m2 of fabric to manufacture, a t-shirt and pair of jeans: Sources: Chapter 3, Exhibit 5; *What Things Weigh,* “How much does a pair of jeans weigh?,” n.d., accessed 2021; *Silver Bobbin,* “How much does a t-shirt weigh (with examples),” n.d., accessed 2022; *Venus Zine,* “How many yards to make a pair of pants?,” January 27, 2022; Leonard M. Pitt, “Los Angeles, California, United States,” *Encyclopedia Britannica,* March 10, 2022.
16 This assumes that 65 percent of total synthetics / man-made cellulosic fibers (MMCFs), 80 percent of total cotton, 40 percent of total down, and 85 percent of total silk, wool, and other fibers are related to apparel. It also assumes the California apparel industry’s share of US raw fiber-equivalent imports, using the California vs. US GDP ratio as a proxy to determine California’s share. The GDP ratio will be used for sizing throughout the report: Sources: Interviews with fashion / circularity experts (October-December 2021); “Raw fiber equivalents of US textile trade data documentation,” US Economic Research Service, US Department of Agriculture, November 17, 2020.
17 Materials that had a life as something other than textiles before being recycled and made into textiles —– for example, rPET from plastic bottles for polyester —– and materials that had a life as textiles before being recycled back into fiber and again made into textiles, for example cotton from jeans recycled back into cotton thread for a new pair of jeans: Source: “A new textiles economy,” 2017.
18 This applies the California GDP / US GDP proportion to US polyester production. 606,000 bales of cotton were produced in California in 2020. This assumes 480 pounds of cotton per bale, then converts it to kilotons to get ~145. US polyester fiber production in 2019 was 1,275 metric kilotons and this assumes similar production for 2020. It uses 2,205 pounds per metric ton conversion to reach ~1,405 kilotons of US production. It also assumes ~202 kilotons of California polyester production (it applies the California GDP / US GDP proportion): Sources: “Crop production annual summary,” USDA Economics, Statistics, and Market Information System, January 12, 2022; American Chemistry Council, “2020 guide,” December 2020.
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20 This assumes the California GDP / US GDP proportion is applied to total US apparel imports in 2020. It then applies 2019 US textiles and apparel re-export rate of ~20 percent: Sources: “Raw fiber equivalents,” 2020; World Trade Organization, “World trade statistical review 2021.”
21 Assumes a production loss rate of about 12 percent on average: Sources: “A new textiles economy,” 2017; Interviews with fashion / circularity experts (October-December 2021); Schindler, “Today’s challenges for the global textile industry,” 2016.
22 Assumes export rate of ~80 percent, based on the US textiles and apparel domestic exports rate: Source: “Textiles and apparel,” 2020.
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27 Ibid.
28 “Textiles: Material-specific data,” July 2, 2021.
29 Estimated percents and volumes per channel for California based on US averages.
30 “The lifecycle of secondhand clothing,” Simple Recycling, October 2014.
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33 Ibid – Also assumes the US CAGR is true for California.
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35 Pre-consumer waste based on estimated percent of fabric materials lost during manufacturing (12-30 percent) and deadstock (5-15 percent). Overall, 30 / 70 split validated with expert interviews: Sources: “A new textiles economy,” 2017; Christian Schindler, “Today’s challenges for the global textile industry,” 2016; Fashion / circularity expert interviews (October-December 2021).
36 World Trade Organization, “World trade statistical review 2021.”

