ISO 14044-CONFORMANT COMPARATIVE LCA REPORT

BANK AND VOGUE REPURPOSED DENIM, CONVENTIONAL DENIM AND CONVENTIONAL COTTON FABRIC

TAPESTRY

NON-CONFIDENTIAL VERSION 1
SEPTEMBER 2024

WSP
1300 SW 5TH AVE
31ST FLOOR
PORTLAND, OR 97201 USA
PHONE: +1 503 478 2820
WSP.COM

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ABBREVIATIONS

ADP	abiotic depletion potential
AWARE	available water remaining
BOM	bill of materials
BWC	blue water consumption
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
CTUe	Comparative Toxic Units equivalent (ecotoxicity)
CTUh	Comparative Toxic Units equivalent (human toxicity)
EOL	end-of-life
GHG	greenhouse gas
GWP	global warming potential
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
kg	kilogram
kWh	kilowatt-hour
L	liter
LCA	life cycle assessment
LCI	life cycle inventory
LCIA	life cycle impact assessment
MJ	megajoule
MWh	megawatt hour
PED	primary energy demand
Sb	antimony
WSP	WSP USA Inc.

GLOSSARY

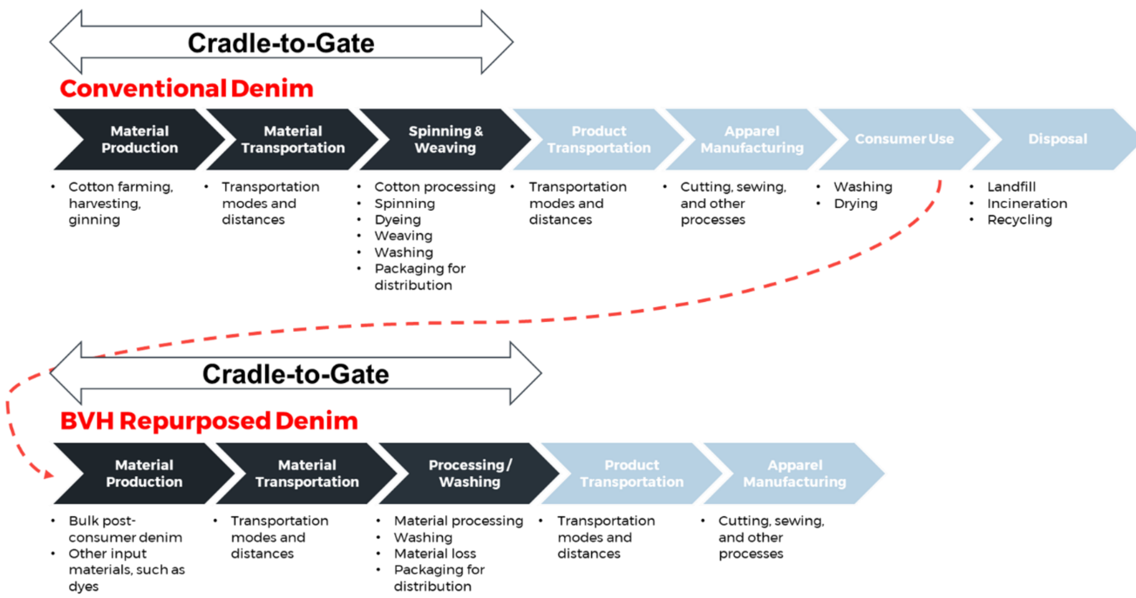
Abiotic resource depletion: the decrease of availability of the total reserve of potential functions of resources (Waterstaat, 2002).
AWARE: the relative available water remaining per area in a watershed, after the demand of humans and aquatic ecosystems has been met (Boulay, et al., 2018).
Blue water consumption: Volume of surface water and groundwater consumed as a result of a production of a good or a service. Consumption refers to the groundwater or surface water that does not return to the source from which it is withdrawn (Hoekstra, et al., 2011).
Comparative Toxic Units equivalent (ecotoxicity): the estimate of the potentially affected fraction of species integrated over time and volume, per unit mass of chemical emitted (USEtox, n.d.).
Global warming potential: a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (US EPA, 2024)

EXECUTIVE SUMMARY

This study is an ISO-conformant comparative Life Cycle Assessment ("LCA") of a repurposed denim product, developed by Bank and Vogue and used by Tapestry Inc. Repurposed denim from Bank and Vogue is a re-used post-consumer fabric made from denim pants collected from the secondhand market. The goal of the study is to calculate the cradle-to-gate environmental impacts of the repurposed denim and compare it to the environmental impacts of conventional first-use denim and woven cotton fabric. This study is intended to inform continued product development by Bank and Vogue, external communications regarding repurposed denim, and also to inform the environmental impacts of Tapestry products using Bank and Vogue repurposed denim.

Denim, including repurposed denim, is a multipurpose fabric that is used for clothes, handbags, shoes, and other apparel and apparel accessories. Apparel and accessories serve many functions, including the coverage or enclosure of certain areas of the body or accessories. This study reports the environmental impacts of denim on the basis of this coverage, using a functional unit of one square meter of fabric. While weight of fabric is also sometimes used as the basis for assessing environmental impacts (e.g. GHG emissions per kg of material), this study uses an area metric because apparel and accessory patterns define the area of fabric used, rather than weight.

The system boundary of this study is cradle-to-gate, including the upstream impacts of sourcing post-consumer denim and the processing of post-consumer denim by Bank and Vogue to produce repurposed denim, as shown in ES-Figure 1. The study has matched the system boundary of the first-use conventional denim and cotton fabric to the same cradle-to-gate system boundary to enable a direct comparison.



ES-Figure 1: System Boundary of repurposed denim, conventional denim, and conventional cotton fabric

The environmental impacts assessed include global warming potential (GWP, also referred to as GHG emissions), blue water consumption, water scarcity, eutrophication, fossil fuels use, ecotoxicity, and human toxicity. The baseline results are generated using a cut-off approach, to avoid allocation of environmental impacts between the two materials produced by Bank and Vogue. This approach provides a conservative estimate of the environmental impacts of repurposed denim. If environmental burdens of Bank and Vogue's sourcing and processing of post-consumer denim are shared with the co-products of this system (the cutting scrap from repurposed denim processing, which is recycled), the burdens allocated to the repurposed denim will be smaller than in these baseline results.

As shown in ES-Table 1, GWP with and without biogenic carbon, blue water consumption and fossil fuel use of repurposed denim are 2.5 $kgCO_2e$, 2.5 $kgCO_2e$, 13 l, and 27 MJ per m^2, respectively. Other impacts like eutrophication, water scarcity, and toxicity are reported in ES-Table 1. The largest contributors to impacts are the cleaning and cutting stages which use electricity from the Indian electric grid. Fossil fuels, primarily coal, are used to generate 72% of electricity on the Indian national grid, which creates substantial GHG emissions, fossil fuel use, water use and toxicity impacts. Blue water consumption and water scarcity impacts are driven by the water used in electricity generation, and also by on-site water demand for washing and processing textiles. Eutrophication impacts are caused primarily by long-distance ocean cargo shipping during post-consumer denim collection.

Bank and Vogue repurposed denim produces substantially lower GHG emissions, consumes substantially less water and fossil fuels, and creates substantially less eutrophication potential than conventional first-use denim fabrics. When compared to two comparable products, denim produced from a leading apparel manufacturer and conventional cotton fabric of similar weight from a global average of agricultural cotton producers, repurposed denim reduces cradle-to-gate GHG emissions by 52% to 83%, reduces blue water consumption by 98% to ~100%, and reduces eutrophication potential by 56% to 91% (ES-Table 1).

ES-Table 1: Comparative environmental impacts per square meter of repurposed denim, conventional denim, and conventional cotton fabric

Impact Category	Repurposed denim	Conventional denim	Conventional cotton fabric
GWP, excl biogenic carbon, $kgCO_2e$	2.5	14 (-83%)	5.8 (-57%)
GWP, incl biogenic carbon, $kgCO_2e$	2.5		5.1 (-52%)
Blue Water Consumption, L	13	3351 (~-100%)	750 (-98%)
Water Scarcity (AWARE), m^3e	0.55		
Fossil fuel depletion, MJ	27		70 (-62%)
Eutrophication Potential, $kgPO_4e$	0.0026	0.028 (-91%)	0.0059 (-56%)
Ecotoxicity, CTUe	0.0075		

Of the post-consumer denim collected by Bank and Vogue for the denim repurposing process, only 28% by weight is sold as repurposed denim. The remaining 72% becomes cutting scraps or "denim skeletons" and is sent for recycling into new cotton fabric by a different organization. Because these denim skeletons also have value to Bank and Vogue and their customers, this study used several alternative methods of allocating the environmental impacts of Bank and Vogue's supply chain and operations between the two products. Using a mass allocation approach, in which repurposed denim and denim skeletons have the same environmental impacts by weight of material, reduces all environmental impacts of repurposed denim by 72%. Using a system expansion approach, in which the environmental impacts of repurposed denim are adjusted to include both the denim skeleton recycling process and offsets for first-use cotton replaced by the recycled denim skeletons, had more varied effects on the study results.

These findings support the following actions to reduce GHG emissions, water impacts, energy impacts, eutrophication, and toxicity impacts of repurposed denim: 1) increase the proportion of energy use from renewable energy, 2) develop local sources of post-consumer denim, 3) continue to identify high-value uses for cutting scraps from the denim repurposing process.

