

# Yale SCHOOL OF THE ENVIRONMENT

## **Sustainable Gear Study & Life-Cycle Assessment**

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# 1. Introduction to Project

In the Fall and Winter of 2020-2021, student researchers Wan Ping Chua (M. Environmental Management 2021) and Leah Wise (M.Div. 2022), under Sara Smiley's directorship, were tasked with undertaking a Life-Cycle Assessment for the purpose of sourcing sustainable and ethically-produced merchandise for Yale School of the Environment.

This report covers agricultural practices, textile production, labor ethics and compliance, responsible dye and printing practices, biodegradability, and consumer use. The second half of the report offers a selection of t-shirts, hoodies, baseball caps, and other products that meet or exceed our criteria.

## 2. Sustainability considerations for textiles

### 2.1 Textiles

Our LCA Approach keeps consumer viability and end-use in front of mind. While some recycled synthetics arguably require fewer resources, the lasting effects of micro-particle pollution and undesired qualities of polyester immediately narrowed our research to natural and organic textiles.

A literature review of LCA studies on fabric choices was conducted and supplemented by anecdotal information from representatives in the garment industry. Existing literature primarily covers environmental LCA and social LCA studies were limited.

Five types of fabric (secondhand fabric made from natural material, cotton, other natural fabric such as hemp, synthetic fabric including recycled PET, and fabric made from blends of different types of fabric) were assessed on 4 criteria - climate change impacts, water use, waste impacts and end-of-life considerations and quality (including longevity) and comfort. **Secondhand textiles made from natural materials are most preferred as they have a considerably less climate and water impact. Following that, 100% organic cotton is most preferred.**

|                                | Climate | Water | Waste & End-of-life | Quality & Comfort |
|--------------------------------|---------|-------|---------------------|-------------------|
| <u>Secondhand</u>              | ●       | ●     | ●                   | ●                 |
| <u>Natural - Cotton</u>        | ●       | ●     | ●                   | ●                 |
| Natural - others (i.e. Hemp)   | ●       | ●     | ●                   | ●                 |
| Synthetic (incl. recycled PET) | ●       | ●     | ●                   | ●                 |
| Virgin Blend                   | ●       | ●     | ●                   | ●                 |

Order of preference ↓

Figure 1. Textile preference tables based on four sustainability criteria – climate, water use, waste and quality and comfort. Secondhand and 100% natural cotton fabrics are most preferred.

**Climate change impact** considers the impact of fabrics on carbon emissions. Although the manufacturing process of synthetic fabrics is somewhat less energy-intensive than natural fabrics, they come from fossil fuel sources and therefore perform poorly from a climate change perspective. (Shen, Worrell & Patel, 2010; Periyasamy & Militky, 2020).

While recycled polyester is becoming an increasingly popular choice for those seeking sustainable options, we would not recommend it. Mechanically and semi-mechanically recycled polyester slightly outperforms cotton when it comes to global warming potential (GWP) and non-renewable energy use (NREU) performance (Shen, Worrell & Patel, 2010; Periyasamy & Militky, 2020) but the fiber cannot be recycled after use (as opposed to virgin cotton). Furthermore, recycled plastic bottles are typically ‘downgraded’<sup>1</sup> to make the recycled polyester. Some have proposed chemical recycling as a way to recycle recycled polyester, but chemically recycling has worse GWP and NREU performance when compared to cotton and is furthermore an uncommon practice in the industry currently (Shen, Worrell & Patel, 2010; Periyasamy & Militky, 2020). Secondhand fiber only have climate and water impacts for the manufacturing process, and not for the raw material phase, so they tend to perform better as the manufacturing phase is a smaller percentage of overall environmental impact, particularly for cotton (Rana et al, 2015; Velden, Patel, & Vogtländer, 2013).

LCA studies are lacking for other natural fabrics, and they also tend to be harder to source. We do not recommend blends as these tend to combine the worst environmental impacts of its composite fabric types, and furthermore, cannot be recycled after use.