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38 According to the Aluminum Association, about 50 percent of post-consumer aluminum cans in the US are collected and recycled successfully, along with over 60 percent of pre-consumer aluminum can waste (e.g., scraps). Moreover, about 75 percent of total aluminum produced in the US remains in use today after factoring in high recycling rates (>90 percent) for aluminum used in building and automotive materials: Sources: “KPI report 2019,” Aluminum Association, 2019; “Recycling,” Aluminum Association, 2019; “Resilient US paper industry maintains high recycling rate in 2020,” American Forest & Paper Association, 2021.
39 “The lifecycle of secondhand clothing,” 2014.
40 Paulien Harmsen and Hariëtte Bos, “Part 1: Fibre resources and recycling options,” *Textiles for Circular Fashion,* Wageningen Food & Biobased Research, 2020.
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62 “The lifecycle of secondhand clothing,” 2014.
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82 Based on a review of CalRecycle policies and programs and validated through interviews with fashion / circularity experts (October-December 2021).
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84 We derived the insights in this chapter from primary data gathered by the McKinsey 2021 California Fashion Circularity Survey (conducted in October 2021). To represent the wider Californian population, the survey reached approximately 1,000 respondents, split about 50 / 50 by gender and across Northern and Southern California locations, and was socioeconomically balanced.
85 169 of 1,002 respondents spent $301-500 and 157 of 1,002 respondents spent $0-100.
86 213 of 1,002 respondents bought 11-15 items a month and 42 of 1,002 respondents bought zero to one items a month.
87 Interviews with fashion / circularity experts (October-December 2021).
88 332 of 1,002 respondents were ages 18-34 and 227 of 1,002 respondents were ages 55-65+.
89 112 of 1,002 respondents were ages 18-24.
90 Interviews with fashion / circularity experts (October-December 2021).
91 434 of 1,002 respondents bought mass market clothing and 125 of 1,002 respondents bought value clothing.
92 “Masstige clothing” includes clothing which is considered luxury or premium but is at price points between midmarket and luxury clothing (Wikipedia 2020). 347 of 1,002 respondents bought “masstige” clothing and 96 of 1,002 respondents bought luxury clothing.
93 Note that the averages in this exhibit differ slightly from the overall averages quoted at the beginning of the chapter because the exhibit excluded respondents who purchase more than 16 items a month.
94 Assumes US apparel landfill rates apply to California: Source: “Textiles: Material-specific data,” July 2, 2021.
95 Some reasons for the actual vs. reported behavior gap could include social desirability and conformity, wishful thinking, and differing contexts / mindsets. In a study designed to compare self-reported recycling behaviors and attitudes with actual behaviors among college students, of the 89 percent who reported using the school’s recycling bins, only 14 percent were observed to actually use the school’s recycling bins: Sources: “The lifecycle of secondhand clothing,” 2014; Kat Matfield, “Bridging the gap between actual and reported behavior,” UX Booth, May 19, 2015; Kathleen M. D. Barker et al., “Comparison of self-reported recycling attitudes and behaviors with actual behavior,” *Psychological Reports*, Volume 75, Number 1, pages 571-577, 1994.
96 The percentages add up to more than 100 percent because respondents could select multiple conditions, e.g., apparel is both “worn but still wearable” and “clean.”
97 The percentages add up to more than 100 percent because respondents could select multiple conditions, e.g., they both mail in and take clothes to a donation center / consignment store.
98 All dollar values for estimated total holistic impact are reported in 2021 US dollars.
99 Holistic impact includes economic, environmental, and social benefits: CO2e emissions abatement, water use reduction, land use reduction, chemical use reduction, job creation, GDP from job creation, revenue growth, and cost savings, and the $50-70 billion potential holistic impact for the US are based on the sizing for the polyester use case in California. Since polyester apparel accounts for an estimated 49 percent of all apparel, an estimated multiplier of two can be used to roughly size the total holistic impact for California of switching from virgin to recycled apparel for all fiber types (e.g., polyester, cotton, man-made cellulosic fibers), which would be an estimated $7-9 billion. Next, since California’s retail industry accounts for ~13 percent of US gross domestic product, an estimated multiplier of seven to eight can be used to roughly size the holistic impact in the US for switching from virgin to recycled apparel for all fiber types: Sources: “Preferred fiber and materials market report,” 2021; “How much does garment industry actually waste?,” 2021; “Gross domestic product (GDP) by state,” US Bureau of Economic Analysis, October 1, 2022, accessed November 2021.