This study demonstrates that repurposed denim has lower environmental impacts than conventional denim and conventional cotton in several categories related to energy use and agricultural production. While data across all impact categories were not publicly available for a comparison, it is clear that repurposed denim has lower GHG emissions, blue water consumption, and eutrophication potential when compared to conventional denim and conventional cotton fabric, while repurposed denim has lower fossil fuel use when compared to conventional cotton fabric.

ASSESSMENT SUMMARY

Comparative life cycle assessment of GHG emissions, water consumption, water scarcity, eutrophication, fossil fuel use, and ecotoxicity of repurposed denim from Bank and Vogue and conventional denim.

Company Name and Contact Information	**Tool Commissioner:** Tapestry, Inc. 10 Hudson Yards New York, NY 10001 **Contacts:** Logan Duran lduran@tapestry.com Megan Dawson-Elli mdawsonelli@tapestry.com **Tool Practitioner:** WSP USA 1300 SW 5th Ave 31st Floor Portland, OR 97201 **Contacts:** WSP USA Julie Sinistore julie.sinistore@wsp.com Isaac Emery isaac.emery@wsp.com Mukunth Natarajan mukunth.natarajan@wsp.com Siddhi Rathi Siddhi.rathi@wsp.com
Standard Used	ISO 14040 - Environmental management - Life cycle assessment - Principles and framework, ISO 14044 - Environmental management - Life cycle assessment - Requirements and guidelines
Product Names	Denim fabric panels
Product Descriptions	Fabric panels cut from post-consumer denim clothing
Functional Unit (Tool Basis)	The functional unit of these fabric panels is one m^2 of denim
Temporal Boundary	Material inventories represent total production of denim fabric panels by Bank and Vogue in 2023. The results in this tool should be considered valid for five years from the publication date
Country/Region	India
Version and Date of Issue	Non-Confidential Version 1 9/9/2024

1 GOAL OF THE STUDY

Tapestry, Inc ("Tapestry") commissioned WSP USA Inc ("WSP") to conduct a life cycle assessment (LCA) of repurposed denim fabric created for Tapestry by Bank and Vogue Ltd ("Bank and Vogue") compared to conventional denim and woven cotton fabric. Repurposed denim from Bank and Vogue is a re-used post-consumer fabric made from denim pants collected from the secondhand market. The material is sorted, cleaned, and cut to customer specifications. Tapestry uses Bank and Vogue repurposed denim in a range of apparel and accessory products under the Coach brand and Coachtopia sub-brand.

The goal of this study is twofold:

1. Determine the global warming potential (GWP), water consumption, water scarcity, eutrophication, fossil fuel depletion, and ecotoxicity impacts of repurposed denim
2. Determine the differences in GWP, water consumption, and eutrophication between repurposed denim and conventional first-use denim, and the differences in GWP, water consumption, eutrophication, and fossil fuel depletion between repurposed denim and woven cotton fabric

1.1 REASONS FOR CARRYING OUT THE STUDY

This study is meant to inform both product development and external communication by identifying differences in environmental impact between the two types of denim – repurposed denim and conventional denim. As they fundamentally fulfill the same function (i.e., used by Tapestry for its product design and production) it is of interest to assess the environmental impacts of the products as they develop to meet increasing demands of Coach and Coachtopia products. Therefore, Tapestry sought an understanding of the comparative environmental impacts of its products, with the intention to communicate its insights internally and externally.

This study was conducted to determine the GWP, water consumption, eutrophication, fossil fuel depletion, and ecotoxicity impacts associated with the raw material, transport and production of Bank and Vogue's repurposed denim products according to International Organization for Standardization (ISO) Standards 14040 and 14044 on LCA (ISO, 2006). The GWP, water consumption, water scarcity, eutrophication, fossil fuel depletion, and ecotoxicity impacts were selected based on potential business value, data availability, requests from stakeholders, and metrics needed for Tapestry's impact estimation of their products. Tapestry is keen on choosing impact categories that align with the Higg Materials Sustainability Index (MSI) methodology (Sustainable Apparel Coalition, 2020). Since the model is in alignment with ISO Standards 14040 and 14044 for LCA the ISO 14044-conformant LCA report will undergo critical review by a panel of three independent critical reviewers.

1.2 INTENDED APPLICATIONS

The intended applications of this study are to:

1. Provide actionable environmental impact information about the GWP, water consumption, eutrophication, fossil fuel depletion, and ecotoxicity impacts of the repurposed denim from cradle-to-gate to Tapestry and Bank and Vogue
2. Compare the GWP, water consumption, and eutrophication between repurposed denim and conventional first-use denim, and the differences in GWP, water consumption, eutrophication, and fossil fuel depletion between repurposed denim and woven cotton fabric, for decision making and product development insights by conducting an ISO 14044-conformant LCA

1.3 TARGET AUDIENCE

The study results are prepared for Tapestry's internal use and to communicate externally about Bank and Vogue's repurposed denim. The study is in conformance with ISO Standards 14040 and 14044. Specific audiences may include the Tapestry's employees (e.g., leadership, product designers, communications, and sustainability professionals), partner organizations (including Bank and Vogue), and external audiences in alignment with ISO standards for communication of product environmental attributes.

1.4 CRITICAL REVIEW

This report is in conformance with the requirements of ISO Standards 14040 and 14044, which set forth the requirements for public disclosures and documentation for LCAs. This report has been critically reviewed by a three-person critical review panel, Arpad Horvath, Bill Flanagan, and Corinne Scown.

2 SCOPE OF THE STUDY

The study is a cradle-to-gate life cycle assessment of Bank and Vogue's repurposed denim compared to conventional denim and conventional woven cotton fabric. Two types of conventional fabric are chosen for comparison to get coverage on key impact categories like GHG emissions, fossil fuel depletion (also referred to as fossil fuel use), and blue water consumption. The conventional cotton fabric is chosen along with conventional denim, because conventional denim only differs from cotton in its weave type. This section outlines the function of the products, declared units, system boundaries, and other scope-specific information.

2.1 PRODUCT FUNCTION AND FUNCTIONAL UNIT

The product under study is Bank and Vogue's repurposed denim. Denim is a multipurpose fabric that can be used for making clothes, handbags, belts, bags, and other products. Since denim is typically used to cover a specific area, the functional unit used in this study is one square meter. While weight of fabric is also sometimes used as the basis for assessing environmental impacts (e.g. GHG emissions per kg of material), this study uses an area metric because apparel and accessory patterns define the area of fabric used, rather than weight. The weight of the product is also determined by thickness, but in this case thickness of the product is similar, leading to the choice of area for functional unit.

2.2 SYSTEM BOUNDARY

This study applies a cradle-to-gate system boundary to the life cycle inventory and impact assessment of conventional, first-use denim, conventional cotton fabric and repurposed denim. This study is to be carried out in conformance with ISO 14044 for Bank and Vogue repurposed denim and compared to publicly available data on conventional denim and conventional cotton. The ecoinvent database version "Allocation, cut-off by classification", or the cut-off system model, is based on the recycled content, or cut-off, approach where wastes are the producer's responsibility ("polluter pays"), and there is an incentive to use recyclable products as they are burden free (cut-off).

2.2.1 CONVENTIONAL DENIM AND CONVENTIONAL COTTON FABRIC

Conventional, first-use denim is made from cotton produced in an agricultural system. This study includes the agricultural inputs and processes to cotton production, processing and transportation of first-use cotton to mills, where it is spun, dyed, and woven into denim (excluding capital goods). As shown in Figure 1, this study includes all stages of denim fabric production but excludes the cut and sew stage of garment production (e.g. jeans) from denim or any subsequent life cycle stages.

In addition to conventional denim, conventional cotton fabric is also used as a comparative product. The key difference between cotton fabric and denim is the weave. Denim is cotton fabric with a twill weave, which increases the its durability and strength. From the perspective of this study cotton fabric and denim have the same upstream processes, until the spinning and weaving stage shown in Figure 1. In addition, denim material also has a higher density and thickness when compared to cotton fabric, and denim also undergoes different treatments in the manufacturing stage which increases its impact when compared to cotton fabric. It is critical to keep these differences in mind while comparing the impact of cotton fabric to repurposed denim.

2.2.2 REPURPOSED DENIM

Repurposed denim is a nonstandard product. Bank and Vogue developed the repurposing process modeled in this study to divert higher-value post-consumer material from a bulk recycling process. Bulk recycling processes reduce the denim to fiber through chemical or mechanical recycling. The system boundary for repurposed denim includes the supply of raw material (collection of post-consumer denim apparel) and the sorting, washing, and cutting stages that comprise repurposed denim manufacturing (Figure 1). Bank and Vogue processes post-consumer denim from jeans for two distinct product pathways: repurposed denim, and recycling. For repurposed denim, the fabric is reused for a different purpose than the original product. For recycling, the fabric is reduced to pulp and new fabric is created from that raw material. First-use denim and repurposed denim undergo different production processes and transportation logistics before they are used by a customer. The repurposed denim material is produced from post-consumer denim products that are collected in Canada and are shipped to India for production. Cutting scrap from the repurposing process is sent to Sweden for recovery and recycling into a textile with properties that can replace first-use cotton. The impacts associated with the collection of the post-consumer denim is excluded since its procurement involves different sources including third party vendors. No pre-consumer denim is collected for the production of repurposed denim. Infrastructure and capital goods (e.g., buildings and machines used for production) are excluded due to their small contribution to the overall impact of the products, as well as the challenges associated with collecting sufficiently detailed and specific data on the depreciable capital involved in textile remanufacturing. Production of infrastructure has been excluded also for background generic processes, in order to ensure consistency between the foreground and background datasets.