**Water use** is one of the most concerning environmental implications of cotton, responsible for 2.6% of world water use (Chapagain et al, 2006). Water use and irrigation differs greatly globally. Cotton generally grows well in arid regions, as these regions are less prone to pests (Texas Organic Cotton Marketing Cooperative (TOCMC), 2020). However, most arid regions also lack rainfall and cotton farmers resort to extensive irrigation, especially in areas that are prone to drought, such as Turkey and Pakistan. The table below shows the irrigation percentage (lower is preferred) for cotton farms globally in high production countries (Chapagain et al, 2006). Sourcing from countries with a lower share of irrigation is one way to reduce the environmental impact of cotton.

| Brazil | India | USA | China | Australia | Uzbekistan | Turkey | Pakistan |
|--------|-------|-----|-------|-----------|------------|--------|----------|
| 15%    | 33%   | 52% | 75%   | 90%       | 100%       | 100%   | 100%     |

*Table 1. Irrigated share of cotton production area in high cotton producing countries based on 1997-2001 data. Countries marked in green are preferred. Source: Chapagain et al, 2006*

Another way to address water use is to choose organic cotton. Studies have shown that the eutrophication and eco-toxicity impact of organic cotton is much lower (Beton et al, 2014). This promotes the health of surrounding waterways around the cotton farms. From a water performance perspective, organic cotton from Brazil, India (commonly found among

<sup>1</sup> Plastic drink bottles are considered ‘recycled’ if they are processed as plastic drink bottles and maintain their food-grade properties. Using plastic bottles for clothing is thus considered a form of “downcycling”, as the bottles can no longer be used for food applications, and new virgin material must be used to produce the drink bottles.

suppliers) and the USA are preferred, as well as cotton made in Africa<sup>2</sup> (CMIA).

**Waste & End of life** is another consideration for sustainability. Cotton and secondhand fabrics made solely of cotton scored the highest in this category as it can be recycled once more, by being blended with other materials (Cottonworks, 2020). Secondhand garment made of recycled fabric cannot be recycled again, as the quality of the fabric would have deteriorated in the initial recycling process. Similarly, synthetic and blended fibers generally cannot be recycled in practice (Shen, Worrell & Patel, 2010), since chemically recycling is not yet at a feasible scale within the industry (Shen, Worrell & Patel, 2010). Due to concerns on microplastic leakage as a result of the garment's wear and tear (see [E&T](#)), synthetics also receive low points in this category.

**Quality and comfort** are the last considerations, as they directly impact the garment's longevity. While blended fabric (a combination of natural and synthetic materials) can be more comfortable, many studies show that traditional synthetic fabrics tend to retain odor over time<sup>3</sup> (Hammer, Berner-Dannenmann & Hoefer, 2013; Abdul-Bari et al., 2020) which may deter the user from continual wear.

## 2.2 Printing

When it comes to printing, the appropriate method often depends on shirt design and color. For instance, inkjet/ direct printing saves water, but is not recommended on dark surfaces. There are relatively few LCA studies which examine textile inks directly. Some note that inkjet/ direct printing saves water resources and contributes to lower eco-toxicity (Kujanpaa & Nors, 2014), but direct printing may also produce suboptimal printing results, which leads to higher material wastage (i.e. test-printing on many shirts to obtain desired results).

The most important sustainability decision regarding printing is to avoid plastisol inks (Wilmanns, 2007) and look for non-PVC, non-toxic and non-phthalates inks instead.

## 3. Labor Ethics and Regulation

### 3.1 Supply Chain

A majority of wholesale brands manufacture in countries that are considered high-risk for labor exploitation. Companies such as [Gildan](#) and [Hanes](#) rank low for worker safety, wages, and access to resources such as healthcare. The international garment industry is not centrally regulated, and the nature of its segmentation means that multinational corporations are not necessarily held responsible for violations occurring at the factories with which they contract.

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<sup>2</sup> See <https://cottonmadeinafrica.org/en/african-cotton/> (Source: Higgs Index)

<sup>3</sup> Emerging studies also show that the finish and fiber type for polyester fabric can significantly reduce odor retention. However, specifying the finish and fiber type is out of scope for this study.