100 Currently, US textile-to-textile chemical recyclers are only able to process <1,000 tons of textiles per month: Sources: Kirstin Linnenkoper, “Ambercycle has ‘elegant’ solution for synthetic fibers,” Recycling International, July 26, 2021; Margaret Rhodes, “The company starting to break down fashion’s waste problem,” Circ, June 2, 2021.
101 See Chapter 4 for further details about the consumer survey of 1,002 Californians.
102 Interviews with fashion / circularity experts (October-December 2021).
103 Polyester and cotton fibers used in blended fabrics are expected to be 50-55 percent of today’s fashion industry, based on Reverse Resources’ reported textile waste by fiber type, which uses data from waste mapping surveys in 20 countries across 1,200+ factories: Sources: “Preferred fiber and materials market report,” 2021; “How much does garment industry actually waste?,” 2021.
104 “Preferred fiber and materials market report,” 2021.
105 Disclaimer: We recognize market values do not capture the full extent of negative externalities associated with resource consumption – the value associated with reduction in the use of these resources could potentially be greater.
106 CO2e emissions reduction sizing based on the average of the 2030 minimum and 2030 maximum values of a carbon offset under California’s cap-and-trade program ($24-100 per metric ton of CO2e) that is triangulated with current estimates of the social cost of carbon (~$50 per metric ton of CO2e, which is expected to increase with time): Source: “Policy Hub: California cap and trade,” Center for Climate and Energy Solutions, accessed in 2021.
107 The Institute for Policy Studies found that for each $1.00 increase paid to minimum wage workers, an average of $1.21 was added to the overall economy due to increased consumer spending and economic activity: Source: Sarah Anderson, “Wall Street bonuses and the minimum wage,” Institute for Policy Studies, March 12, 2014.
108 According to ISO 14040:2006, recycling benefits can be measured based on the reduced environmental burden of virgin raw material consumption and disposal. The environmental burdens of recycled versus virgin raw material consumption are measured and the difference is a benefit of the closed-loop system. Future research into closed-loop textile recycling could also incorporate the environmental benefits of avoiding landfill disposal of textile waste (e.g., methane emissions from degradation of natural fibers).
109 Aglaia Fischer and Stefano Pascucci, “Institutional incentives in circular economy transition: The case of material use in the Dutch textile industry,” *Journal of Cleaner Production*, Volume 155, December 2016; Maria A. Franco, “Circular economy at the micro level: A dynamic view of incumbents’ struggles and challenges in the textile industry,” *Journal of Cleaner Production*, Volume 168, pages 833-845, December 1, 2017; Claudia Elisabeth Henninger, Nina Bürkin, and Kirsi Niinimäki, “The clothes swapping phenomenon – when consumers become suppliers,” *Journal of Fashion Marketing and Management,* Volume 23, Issue 3, August 9, 2019; Interviews with fashion / circularity experts (October-December 2021); Rudrajeet Pal, Bin Shen, and Erik Sandberg, “Circular fashion supply chain management: Exploring impediments and prescribing future research agenda,” *Journal of Fashion Marketing and Management*, Volume 23 Issue 3, August 9, 2019; Manoj Kumar Paras, Antonela Curteza, and Geetika Varshneya, “Identification of best reverse value chain alternatives: A study of Romanian used clothing industry,” *Journal of Fashion Marketing and Management*, Volume 23 No. 3, August 9, 2019; Esben Rahbek Esjerdrum Pedersen, Rebecca Earley, and Kirsti Reitan Andersen, “From singular to plural: Exploring organisational complexities and circular business model design,” *Journal of Fashion Marketing and Management*, Volume 23 No. 3, August 9, 2019; Ida Sandvik and Wendy Stubbs, “Circular fashion supply chain through textile-to-textile recycling,” *Journal of Fashion*