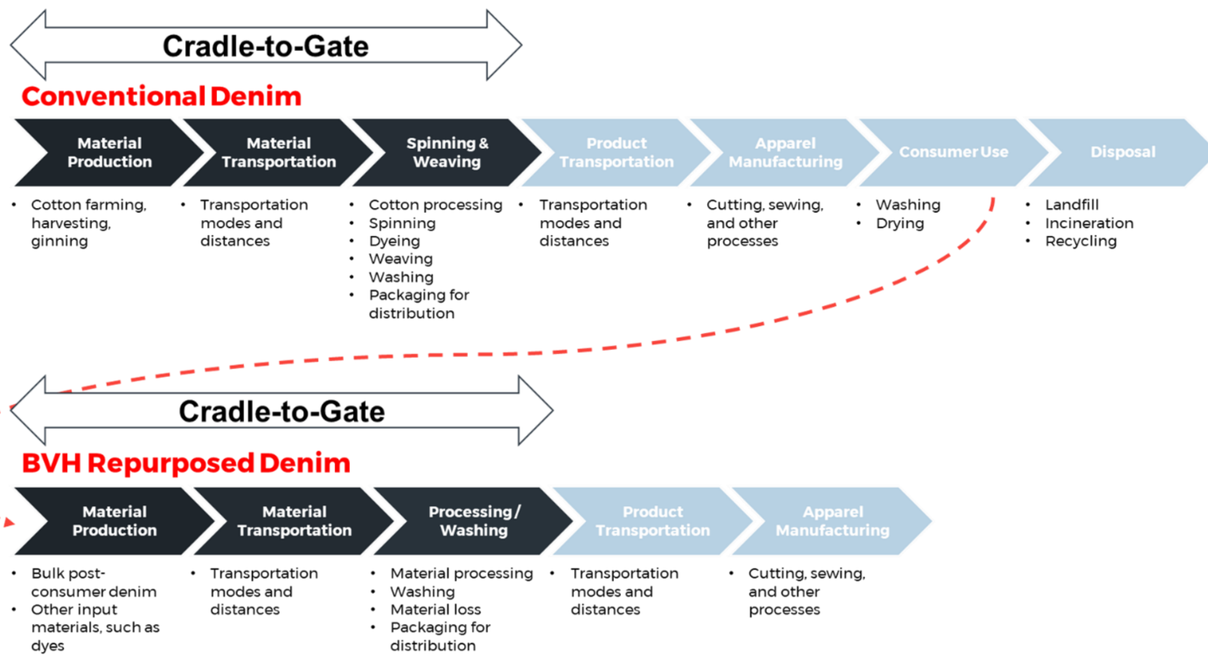


Figure 1: System boundary of conventional and repurposed denim, with included (black) and excluded (light blue) processes.

2.3 TEMPORAL AND GEOGRAPHICAL BOUNDARY

All material, transportation and manufacturing, and use data inputs for Bank and Vogue repurposed denim are from 2023. Background processes used in the life cycle inventory model are valid for 2023.

Bank and Vogue repurposed denim production occurs in India, and all material and energy inputs to denim repurposing are matched to inventory processes that are either India-specific or global averages. The collected discarded denim is initially transported out of Canada.

2.4 CUT-OFF CRITERIA AND LIMITATIONS

LCA for Experts (formerly GaBi) databases were used, including the LCA for Experts implementation of the ecoinvent v3.9.1 database. Any cut-off criteria implemented in the ecoinvent or LCA for Experts databases are included in this assessment according to the LCA for Experts Modeling Principles (Sphera, 2023b). Where applicable, cut-off criteria would only be applied for components that contribute to 1 percent or less of total mass or energy of the system and 5 percent or less of the total environmental impacts.

Most of the material and energy inputs needed for Bank and Vogue's denim repurposing process could be readily matched with existing background processes provided by Sphera and ecoinvent, though some chemicals, such as a detergent, were not available and matched with proxy datasets. The primary limitation of this study is therefore related to the lack of primary data for collection of post-consumer denim. Bank and Vogue does not have access to detailed information on the collection of denim jeans from consumers, except that they are primarily purchased in bulk from secondhand apparel providers.

2.5 ALLOCATION

Processing of repurposed denim by Bank and Vogue for Tapestry includes production of a substantial quantity of cutting scrap. This cutting scrap is returned to the bulk denim recycling stream from which the raw materials for denim recycling were taken. This study conservatively applies the cut-off approach as a base case. The cut-off approach assigns all of the environmental burdens of the denim repurposing process to the repurposed denim and none to the cutting scrap, potentially overestimating the environmental impacts of repurposed denim. Other approaches aligned with ISO-14044, including mass allocation and system expansion, are explored in a sensitivity analysis.

The life cycle inventory datasets from Sphera and ecoinvent used to model the materials and energy used in the repurposed denim supply chain may apply different allocation methods to upstream processes. These inventories were not modified for use in this study and may not be entirely consistent with the allocation methods used.

3 LIFE CYCLE INVENTORY ANALYSIS

3.1 REPURPOSED DENIM LIFE CYCLE INVENTORY

This section outlines the inventory compiled to assess the life cycle environmental impacts of both first-use and repurposed denim. Denim is a cotton twill weave fabric commonly used in pants ("jeans") and other outerwear. Bank and Vogue processes post-consumer denim from jeans for two distinct product pathways: repurposed denim, in which the fabric is reused for a different purpose than the original product, and recycling, in which the fabric is reduced to pulp and new fabric is created from that raw material. First-use denim and repurposed denim undergo different production processes and transportation logistics before they are used by a customer. The repurposed denim material is produced from post-consumer denim products that are collected in Canada and are shipped to India for production. Cutting scrap from the repurposing process is sent to Sweden for recovery and recycling into a textile with properties that can replace first-use cotton. Conventional first-use denim production involves the agricultural production and harvesting of cotton lint, ginning, spinning, and weaving to produce the fabric. The fabric is then prepared through processes such as bleaching and heat setting, after which the material is dyed to produce denim.

The life cycle inventory used in this study represents the total production of repurposed denim by Bank and Vogue for a single customer, Tapestry, in 2023.

3.2 POST-CONSUMER DENIM SUPPLY

Bank and Vogue repurposed denim is produced from post-consumer denim products purchased from thrift stores and charities across North America. A part of the supply is also purchased directly from the public. These post-consumer products, unless purchased as second hand, typically end up in a landfill. Post-consumer denim products are purchased in bulk by weight and moved by truck from the collection facility in Maple Ridge, Canada to the port in Vancouver, Canada. The impacts associated with the collection and transport of post-consumer denim to Maple Ridge, Canada is not included in this study. The system boundary begins at the transport of the collected post-consumer denim at Maple Ridge, Canada. The post-consumer denim is then shipped to Kandla port in Gujarat, India by freight ship, and then transported by truck to a controlled storage area and sorting facility exclusive to post-consumer materials in Gandhidham, India. Sorted denim meeting Bank and Vogue's quality standards is then trucked to the Bank and Vogue facility in Gandhidham, India. There, zippers, buttons, and other hardware is removed. The inventory processes used to model raw material supply for Bank and Vogue repurposed denim are shown in Table 1.

Table 1: Transportation inventory for post-consumer denim supply to Bank and Vogue

Stage	Process Name	Weight in tons	Distance in km
Truck, to Port of Vancouver, Canada	GLO: Truck, Euro 6 D-E, 28 - 32t gross weight / 22t payload capacity Sphera	9.64	45
Ocean freight, to Gujarat, India	GLO: Transoceanic ship, containers, 27,500 dwt payload capacity, ocean going Sphera	9.64	29,160
Truck, to Gandhidham, India	GLO: Truck, Euro 6 D-E, 28 - 32t gross weight / 22t payload capacity Sphera	9.64	16
Truck, in Gandhidham	GLO: Truck, Euro 1, up to 7.5t gross weight / 2.7t payload capacity Sphera	9.64	3

3.2.1 *REPURPOSED DENIM MANUFACTURING*

The post-consumer denim arrives at the Bank and Vogue facility and the material is sorted by color and patterns as needed. The material received is measured for thickness and then pre-cut. The pre-cut material is then weighed and assorted in 70 kg batches for washing and drying. Samples are prepared, labelled and sent to testing for screening and quality control.

Washed garments are cut to flat sheets and separated by size. Quality control is carried out to remove seams and stains. Stickers are used to mark the material and avoid duplication. Garment batches are cleaned again to remove dust and loose threads. The fabric is then steamed and prepped for cutting. Cutting machines are used to process fabric into custom panel sizes based on the dimensions provided by Tapestry. Once cutting is done, the components go through quality checks to make sure that the shapes are accurate and that there is no dust or loose threads. The checked material is then packed for shipment. The inventory of input and output material data is provided in Table 2.