Additionally, the prevalence of sub-contracting - in which the contracted factory makes an independent, short-term contract with secondary manufacturers in order to complete large orders - fractures the chain of accountability from corporation to producer. Corporations can deny culpability for poor working conditions at sub-contracted factories since, legally, they did not enter into a contract with those factories. Yet, there is ample evidence that sub-contracting is par for the course in the garment industry. As such, corporations should, at the very least, create robust auditing standards to ensure that they understand the complexities of their own supply chain.

**Pressing Labor Concerns:** In recent months, two additional labor concerns have come to the fore: 1. China's use of Uighur people for forced labor in the garment industry, 2. Large corporations' refusal to pay factories for completed orders ([The Guardian](#)), citing complications from Covid-19.

The Guardian suggests that an estimated 1.8 million Muslim and Turkic people are being held in internment camps in China, forceably producing cotton that makes it into as many as one in five garments produced globally ([The Guardian](#)). Garment centers of particular concern include Bangladesh, Cambodia and Vietnam. In addition to forced labor, China has begun sterilizing Uighur women, an act of cultural genocide ([Genocide Studies and Prevention](#)). Prominent athletic brands are culpable here: Nike has been linked to Uighur forced labor and Adidas is among those brands that has yet to pay for completed orders.

The above are serious causes for concern, emphasizing the need for more robust labor laws, better auditing practices, and more expansive certifications. In order to ensure a baseline of ethical labor principles, we examined labor-focused certifications and countries of production.

### 3.2 Certifications

**Fair Trade Certifications:** The below certifications ensure a basic wage (typically above minimum wage), safe working conditions, and community resources (such as healthcare, education, daycare, etc.). They also include a basic disclaimer about environmental responsibility.

Potential pitfalls include a lack of data on what constitutes a living wage in countries where certification takes place, as well as inconsistent guidelines regarding employee welfare. Also worth considering: the high cost of accreditation leaves a significant number of potentially "ethical" companies off of fair trade rosters and can [overtax smaller, family-run factories](#).

#### Fair Trade Federation

US-based, the Fair Trade Federation works to build sustainable, long term partnerships with marginalized artisan communities. [Learn more here](#).

#### Fair Trade Certified/Fair Trade USA

"The leading independent third-party certifier of Fair Trade products in North America," Fair Trade USA offers certification to producers of both food and textiles. [Learn more here](#).

#### Fair Trade America

Fair Trade America is the US arm of Fair Trade International and operates under its standards. Members include food companies like Divine Chocolate and Ben & Jerry's, but they also certify cotton. [Learn more here](#).

#### Fair For Life

Founded in Switzerland, The Fair For Life credential applies to both food and textile products, and currently boasts over 3,000 products under its certification program. [Learn more here](#).

#### World Fair Trade Organization

Founded in 1989, WFTO is one of the world's largest fair trade certifiers, with over 324 networked organizations across the world. All certified organizations must meet the WFTO's [Ten Principles of Fair Trade](#), which includes environmental stipulations. [Learn more here](#).

**Inclusive Certifications:** The below certifications assess sustainability from a holistic perspective, providing environmental, labor, and lifecycle guidelines.

Generally speaking, broad certifications still tend to prioritize one category over others. For instance, GOTS certifications are the gold standard for sustainable and nontoxic manufacturing practices, but recommend only minimum guidelines for worker welfare.

#### GOTS (Global Organic Textile Standard)

The leading certifier for organic textiles, GOTS sets a universal definition for what constitutes the category "organic" when it comes to fibers like cotton and wool. In addition, textile companies must make a commitment to exclude toxic dyes and chemicals, use environmentally responsible processing and manufacturing practices, and consider worker welfare using the International Labour Organization's criteria. [Learn more here](#).

#### Better Cotton Initiative

Certifies the production of sustainable cotton, but not the manufacturing of clothing or finished goods. Certifies farmers who take action to protect crops, promote water stewardship, soil health and water biodiversity and decent work. [Learn more here](#).