Marketing and Management, Volume 23 No. 3, August 9, 2019.

110 In the US, synthetics account for 50-55 percent of US apparel and textile imports, according to the US Economic Research Service. The vast majority of synthetic fibers consist of polyester: Source: "Raw fiber equivalents," 2020.

111 Interviews with fashion / circularity experts (October-December 2021).

112 For example, Coca-Cola, Pepsi, and Nestle have all committed to use at least 50 percent recycled content in their plastic packaging by 2030 or sooner. In addition, California passed a law in November 2020 requiring plastic beverage containers to gradually increase their percent of recycled content to at least 50 percent by 2030.

113 "Preferred fiber and materials market report," 2021; "Fiber recycling using mechanical and chemical processes," 2019.

114 Interviews with fashion / circularity experts (October-December 2021).

115 "A new textiles economy," 2017; Schindler, "Today's challenges for the global textile industry," 2016.

116 For example, there are 90+ local apparel manufacturers located in Los Angeles County.

117 An estimated 20,000 tons of polyester waste are available in California because the majority of apparel sold in California is manufactured abroad.

118 Based on analysis presented in Chapter 2.

119 "The lifecycle of secondhand clothing," 2014.

120 "California population density by county in California population 2021," World Population Review, 2021.

121 At the time of writing, there are two major providers of automated sorting technology: Valvan Baling Systems (Fibersort) and Tomra (Autosort).

122 At the time of writing, early-stage technologies were beginning to experiment with automated apparel deconstruction, but it would be difficult to estimate the costs or accuracy of the technologies.

123 "Gross domestic product (GDP) by state," accessed November 2021.

124 Based on sizing for the polyester use case in California. Because pure and blended polyester apparel accounts for an estimated 49 percent of all apparel, an estimated multiplier of two can be used to roughly size California's total potential holistic impact from switching to recycled materials from virgin for all fiber types (e.g., polyester, cotton, man-made cellulosic fibers): Sources: "Preferred fiber and materials market report," 2021; "How much does garment industry actually waste?," 2021.

125 Based on estimated 510,000-530,000 ton volume of apparel waste generated in 2020 in California with a 1.3 percent compound annual growth rate (CAGR) until 2030. Also estimates 49 percent of all apparel waste is pure and blended polyester: Sources: "Preferred fiber and materials market report," 2021; "How much does garment industry actually waste?," 2021; "US apparel industry data," 2022 edition, accessed December 2021.

126 Today, an estimated 10-20 percent of donated garments are sold secondhand at local or online thrift shops. Unless demand for secondhand clothing grows dramatically, we would expect this percentage to decrease if the volume of collected / donated garments increased from <15 percent of all used apparel today to >90 percent in the future: Source: "Resilient US paper industry," 2021.

127 30-40 percent range accounts for the different potential market values of land and water, which depend on whether California land prices or low-cost country land prices are used to convert land-use reduction into a dollar value. We recognize that the actual geographies where land is conserved could vary depending on where virgin raw materials are produced.

128 Estimated carbon emissions in the production of virgin polyester raw materials measured around 2-4 kg CO2e per kg of virgin polyester, versus 0.5-2 kg CO2e per kg for recycled polyester. Virgin polyester produces carbon emissions from the energy required to extract crude oil, transforms it into naphtha, uses a steam cracker to produce monomers, and polymerizes the monomers. Recycled polyester's carbon emissions come from the energy required to depolymerize used textiles into monomers, then repolymerize them into recycled polyester. If renewable energy is used, you can achieve low carbon emissions of ~0.5 kg CO2e per kg for recycled polyester; however, ~2 kg CO2e per kg of recycled polyester is more typical if using non-renewable energy. Based on California's aspiration to reach 50 percent renewable energy by 2025, our sizing takes the average of 0.5-2 kg CO2e. The price of carbon was estimated at $62 per metric ton of CO2e based on the average of the set 2030 minimum and 2030 maximum prices of a carbon offset under California's cap-and-trade program: Sources: "Material snapshot: Virgin polyester," Textile Exchange, 2016; "Identifying low-carbon sources of cotton and polyester fibers," Fashion Industry Charter for Climate Action, UN Climate Change, April 23, 2021. This was launched in December 2018 and renewed in November 2021; "EcoCosy climate leadership white paper 2020," Office of Social Responsibility of the China National Textile and Apparel Council (CNTAC-SDG), January 2020; "Fashion on climate full report," August 2020; Interviews with fashion / circularity experts (October-December 2021); *Sustainable Business,* "California to boost solar and wind capacity to meet renewable goals," Reuters, August 24, 2021; "Policy Hub: California cap and trade," 2021; Katherine Ricke, Laurent Drouet, Ken Caldeira, and Massimo Tivoni, "Country-level social cost of carbon," *Nature Climate Change,* Vol. 8, Sept. 24, 2018; Tamma Carleton and Michael Greenstone, *Updating the United States government's social cost of carbon,* University of Chicago, Becker Friedman Institute for Economics Working Paper No. 2021-04, last revised Nov. 16, 2021; Gustav Sandin, Sandra Roos, and Malin Johansson, "Environmental impact of textile fibers – what we know and what we don't know: The fiber bible, part 2," Mistra Future Fashion, March 2019.