Table 2: Denim repurposing model inventory

Inputs	Process Name	Quantity	Unit
Post-consumer denim	n/a	9,640	kg
Detergent	GLO: Detergent (fatty acid sulphonate derivate) Sphera	34	kg
Anti-scalent	GLO: chemical production, inorganic ecoinvent 3.9.1	2.04	L
Sodium Metabisulfate	GLO: disodium disulphite production ecoinvent 3.9.1	143	kg
HCl	RoW: hydrochloric acid production, from the reaction of hydrogen with chlorine ecoinvent 3.9.1	6.8	L
Polymer for water treatment	GLO: Soaping agent (acrylic polymer) Sphera	143	kg
Water	IN: tap water production, underground water with chemical treatment ecoinvent 3.9.1	135,800	L
Electricity (grid)	IN: Electricity grid mix Sphera	9,812	kWh
Electricity (solar)	IN: Electricity from photovoltaic Sphera	3,088	kWh
Diesel	GLO: machine operation, diesel, < 18.64 kW, generators ecoinvent 3.9.1	100	L
Outputs			
Repurposed denim	n/a	2730	kg
Cutting scrap	n/a	6910	kg

3.3 FIRST-USE DENIM LIFE CYCLE INVENTORY

Two conventional fabric processes were used as comparisons for the Bank and Vogue repurposed denim. LCA results for denim from a major apparel manufacturer and cotton fabric from a global average of agricultural cotton fiber production represent benchmarks for the environmental impacts of producing first-use material equivalent to Bank and Vogue's repurposed denim.

An in-depth review of life cycle inventories from publications on the LCA of denim and cotton fabric production revealed a range of omissions and modeling errors in the recent literature. While cotton fabric is not a direct substitute for denim, which undergoes a unique weaving and dyeing process, this study includes cotton fabric as an additional point of comparison alongside the selected conventional denim study. With this range this study can assess where the environmental impact of the Bank and Vogue repurposed denim falls with respect to the spectrum of impacts where the cotton fabric is at the lower end of the spectrum and the conventional denim product is the higher end of the spectrum.

3.3.1 CONVENTIONAL DENIM FROM A LEADING APPAREL MANUFACTURER

The LCA study on denim conducted by a leading denim brand was based on ISO 14040 and 14044 standards in which all significant processes from cradle-to-grave were analyzed for one pair of jeans. As shown in Figure 2, the following LCA stages were included: raw materials production, fabric production, garment production, transportation and distribution, consumer care, and end-of-life. This assessment adapts the reported cradle-to-gate impacts of denim fabric production to generate a representative comparative product to Bank and Vogue repurposed denim.

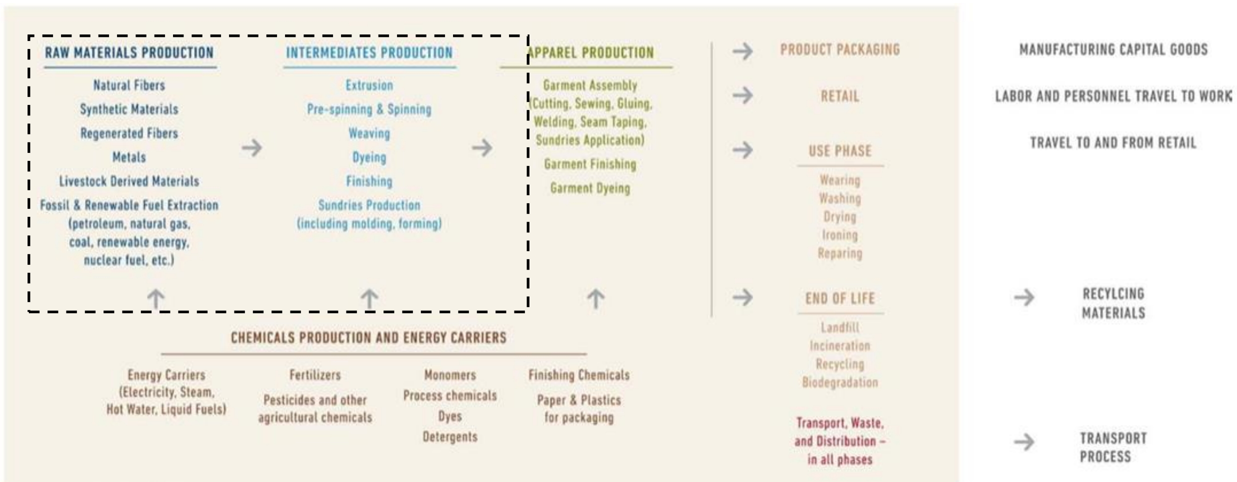


Figure 2: Conventional denim LCA system diagram. Impacts of the raw materials production and intermediates production stages were used to compare cradle-to-gate denim fabric with repurposed denim (Levi Strauss & Co., 2015). The dotted line indicates the processes included in the system boundary used for this comparison.

The study of first-use jeans was conducted in 2013 using data from the 2012 production cycle. The product weight is 340 g per pair and the average denim density is 410 g per m^2. The supply chain for the conventional denim product is global with the cotton being sourced from US, Mexico, Brazil, China, Greece and Pakistan. Spinning, weaving and dyeing were done in Mexico, China and Pakistan. While there is more detail available in the LCA study, our system boundary for the comparative product ends with fabric finishing.

3.3.2 CONVENTIONAL COTTON FABRIC

The cradle-to-grave inventory for global average cotton fiber covers raw material production from field through ginning. The impacts are calculated for a functional unit of 1,000 kilograms (kg) of fiber. The cradle-to-gate LCIs for global average fabric take the fiber LCI through yarn formation, knitting or weaving, dyeing, finishing, and compacting. The impacts for fabric manufacturing are calculated for a functional unit of 1,000 kg of finished fabric. All stages included in the cradle-to-gate system boundary as well as the cradle-to-grave system boundary are shown in Figure 3.

The study focused on the top producing and exporting countries due to their significant contribution to global cotton production. The diversity within these countries regarding growing regions, farm sizes, and agricultural practices necessitated region-specific data collection and modeling. The differences in farm sizes and mechanization levels between countries like China and India (small, labor-intensive farms) versus the United States and Australia (large, highly mechanized farms) were highlighted. The adoption of transgenic technology was noted as being above 90% in all four countries.

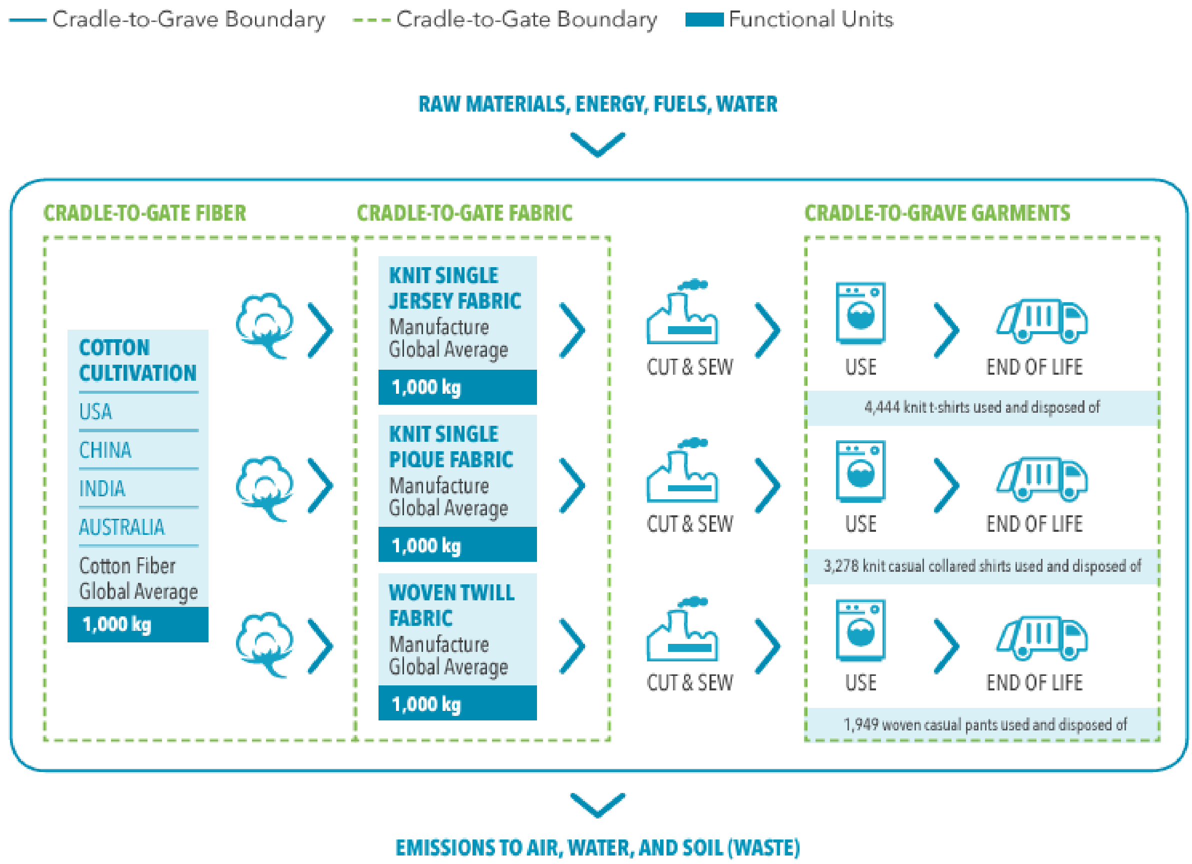


Figure 3: System boundary diagram for conventional cotton fabric (Cotton Inc, 2017). The cradle-to-gate fiber and fabric subsystems are used to represent first-use cotton fabric in this study.