#### Oeko-tex Made in Green

More rigorous standard of the commonly found Oeko-tex 100 standard, which certifies that a clothing or finished foods is non-toxic to humans. The Made in Green standard ensures that products are tested for harmful substances, made in environmentally friendly facilities and in safe and socially responsible workplaces (to less rigorous/ mainstream standards). It concerns primarily the manufacturing phase. [Learn more here](#).

#### Bluesign

Sustainable certification program used primarily for denim products, where the manufacturing process is known to be especially harmful to human health and the environment. Bluesign differs from other certification programs in that it is an approach. Companies engage Bluesign as a consultant to find ways to improve the social and environmental performance of their supply chain. [Learn more here](#).

### Cradle to Cradle

With a focus on preventative measures, Cradle to Cradle certifies that businesses have made an effort to decrease energy, water usage, and waste in their supply chain in addition to using nontoxic processes and treating workers and communities fairly. [Learn more here.](#)

### B-Corp

Based in the US but open internationally, B-Corp Certification is tailored toward for-profit social enterprises that seek to meet high transparency standards along with responsible labor and environmental practices. [Learn more here.](#)

## 3.3 Country of Production

Bangladesh, Cambodia, Vietnam, and China should be avoided at this time due to the likelihood of involvement with Uighur forced labor. Products made in the EU, Great Britain, Canada, and the United States are generally considered to have more enforceable labor regulations, but [sweatshops are still a concern.](#)

We have opted to prioritize US-production with US-grown cotton, when possible, because this ensures a shorter supply chain and thus, better traceability. For some products, we were able to find union-made production, which provides better labor accountability. For others, we were able to review factory standards and discuss supply chain with vendors.

When not able to source US-grown cotton, we focused our efforts on US-labor and tried to match it with GOTS-certified, organic cotton from less resource-intensive agricultural centers such as Africa and India.

## 4. Consumer Considerations

The Consumer-Use Phase is considered one of the most resource-intensive segments of a product's lifecycle. Laundering is both water and energy-intensive, with an estimated 90% of laundering waste occurring as water is heated ([Energy Star](#)).

**Quality and comfort:** Blended and synthetic fibers - such as polyester, viscose, and rayon - tend to retain odor over time (Callewaert et al., 2013; Hammer, Berner-Dannenmann & Hoefler, 2013; Abdul-Bari et al., 2020).

With that in mind, we considered fabrics and fits that ensure ease-of-use for the consumer. Cotton is easy to wash and does not pill like polyester and mixed fibers can. Unlike hemp (arguably a more sustainable textile overall), it does not need to be blended with cotton or other fibers for a soft hand-feel, which increases the likelihood of long term use. Additionally, the wash process for cotton is effective at removing stains and odors without harsh detergents (Abdul-Bari et al., 2020).

**Inclusive Sizing:** In addition to textile considerations, we found it important to include only those brands that offer standard fits (straight-cut rather than slim fit) in a broad range of sizes - at least up to 2X - for the purposes of size accessibility.

**Ongoing Education:** Education is a key component of this category. By washing in cold

water and reducing dryer use, the consumer can make a significant impact on water and energy use. We recommend providing a hang tag or other marketing materials to each consumer at point-of-purchase.

## 5. Merchandise

YSE stakeholders have expressed an interest in ordering blank merchandise for local printing. As such, we have adjusted our original presentation to reflect priorities.

Students and YSE teams have requested t-shirts and hoodies in three colors: Navy, Forest Green, and Light Gray. In addition, they have requested a baseball cap and patch option.