129 Estimated 0.06 m3 of water is consumed in the production of 1 kg of virgin polyester raw materials, versus virtually no water required to produce recycled polyester. The high estimated value of metered, non-residential water is based on the price of water in the Bay Area, California: ~$2.60 per m3. Because we recognize that water savings may be realized in low-cost countries where polyester is currently produced, we also considered a low estimated value of water use reduction based on the price of water in low-cost countries (e.g., $0.17 per m3 of water in Dhaka, Bangladesh): Sources: "Non-residential metered service in 2021 in California Water Service's rates and tariffs," California Water Service, January 2021; "Dhaka WASA raises water price by 24.97 percent for households," *bdnews24.com*, February 28, 2020; Nia Cherrett et al., "Ecological footprint and water analysis of cotton, hemp and polyester," Stockholm Environment Institute, 2005.

130 Estimated hectares required to produce raw materials are 0.2-1.8 hectares per ton of virgin polyester, versus 0-0.2 hectares per ton of recycled polyester. The figure for virgin polyester includes additional land required to extract crude oil. The high estimated value of land is based on the average price for undeveloped land in California: ~$8.5k per acre. Because we recognize that land savings may be realized in low-cost countries where polyester is currently produced, we also considered the low estimated value of land-use reduction based on the average price of undeveloped land in low-cost countries (e.g., $1.1-1.2 per acre in Bangladesh): Source: "Land values: 2021 summary," US Department of Agriculture, August 2021.

131 Polyester is produced from two crude oil-derived chemicals (ethylene glycol and terephthalic acid). The main source of savings is from no longer needing to extract crude oil to produce these two chemicals, since recycled polyester uses existing plastic waste. The prices of ethylene glycol and terephthalic acid were based on proprietary 2021 data from IHS Markit: Sources: "AP-42, Ch. 6.6.2", accessed October 2021; "Terephthalic acid required to produce PET pellets," accessed October 2021.

132 8,500-9,000 incremental jobs include estimated FTEs required to operate pre- and post-consumer waste collection initiatives, an automated sorting facility with manual deconstruction, and a chemical textile recycling facility. Post-consumer waste collection could account for ~75 percent of total incremental jobs due to labor requirements for material handling, transportation, and first sort. Automated sorting facility could account for an additional ~15 percent of total incremental jobs, mainly due to the manual deconstruction process: Source: Interviews with experts in the waste collection, apparel sorting, and textile recycling industries (October-December 2021).

133 Since pure and blended polyester apparel accounts for an estimated 49 percent of all apparel, an estimated multiplier of two can be used to roughly size the total number of incremental collection, sorting, and recycling jobs that could be created to produce all types of recycled apparel materials in California. This would assume that the ratio of incremental FTEs to tons of produced recycled apparel materials would remain the same across all material types (e.g., polyester, cotton, man-made cellulosic fibers). Growth in number of jobs affiliated with the waste management and remediation services sector in California based on a May 2020 estimate of 51,400 jobs involved in waste collection, waste treatment and disposal, and remediation and other waste management services: Sources: "Preferred fiber and materials market report," 2021; "How much does garment industry actually waste?," 2021. "Occupational employment and wage statistics: OEWS research estimates by state and industry," US Bureau of Labor Statistics, accessed March 29, 2022.

134 Sum of the capital expenditure (CapEx) and operating expenditure (OpEx) estimates for each of the 12 potential initiatives to advance apparel circularity in California. CapEx and OpEx estimates were calculated at a high level for each individual initiative and were based on public data inputs and cost estimates from experts in the apparel and textile waste management industries.