The agricultural phase of cotton's life cycle assessment (LCA) involved collecting primary data through customized templates distributed to data providers across the United States, China, India, and Australia. These regions were selected based on their specific growing conditions and their significance in global cotton production, together accounting for 67.2% of the world's cotton fiber production for the study period (2010-2014). Data validation involved cross-checks for completeness and plausibility using mass balance stoichiometry, internal and external benchmarking, and resolving inconsistencies through direct engagement with data providers. Global climate and soil datasets provided high-quality information for all countries involved in the study. The CLIMWAT 2.0 Database offered 30-year average weather station records, which were used alongside the CROPWAT 8.0 program to estimate irrigation levels and verify with regional data. Soil properties were estimated using a global data set, reflecting the percentage of sand, silt, and clay in each region.

Secondary data were utilized when primary data were unavailable or inconsistent, sourced from literature, machinery manufacturers, previous LCI studies, and life cycle databases. The agricultural data encompassed information from grower interviews, surveys, scientific papers, reports, and national statistics, reviewed and compared against existing LCA studies for quality assurance.

Regional Summaries

- **United States:** Data were segmented by regions, reflecting the diverse production environments across the country. Sources included USDA statistics and surveys conducted by Cotton Incorporated, emphasizing production practices, irrigation, and ginning processes.

- **China**: Focused on the major cotton-producing regions, with data revealing the shift towards the Northwest for increased production and irrigation. Practices highlighted include the use of plastic mulch and intercropping, with data improvements noted over previous LCA studies.
- **India**: Characterized by small farm sizes and diverse regional climates, data collection emphasized the variances in irrigation, crop rotations, and tillage systems across different provinces.
- **Australia**: Noted for having the highest yields due to ideal climatic conditions and comprehensive irrigation practices. Data collection was coordinated by the Cotton Research and Development Corporation, focusing on the Namoi Valley as a representative production area.

Each region's data collection emphasized the specifics of agricultural practices, including tillage systems, pesticide applications, crop rotations, soil erosion rates, and the energy used in irrigation and ginning processes. This comprehensive data collection and modeling effort underlines the complexities involved in assessing the environmental impact of cotton production, considering the diverse agricultural practices, climatic conditions, and technological adoptions across major cotton-producing regions worldwide.

Textiles Data Collection

The textile manufacturing data compiled for the LCA were derived from primary sources and supplemented with literature and industry averages. The methodology encompassed all textile unit processes, calculating global averages for each process. Background data were sourced from the GaBi database. Primary data collection involved 15 textile mills (6 knit and 9 woven), though errors or missing information led to the exclusion of data from 2 mills. The mills, varying in their level of vertical integration, reported material flows for either knit or woven fabrics. To ensure comparability, each process was evaluated across all mills that reported on that process, facilitating the creation of horizontal averages at each step. This approach allowed for the amalgamation of data into global averages. The processes were grouped as per the updated methodology compared to the 2010 study due to complexity and time constraints.

Textile Manufacturing

For high-quality data collection, textile mills were selected based on their product line, level of vertical integration, and geographic location, focusing on regions of interest like Eurasia, East Asia, South/Central Asia, and Latin America. From an initial pool of 39 textile mills, 22 agreed to participate, providing detailed data through Excel templates. The data collection aimed to capture the entire textile production process, from raw bales of cotton to dyed and finished fabric. The collective effort of Cotton Incorporated experts ensured the review and validation of submitted data, culminating in a quality-checked dataset from 13 mills. This comprehensive approach allowed for the independent modeling of each unit process step, enhancing the flexibility and accuracy of the textile manufacturing LCA.

For ease of comparison between repurposed denim, the conventional denim from a market leader in denim clothing (indicated as "Denim 1") and cotton fabric from the 2016 Cotton Inc LCA study, the results are aggregated between two stages – raw materials, and material processing. Table 3 below indicates the stages that have been combined for each comparative product across raw materials and material processing. Impact assessment results for conventional woven cotton fabric from this study were assessed on an equivalent weight basis to repurposed denim. Although results are presented on the per m^2 functional unit, these conventional cotton results have been adjusted to contain the same weight of material per m^2 as repurposed denim.

Table 3: Life cycle stages in the present study and from conventional product assessments used to compare the cradle-to-gate environmental impacts of repurposed denim to first-use material.

Comparative product	Raw materials	Material Processing
Repurposed denim	Post-consumer denim transport	Cleaning; cutting; wastewater treatment; packaging
Denim 1	Fiber production	Fabric assembly
Cotton fabric	Cotton production, ginning	Yarn production and fabric production

3.4 SENSITIVITY ANALYSES

3.4.1 SENSITIVITY TO ELECTRICITY GENERATION

The source of electricity is a major contributor to several environmental impacts of Bank and Vogue repurposed denim production. Because project stakeholders had indicated an interest in expanding the renewable electricity use, this study includes a sensitivity case study to assess the impacts of operating the Bank and Vogue facility using only solar photovoltaic power. The sensitivity assessment models the impacts of one square meter of Bank and Vogue repurposed denim if 100% of the electricity consumed for cutting and cleaning is from solar power.

3.4.2 SENSITIVITY TO ALLOCATION METHOD

The Bank and Vogue denim repurposing system creates two products: repurposed denim and cutting scrap. Neither of these materials are waste, and both provide economic value to Bank and Vogue. However, due to the large qualitative differences between these two products, this study applies the cut-off approach as a highly conservative baseline case for the assessment. Under the cut-off approach, also known as the recycled content approach, all of the environmental impacts of a process are assigned to the primary product – in this case, the repurposed denim. Cutting scraps are treated as a burden-free byproduct or waste material.

Because the cut-off approach likely overestimates the environmental impact of repurposed denim while underestimating the environmental impacts of cutting scraps, this approach is used for the baseline results. Mass allocation and system expansion methods were used to assess the sensitivity of the results to the choice of allocation procedure (Figure 4). Mass allocation assigns environmental burden of upstream processes equally to all downstream products by mass. In this case, one kg of repurposed denim would have an identical environmental impact as one kg of cutting scrap.

System expansion avoids allocation of impacts between products by redefining the system boundary based on a primary product and the expected substitution effects of any co-products in the global economy. In this case, repurposed denim is the primary product and receives the full environmental burden of Bank and Vogue denim processing operations. That environmental burden is then adjusted to account for the replacement (substitution) of conventional first-use cotton fiber by recycled cutting scraps, as well as the environmental burdens associated with that recycling process.

3.4.3 RECYCLING OF DENIM CUTTING SCRAP

An inventory model of the recycling of cutting scrap from the Bank and Vogue process was developed in order to evaluate the environmental impacts of repurposed denim using system expansion. Fabric remaining after the cutting process, referred to as denim "skeletons" are collected, combined with the fabric filtered out during the quality control stages and baled for shipment via cargo ship to Sweden for recycling. At the recycling facility, denim skeletons are shredded and bleached. The bleached fibers are then filtered to remove any synthetic fibers. The fibers are then dried before the recovered cotton fabric is recycled. According to the fabric recycler, the recycling process is very similar to the processing of wood pulp and takes place in a wood pulp mill. This recycling process is designed for cotton fibers, though the system can handle up to 5% of non-cotton material. The production process efficiency is 85%, with 15% of incoming baled denim filtered out during sorting or lost as waste. This 15% waste material is assumed to be incinerated.