### T-Shirts & Hoodies



#### Everybody.world

- 100% recycled cotton
- USA-grown cotton and US-manufacturing
- Standard, unisex fit
- Available in sizes XS-2XL
- Water-based dyes
  - Navy, Forest Green, & Light Gray are custom colors with 4-6 week turnaround
  - \$60 lab dip fee or free “eyeball” color-matching
- **T-Shirt Pricing:** 100-450 pieces - \$13.50
- **Hoodie Pricing:** 100-450 pieces - \$55.00
  - Price breaks available over 500 pieces
- **Point of Contact:** Irene, sales@everybody.world
- [Wholesale Information](#)



#### Royal Apparel (wholesale from manufacturer)

- 100% organic, OCS and GOTS-certified cotton
- Manufactured in USA with Turkish/US blended cotton
- Standard, unisex fit
- Sizes XS-3X
- Available in Navy, Forest Green, and Mid-Gray (no light gray)
- **T-Shirt Pricing, 5051Organic:** \$7.70 per-piece
- **Hoodie Pricing, 21052Organic:** \$21.40 per-piece
- *Price breaks available - please open wholesale account*
- **Point of Contact:** 866.769.2517



## Baseball Cap



### [Unionwear Brushed Slide Buckle Dad Cap](#)

- 100% GOTS-certified cotton from India
- Union-made in the USA
- Hunter Green, Navy, Light Gray available
- Metal adjustment tab in back
- Made to order in 3-4 weeks
- **Pricing:** \$7.43 each, quantity of 150
- **Point of Contact:** [cindy@unionwear.com](mailto:cindy@unionwear.com)

## Patch



### [Nosopatches Customized Patches](#)

- Adhesive made from edible materials
- 100% made in the USA
- Customized design available (Polyester fabric)
- Water resistant and weather-proof
- Sustainable packaging options available
- **Pricing:** \$6-10 each, quantity of 200
- **Point of Contact:** [custom@nosopatches.com](mailto:custom@nosopatches.com)

## 6. Alternatives Hierarchy

Where the recommendations in Section 5 are not available or preferred (i.e. due to color availability, size range, or price etc.), the team may wish to consider other options. The below alternatives table provides additional flexibility in making a purchasing decision.

### T-Shirts/ Hoodies

| Sustainability   | Specifications  | Example of Suppliers   |
|------------------|---|--|
| Most sustainable | <ul style="list-style-type: none"> <li>• Secondhand 100% cotton</li> <li>• 100% certified organic cotton, made in the USA, preferably sourced from Brazil, India or USA (as indicated in Section 2. Table 1) USDA and GOTS organic certifications are preferred.</li> </ul> | <a href="#">Everybody.World</a> , <a href="#">Royal Apparel</a> , <a href="#">Farm Fresh Clothing</a> , <a href="#">SOS from Texas</a> . |
| Sustainable      | <ul style="list-style-type: none"> <li>• 100% certified organic cotton,</li> </ul>  | <a href="#">Econscious</a> , <a href="#">Bella + Canvas</a> ,  |

|                 |  |   |
|-----------------|--|---|
|                 | <p>made in the USA, sourced from Turkey/ Pakistan/ other countries. USDA and GOTS organic certifications are preferred.</p> <ul style="list-style-type: none"> <li>• 100% certified organic cotton, sourced from Brazil, India or USA, not made in the US. USDA and GOTS organic certifications are preferred.</li> <li>• Secondhand blended/ synthetic fabric</li> <li>• 100% sustainable fabric, made in the USA, with traceability</li> </ul> | <a href="#">TS Designs (screen printer)</a> , |
| Acceptable      | <ul style="list-style-type: none"> <li>• 100% cotton, made in the USA</li> </ul>   |   |
| Not recommended | <ul style="list-style-type: none"> <li>• Synthetic fabrics/ blends</li> <li>• 100% cotton, not made in the USA</li> </ul>  |   |

### Caps/ Hats

| Sustainability   | Specifications  | Example of Suppliers                                     |
|------------------|---|--|
| Most sustainable | <ul style="list-style-type: none"> <li>• 100% certified organic cotton, made in the USA. USDA and GOTS organic certifications are preferred.</li> </ul>     | <a href="#">Econscious</a> , <a href="#">Unionwear</a> . |
| Sustainable      | <ul style="list-style-type: none"> <li>• 100% certified organic cotton, not made in the USA. USDA and GOTS organic certifications are preferred.</li> </ul> |  |
| Acceptable       | <ul style="list-style-type: none"> <li>• 100% cotton, made in the USA</li> </ul>  |  |
| Not recommended  | <ul style="list-style-type: none"> <li>• Synthetic fabrics/ blends</li> <li>• 100% cotton, not made in the USA</li> </ul>                                   |  |