135 Compares estimated total annual holistic impact with estimated total annualized cost across the set of 12 initiatives. Annualized cost is calculated as total capital expenses amortized linearly over the lifespan of the asset, plus annual run-rate operating expenses.

136 Annual run rate operating expenses are calculated based on the implied volume throughput necessary to collect, sort, and recycle ~225,000 tons of recycled polyester.

137 Annual cost is based on the current price of virgin polyester raw materials (estimated at $1,400 per US ton) and the expected price of recycled polyester raw materials (estimated at $1,750 per US ton, assuming a 25 percent premium over virgin polyester based on expert interviews). This cost difference was multiplied by the total volume procured, ~225,000 tons.

138 Based on findings from our consumer survey, which suggests that value and mass market consumers may be willing to pay a 2-3 percent premium for recycled clothing (see Chapter 4).

139 Consumers' stated willingness-to-pay a 2-3 percent premium for recycled apparel used as a proxy to estimate the total potential economic impact that could be created through a combination of 1) premiums paid by end consumers, 2) scale efficiencies, and 3) policy-driven interventions. The 2-3 percent range is based on the percent of consumers who would theoretically be willing to pay more for recycled polyester, estimated at 55-100 percent of California consumers.

140 CapEx and OpEx were estimated for one textile chemical recycling facility with a capacity of ~250,000 tons annual throughput and were based on cost and FTE estimates from experts who own, operate, or work with textile recycling companies. Methodology accounts for significant economies of scale; when the size of the textile chemical recycling facility is doubled, the expected increase in CapEx is only 20-40 percent according to experts and previous McKinsey analysis.

141 Costs were estimated based on the $0.20-0.40 cost per pound to transport apparel waste, plus labor costs based on the occupational profile of existing collection facilities. Several experts were interviewed (October-December 2021) to validate our inputs and assumptions.

142 We estimate there could be a total volume of ~295,000 tons of post-consumer polyester waste generated in California in 2030, ~225,000 of which could be collected if 76 percent of polyester waste sent to the landfill today were diverted for closed-loop recycling instead. Our model calculates costs if 135,000 tons of polyester waste were collected through methods such as donation centers, consignment stores, drop-off containers, mailed collection, and in-store brand take-back programs, and the remaining 95,000 from curbside collection. Operating expenses were estimated based on approximately $1.00 cost per pound to transport apparel waste, plus labor costs based on the occupational profile of waste hauling operations. Costs account for the collection of a total volume of end-of-life textiles greater than the ~225,000 tons of polyester that could be recycled; these costs also account for the assumptions that the post-consumer collection of textile waste would need to obtain more waste to make up for materials that are not polyester and / or polyester that cannot be recycled (e.g., due to impurities, poor condition).

143 Current feedstock prices for unsorted textile waste were estimated at $0.10-0.20 per kg. However, international clothing wholesalers may be willing to pay $0.25-1.50 per kg. Without additional financial incentives, it may be more profitable for collectors to sell their textile waste overseas rather than to closed-loop recycling: Sources: *Manufacturer*, "How does the RR platform work?," Reverse Resources, n.d., accessed 2021; "International Wholesale Clothing," online marketplace on *Alibaba.com*, n.d., accessed December 2021 – this is a list of garments that you could buy and serves as a proxy for the prices an international wholesaler would pay.

144 Assumes 80-90 percent of collected materials are sold to textile-to-textile recyclers. The remaining 10-20 percent could be sold second-hand or could be textiles that cannot be recycled.

145 "Overview for refashionNYC," *City of New York*, n.d., accessed 2021.

146 Avi Glickstein, "It's spring cleaning time! Got a refashionNYC bin?," *Bklyner,* May 8, 2018.

147 Select Bay Area counties include San Francisco, San Mateo, Santa Clara, Alameda, and Contra Costa counties. Curbside textile collection is also being rolled out at-scale in the European Union, where member states have committed to collect textiles separately by 2025 and ensure the collected textiles are not incinerated or landfilled: Source: "Textiles in Europe's circular economy," *European Environmental Agency*, last updated March 19, 2021.

148 Number of households estimated from 2015-2019 data from the US Census which accounts for the projected California population increase through 2030. It is based on the California Department of Finance's projections.