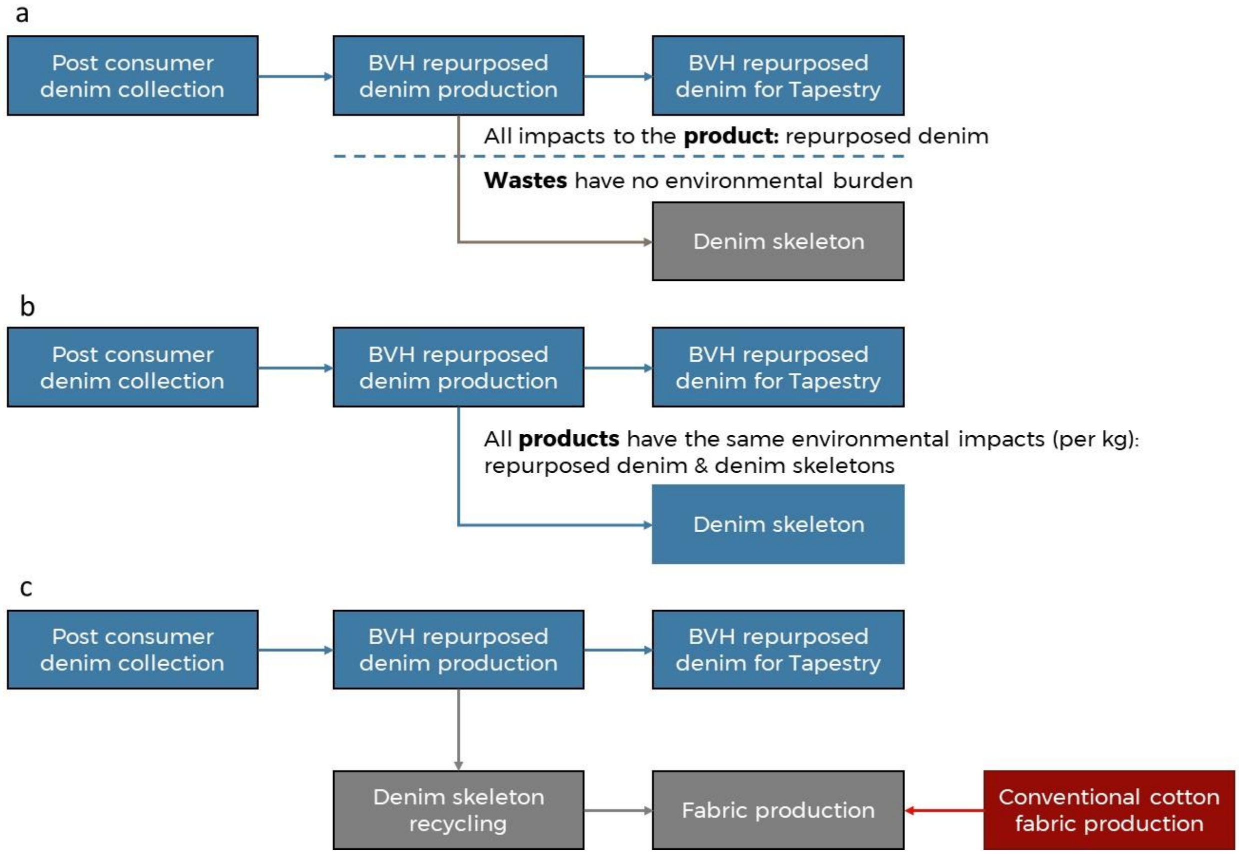


Figure 4: System diagrams illustrating the modeling procedures in the (a) cut-off (default), (b) mass allocation, and (c) system expansion approaches to co-product treatment. Processes which receive allocated environmental burdens are shown in blue, wastes and coproducts that do not receive allocated environmental burdens are shown in gray, and offset production processes are shown in red.

4 LIFE CYCLE IMPACT ASSESSMENT

4.1 LIFE CYCLE IMPACT ASSESSMENT PROCEDURES AND CALCULATIONS

The life cycle impact assessment (LCIA) was conducted using characterization factors programmed into LCA for Experts (formerly known as GaBi®). This study assessed global warming potential (GWP), water consumption, eutrophication, fossil fuel depletion, and ecotoxicity of Bank and Vogue repurposed denim using the following impact assessment methods:

- The Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report (AR5[1]) 100-year timescale excluding biogenic carbon (IPCC AR5 GWP 100 excl. biogenic) and including biogenic carbon[2] (IPCC AR5 GWP 100 incl. biogenic) methods were used to quantify GHG emissions, measured in carbon dioxide equivalents (kg CO_2e). This metric is a midpoint assessment method. Throughout this report, references to GWP or GHG emissions refer to emissions excluding biogenic carbon unless otherwise specified.
- Blue water consumption (BWC) is measured in kilograms of water by determining the total amount of water withdrawn from surface and groundwater sources. The BWC results are presented in kilograms in the LCA model, but since 1 kg of water is equal to 1 liter (L) of water, results are presented in liters. This metric is a midpoint assessment method.
- Water scarcity assessed using the Available WAter REmaining (AWARE) method represents the relative water remaining per area in a watershed after the demands of humans and aquatic ecosystems are met. It assesses the potential of water deprivation, to either humans or ecosystems, due to water use by the product system. The AWARE metric is reported in cubic meter of water equivalents (m^3e), representing water consumption weighted by regional scarcity impact factors across the supply chain (WULCA, n.d.; Boulay, et al., 2018; WULCA, n.d.).
- Eutrophication is the enrichment of nutrients that can lead to ecosystem collapse and is characterized using the CML–IA methodology (Morelli, et al., 2018). All emissions of N and P to air, water, and soil and of organic matter to water are aggregated into a single measure (kg PO_4e).
- Abiotic depletion describes the reduction of the global amount of non-renewable raw materials. This study assessed the product system impacts on availability of fossil fuels based on the remaining reserves and rate of extraction using the CML–IA methodology (Van Oers & Guinee, 2016). Fossil fuels abiotic depletion is expressed as the energy content of crude oil (MJ).
- Ecotoxicity was evaluated in LCA for Experts using the USEtox model. This model evaluates ecotoxicity using chemical-specific environmental fate, exposure, and effect parameters. The results presented in this section for the different indicators are based on the cut-off approach.

4.2 CONVENTIONAL DENIM LIFE CYCLE IMPACT ASSESSMENT

Life cycle impact assessment results for conventional first-use denim were sourced from the two selected studies described in the previous chapter. Reported environmental impacts for conventional denim fabric from a major apparel company that align with the impacts selected for this study are shown in Table 4. Agricultural production of cotton is the largest contributor to water, eutrophication, land occupation, and abiotic depletion within the

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1 This report uses the AR5 values for GWP of greenhouse gases instead of the more recent AR6 GWP values because the goal of the study is to present comparative results and provide values compatible with the Higg MSI database. Available comparative literature and the Higg MSI database use AR5 GWP values.

2 Biogenic carbon emissions are those that originate from biological sources such as plants, trees, and soil. Because biogenic carbon cycles with atmospheric carbon on relatively short timescales (hours to decades), it is accounted for differently than fossil carbon, which has remained in geologic storage for millions to hundreds of millions of years.

cradle-to-gate system boundary. Water consumption is driven by irrigation, eutrophication is driven by fertilizer run-off, land occupation is driven by the area of land occupied for agriculture and abiotic depletion is driven by the different chemicals used in fertilizers and pesticides. Climate change impacts are driven by the fabric assembly process where large amounts of electricity are used to spin and weave the cotton material into denim fabric.

Table 4: Contribution of fiber production and fabric assembly to cradle-to-gate environmental impacts of conventional denim per m² (Levi Strauss & Co., 2015)

	Fiber	Fabric assembly	Total
GHG emissions, excl. biogenic (kg CO_2e)	24%	76%	14
Water consumption (L)	92%	8%	3,378
Eutrophication (g PO_4e)	77%	23%	28

Reported environmental impacts for first-use cotton fabric from the Cotton Inc 2016 LCA are shown in Table 5 for the relevant impact categories that were available for comparison. While detailed breakdown of contributions by input type is provided in this LCA study, they have been aggregated to cotton production, which includes all on-farm activities and ginning, and fabric production, which includes fabric production activities. Results were converted from per 1,000 kg of fabric in the Cotton Inc study to per m² of fabric using the same 0.48 g/m² fabric weight reported for repurposed denim by Bank and Vogue.

Table 5: Contribution of cotton production and fabric manufacturing to cradle-to-gate environmental impacts of first-use cotton fabric from global average agricultural cotton fiber production per m² (sums may not equal 100% due to rounding) (Cotton Inc, 2017)

Impact category	Cotton production	Fabric manufacturing	Total
GHG emissions, excl. biogenic (kg CO_2e)	11%	89%	5.8
GHG emissions, incl. biogenic (kg CO_2e)	-1.1%	100%	5.1
Primary energy demand (MJ)	9.4%	91%	70
Eutrophication potential (g PO_4e)	64%	36%	5.9
Blue water consumption (L)	100%	0.012%	750

4.3 REPURPOSED DENIM LIFE CYCLE IMPACT ASSESSMENT

4.3.1 GLOBAL WARMING POTENTIAL (GWP)

The GWP results presented here exclude and include biogenic carbon. GWP excluding biogenic carbon results were available for the two comparative products identified, but the including biogenic carbon results were comparable only to cotton fabric results from the Cotton Inc study.

The GWP, excluding biogenic carbon, is 2.5 kg CO_2e per m² of repurposed denim and GWP, including biogenic carbon, is 2.5 kg CO_2e per m², as shown in Figure 5. The GWP impacts, excluding biogenic carbon, are driven by the cleaning the denim (48% in GWP excluding biogenic carbon and in GWP including biogenic carbon), with 98% of cleaning impacts coming from the electricity used for washing and drying the denim. The high GWP from electricity is due to the fossil fuel sources used for electricity production in the Indian electric grid. In the 2022 electricity dataset used for this model, 72% of the electricity in the Indian electric grid is produced using hard coal and lignite. Some carbon is stored in the post-consumer denim as biogenic carbon, since this analysis is only a cradle to gate assessment, and hence this carbon is not released back into the atmosphere until the denim reaches its end-of-life.

Despite containing cotton fiber, a carbon-based biological material, there is not a substantial difference between the GWP results including and excluding biogenic carbon. For this repurposed product, the biological removal to atmospheric carbon through photosynthesis is credited to the first use of the product, and there are not further flows of carbon from the product to the atmosphere within the system boundary. The rate and form in which the biogenic carbon contained in Bank and Vogue repurposed denim returns to the atmosphere (i.e. as CO_2, CH_4, or long-term storage) will be determined by end-of-life processes beyond the scope of this study.