## References

- Abdul-Bari, M. M., McQueen, R. H., de la Mata, P. A., Batcheller, J. C., & Harynuk, J. J. (2020). Retention and release of odorants in cotton and polyester fabrics following multiple soil/wash procedures. *Textile Research Journal*, 90(19-20). Doi:[10.1177/0040517520914411](https://doi.org/10.1177/0040517520914411)
- Beton, A., Dias, D., Farrant, L., Gibon, T., Le Guern, Y., Desaxce, M., Perwuelz, A., Boufateh, I., 2014. Environmental improvement potential of textiles (IMPRO-textiles). In: Wolf, O., Cordella, M. (Eds.), JRC Scientific and Technical Reports. European Commission
- Callewaert, C., De Maeseneire, E., Kerckhof, F., Verliefde, A., Van de Wiele, T., & Boon, N. (2014). Microbial Odor Profile of Polyester and Cotton Clothes after a Fitness Session. *Applied and Environmental Microbiology*, 80(21), 6611-6619. <https://doi.org/10.1128/AEM.01422-14>
- Cottonworks. (2020, November 02). Recycled Cotton: CottonWorks™. Retrieved December 28, 2020, from <https://www.cottonworks.com/topics/sustainability/cotton-sustainability/recycled-cotton/>
- Chapagain, A., Hoekstra, A., Savenije, H., & Gautam, R. (2006). The water footprint of cotton consumption: An assessment of the impact of worldwide consumption of cotton products on the water resources in the cotton producing countries. *Ecological Economics*, 60(1), 186-203. doi:10.1016/j.ecolecon.2005.11.027
- Hammer, T. R., Berner-Dannenmann, N., & Hofer, D. (2013). Quantitative and sensory evaluation of malodour retention of fibre types by use of artificial skin, sweat and radiolabelled isovaleric acid. *Flavour and Fragrance Journal*, 28(4), 238-244. <https://doi-org.yale.idm.oclc.org/10.1002/ffj.3134>
- Econscious printing. Santa Barbara, December 2007, Eric Wilmanns, Brown and Wilmanns Environmental LLC. <http://www.bw-environmental.com/cont.htm>
- Kujanpaa, M. & Nors, M. (2014). Environmental Performance of Future Digital Textile Printing. VTT Research. <https://www.vttresearch.com/sites/default/files/julkaisut/muut/2014/VTT-CR-04462-14.pdf>
- Periyasamy, A. P., & Militky, J. (2020). LCA (Life Cycle Assessment) on Recycled Polyester. In S. S. Muthu (Ed.), *Environmental Footprints of Recycled Polyester* (pp. 1-30). Singapore: Springer. doi:10.1007/978-981-13-9578-9\_1
- Rana, S., Parveen, S., & Figueiro, R. (2016). Life cycle assessment of cotton textiles and clothing. In S. Karunamoorthy (Ed.), *Handbook of Life Cycle Assessment (LCA) of Textiles and Clothing* (pp. 195-216). Woodhead Publishing.
- Shen, L., Worrell, E., & Patel, M. K. (2010). Open-loop recycling: A LCA case study of PET bottle-to-fibre recycling. *Resources, Conservation and Recycling*, 55(1), 34-52. doi:10.1016/j.resconrec.2010.06.014
- Texas Organic Cotton Marketing Cooperative (TOCMC). (2020). Why TOCMC. Retrieved December 28, 2020, from <https://www.texasorganic.com/information>
- Velden, N. M., Patel, M. K., & Vogtländer, J. G. (2013). LCA benchmarking study on textiles made of cotton, polyester, nylon, acryl, or elastane. *The International Journal of Life Cycle Assessment*, 19(2), 331-356. doi:10.1007/s11367-013-0626-9