149 Capital expenses include one-time building and engineering (e.g., HVAC and electrical) costs modeled after materials recovery facilities, plus the costs to install equipment for optical sorting, which are derived from a proprietary analysis.

150 There are very few automated textile sorting facilities at scale today, so we used cost data for analogous materials-recovery facilities to estimate high-level operating expenses. These materials recovery facilities employ automated technologies to sort and bale single stream recycling waste.

151 Average price of sorted waste estimated at $100-300 per ton of polyester, according to textile recycling experts. However, the price of feedstock in the future is highly uncertain because it depends on supply / demand economics that are hard to predict as the nascent industry evolves.

152 "Industry talk: first fully automated sorting plant," 2021; "Tomra and Stadler deliver the world's first," 2021.

153 For example, a supply truck that would otherwise drive back from the retail store to the distribution center nearly empty could be loaded with used garments collected in-store for a low incremental cost.

154 Based on perspectives from multiple experts in the industry, including textile collectors and sorters.

155 P.E. Quarterman Lee, "Learning & experience curves in manufacturing," Strategos Inc., October 20, 2014; Winfred P. Hirschman, "Profit from the learning curve," *Harvard Business Review,* January 1964, accessed 2021.

156 Breakdown of fiber type is based on the Textile Exchange (2021) report on global textile use and adjusted for California apparel waste. It is based on the following assumptions: 65-75 percent of total fiber output is used in apparel manufacturing, with a breakdown by fiber type of: 60-70 percent of synthetics, 75-85 percent of cotton, 60-70 percent of man-made cellulosic fibers, 80-90 percent of other plant-based, silk, and wool, and 30-50 percent of down. Although 80 percent of all apparel is made predominantly from one of the three major types of fibers that can be chemically recycled, up to one-third could be apparel that blends fiber types (e.g., a t-shirt that is 60 percent polyester and 40 percent cotton or athletic wear that is 57 percent cotton, 40 percent polyester, and 3 percent elastane). There are chemical recycling processes that can handle cotton-polyester blends, but other blends, such as those containing elastane, cannot be processed by current technologies: Source: "Preferred

fiber and materials market report," 2021; Interviews with fashion / circularity experts (October-December 2021).
157 Audi and Ford company websites.
158 Employees who say that they have experienced purpose at work are 2.8 times more likely to stay at their current employer. There was also a 69 percent lower likelihood of quitting in the next six months for employees who found their work meaningful: Sources: The Energy Project and Harvard Business Review, "The human era @work," 2014, accessed 2022; Caroline Castrillion, "Why purpose is the new competitive advantage," *Forbes,* April 28, 2019.
159 *Style Clinic,* "Fabric matters: Blended fabrics," February 2017.
160 Nina Notman, "Recycling clothing the chemical way," *Chemistry World*, January 27, 2020.
161 *GreenBlue,* "Feature: Carbios – Chemical recycling: Making fiber-to-fiber recycling a reality for polyester textiles," 2021; Alexander H. Tullo, "Plastic has a problem; is chemical recycling the solution?," *Chemical and Engineering News*, October 6, 2019.
162 "Fiber recycling using mechanical and chemical processes," 2019.
163 "The circular economy action agenda," February 2021.
164 RoadRunner Recycling Inc, 2021.
165 Merriam-Webster, 2021.
166 Abby Jenkins, "What is deadstock? Why it's bad and how to avoid," Oracle Netsuite, March 12, 2021.
167 Merriam Webster, 2021; Wikipedia, 2021.
168 *GreenBiz,* "How companies can source man-made cellulosic fibers more sustainably," blog entry by Liesl Truscott, January 27, 2020.
169 "Fiber recycling using mechanical and chemical processes," 2019.
170 Ibid.
171 Ibid.
172 Merriam Webster, 2021.
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175 *Online Clothing Study,* "14 different types of clothing samples," Prasanta Sarkar, August 26, 2018.
176 Ida Marie Sandvik, "Circular fashion supply chain," May 21, 2019.
177 Oxford English Language Dictionary, 2021.
178 Oxford Reference, "Virgin materials," 2021.

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