Figure 6 shows the GWP excluding biogenic carbon, with the Bank and Vogue repurposed denim having 83% lower impacts than conventional denim and 57% lower GWP than cotton fabric. In the case of conventional denim, fabric production contributes 76% of GWP, which the LCA summary report indicates is driven by use of

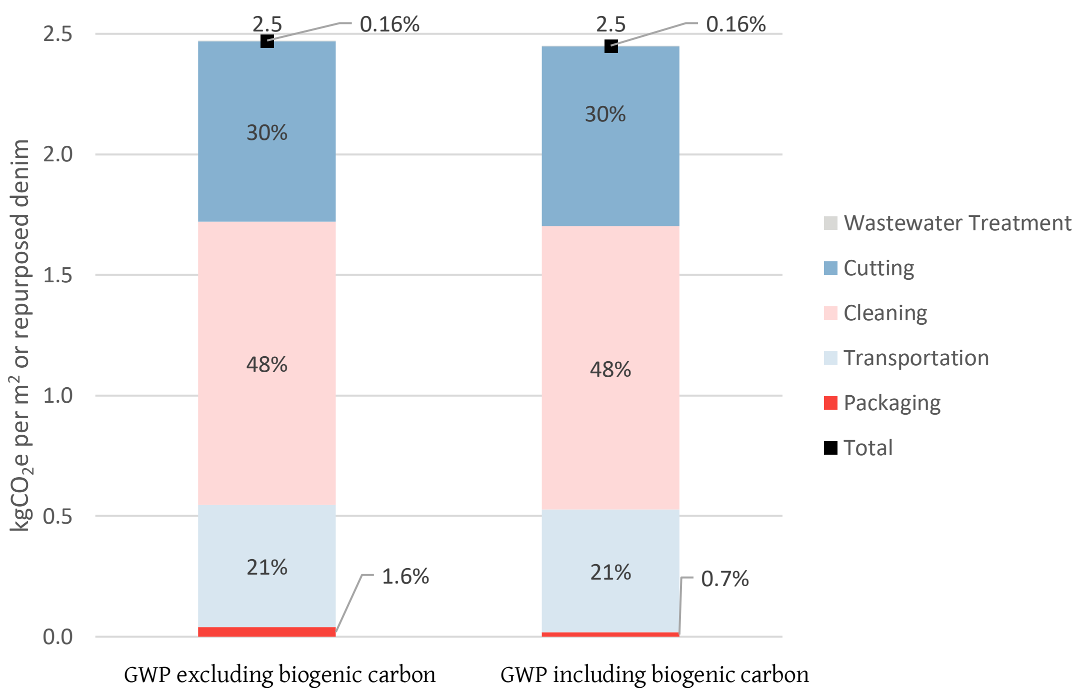

Figure 5: GWP impacts of 1 m² of Bank and Vogue repurposed denim

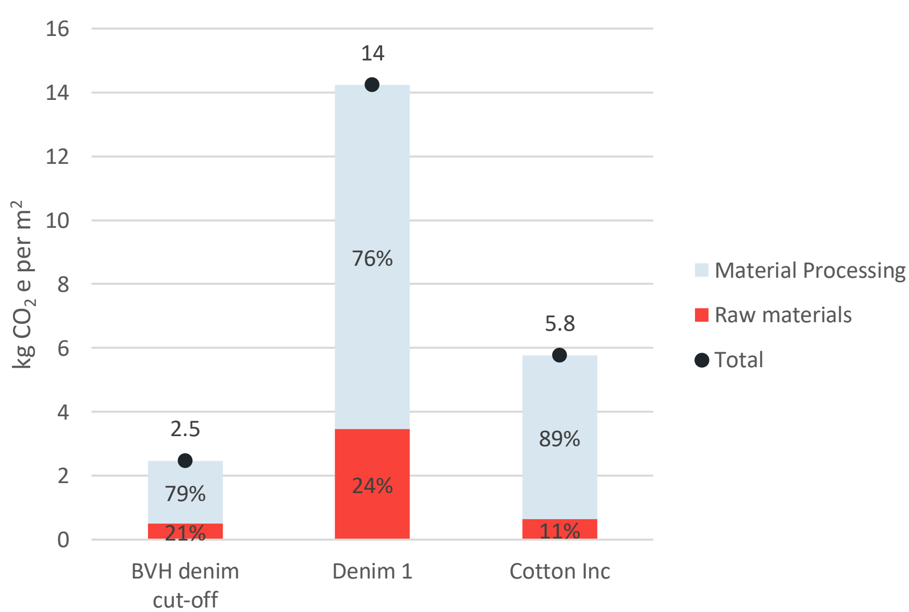

Figure 6: GWP (excluding biogenic carbon) from Bank and Vogue repurposed denim and comparative products.

non-renewable energy. In the case of cotton fiber from the Cotton Inc 2016 LCA study, 89% of GWP impacts are from fabric processing, within which 20% of the impacts are from weaving energy. The weaving energy is based on a global average grid, a grid that is heavily dependent on fossil fuels. Figure 7 shows that the repurposed denim impacts are 64% lower than that of cotton fabric.

The GWP including biogenic carbon is 2.5 kg CO_2e per m^2 of repurposed denim, as shown in Figure 7. Table 6 reflects the breakdown of impacts between Transportation of denim collected, cleaning, cutting, wastewater treatment, and packaging of the repurposed denim products that are sent to tapestry. Cleaning and cutting electricity add more than 75% of GHG emissions for both GWP categories (including and excluding biogenic carbon).

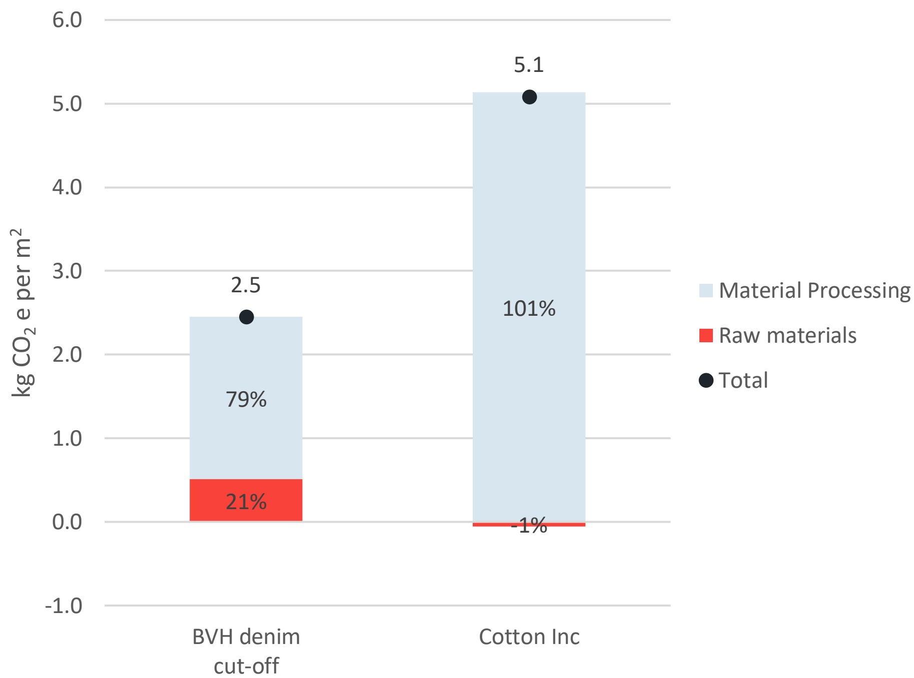

Figure 7: GWP (including biogenic carbon) from Bank and Vogue repurposed denim and comparative product.

Table 6: GWP from Bank and Vogue repurposed denim (including and excluding biogenic carbon) by life cycle stage.

Impact Category	Packaging	Transportation	Cleaning	Cutting	Wastewater treatment	Total
GHG emissions (excl biogenic) [kg CO_2 eq.]	0.039	0.51	1.2	0.75	0.0039	**2.5**
	1.6%	21%	48%	30%	0.16%	
GHG emissions (incl biogenic) [kg CO_2 eq.]	0.018	0.51	1.2	0.75	0.0039	**2.5**
	0.74%	21%	48%	30%	0.16%	

4.3.2 BLUE WATER CONSUMPTION (BWC) AND WATER SCARCITY (AWARE)

Water consumption impacts and water scarcity impacts were calculated for Bank and Vogue repurposed denim using the blue water consumption impact and high characterization factor AWARE methodology. Comparative results for conventional denim and cotton fabric were available only for the water consumption metric and were not available for the water scarcity metric.

The blue water consumption of repurposed denim is 13 L per m^2, as shown in Figure 8. The largest contributor to blue water consumption is the cleaning (75%) stage, as shown in Table 7. 52% of cleaning stage impacts are from

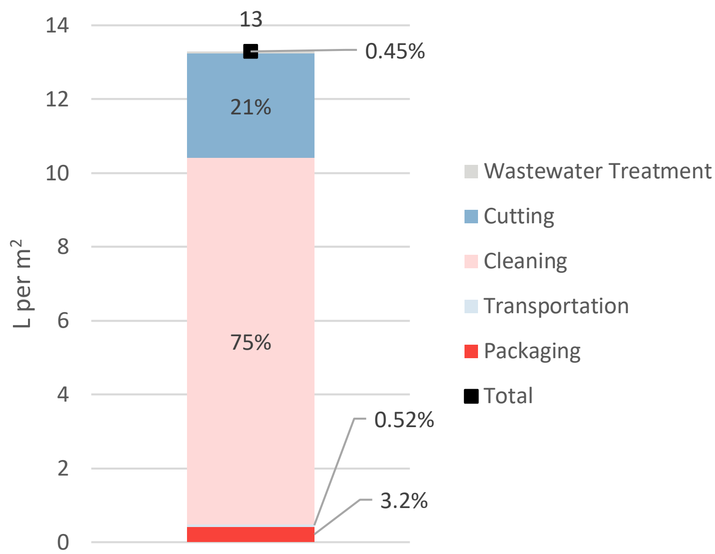

Figure 8: Blue water consumption impact per m² of Bank and Vogue repurposed denim

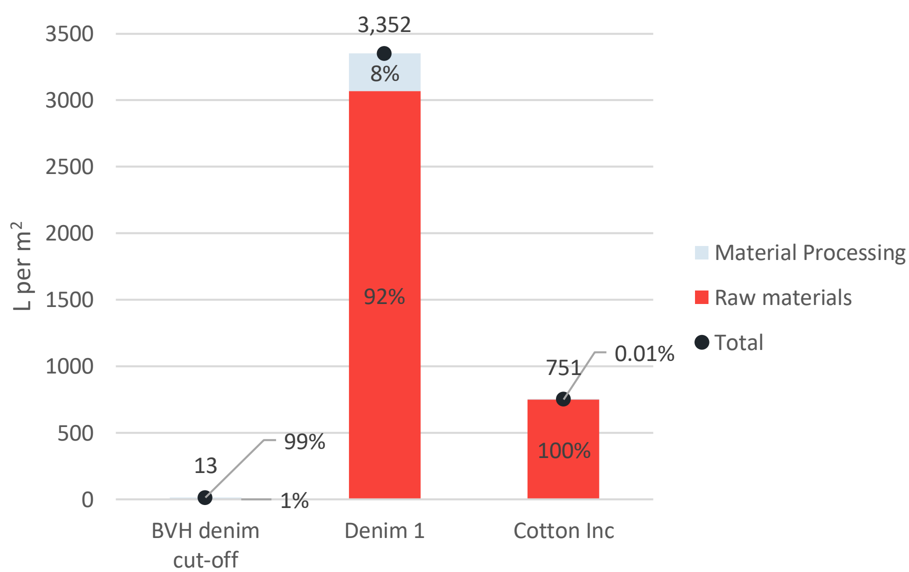

Figure 9: Blue water consumption from Bank and Vogue repurposed denim and comparative products.

the water consumed for washing the denim, but there is another 47% contribution to cleaning from the water embedded in electricity production.

Figure 9 shows that Bank and Vogue repurposed denim has 99% lower impacts than conventional denim and 98% lower impacts than cotton fabric. In comparison, water consumption impacts are largely from the fiber production stages for conventional denim (90%) and cotton fabric (100%). There is no virgin material production for the repurposed denim product leading to extensive savings in water. The water footprint of cotton cultivation is widely studied and recognized across different countries (Chapagain, et al., 2006; Jans, et al., 2021).

Water scarcity is measured as the available water remaining per area (AWARE) in a watershed after demand of humans and aquatic ecosystems has been met. It is calculated as water availability minus demand of humans and aquatic ecosystems and is relative to area. The value is normalized with world average and is inverted, which represents the surface-time equivalent to generate unused water in this region. This indicator is aggregated as needed to represent agricultural use or industrial use. The water scarcity impact for Bank and Vogue repurposed

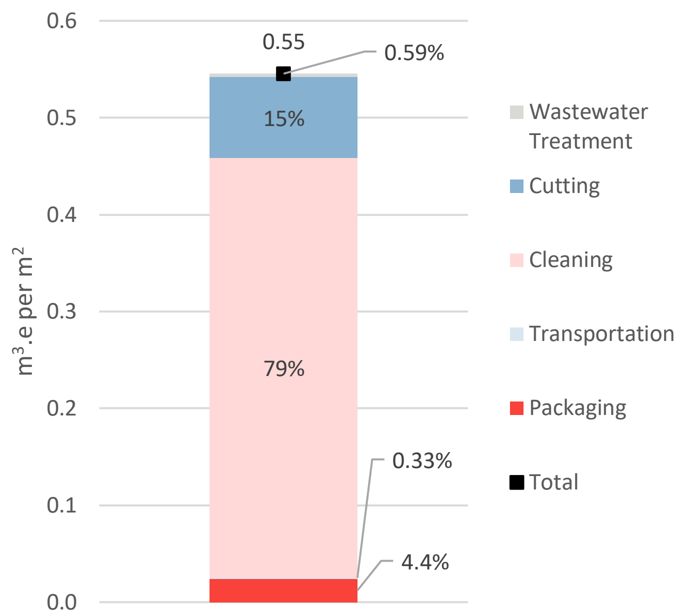

Figure 10: Water scarcity impact of 1 m² of Bank and Vogue repurposed denim

denim is 0.55 m^3 per m^2 as shown in Figure 10. This study uses the high characterization factors characterizes the average global agricultural water demand. Since the Bank and Vogue repurposed denim does not involve agricultural products like cotton, the largest driver or water scarcity is cleaning, primarily driven by water consumed for washing and the water embedded in electricity.

Table 7: Water scarcity and blue water consumption from repurposed denim by life cycle stage.

Impact Category	Packaging	Transportation	Cleaning	Cutting	Wastewater treatment	Total
Water scarcity, AWARE [m³e]	0.024	0.0018	0.43	0.084	0.0032	**0.55**
	4.4%	0.33%	79%	15%	0.59%	
Blue water consumption [L]	0.42	0.069	9.9	2.8	0.060	**13**
	3.2%	0.52%	75%	21%	0.45%	

4.3.3 FOSSIL FUEL DEPLETION

Fossil fuels use is measured using the abiotic depletion potential impact category which represents the extent to which non-renewable resources are consumed. The fossil use measurement is not available for conventional denim. Primary energy demand assessment was done for cotton fabric, which is equivalent to the fossil energy used to produce cotton fabric.

The fossil fuel depletion impact is 27 MJ per m^2 of repurposed Bank and Vogue denim. The top contributor of fossil fuel use impact is electricity consumed for washing denim. The cleaning stage creates 45% of total repurposed denim impacts, as shown in Table 8, and electricity drives 97% of cleaning impacts. The high ADP from electricity is due to the fossil fuel sources used for electricity production in the Indian electric grid. In the 2022 electricity dataset used for this model, 72% of the electricity in the Indian electric grid is produced using hard coal and lignite.

Repurposed denim has a fossil fuel use impact that is 62% lower than that of cotton fabric from Cotton Inc, as shown in Figure 12. In the case of cotton fabric, the largest contributor to impacts is fertilizer use. Fabric manufacturing involves multiple stages of knitting and weaving which are largely mechanized, and hence consume electricity. The cotton fabric LCA is a global average where electricity production has a large fossil fuel dependance, driving fossil fuel use.

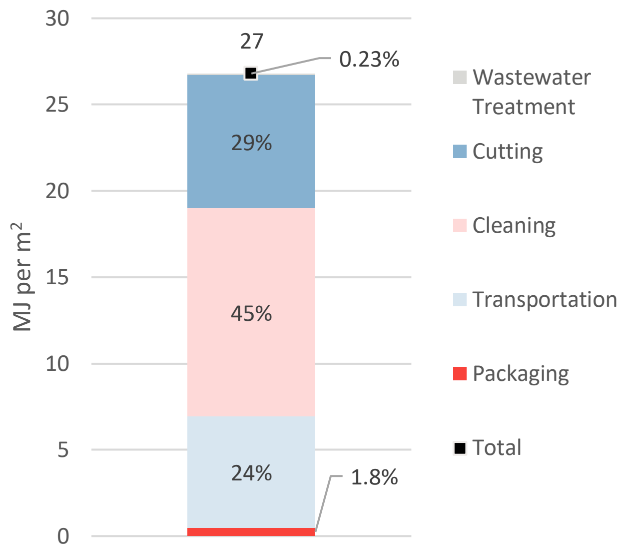

Figure 11: Fossil fuel use of Bank and Vogue repurposed denim per 1 m^2

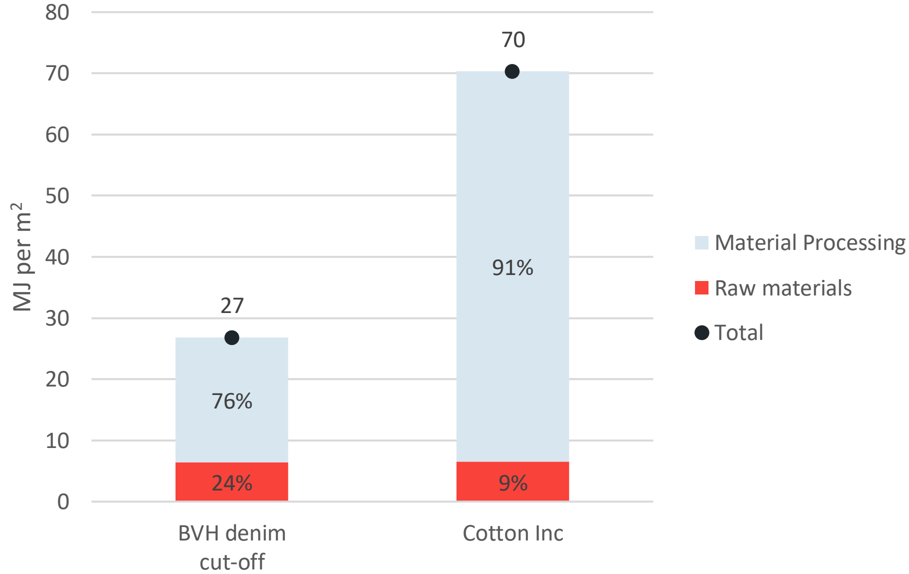

Figure 12: Abiotic depletion potential (fossil fuels) from repurposed denim and first-use cotton fabric.

Table 8: Abiotic depletion potential (fossil fuels) from repurposed denim by life cycle stage.

Impact Category	Packaging	Transportation	Cleaning	Cutting	Wastewater treatment	Total
Fossil fuel depletion, CML2001 (ADP fossil) [MJ]	0.48	6.5	12	7.7	0.063	**27**
	1.8%	24%	45%	29%	0.23%	

4.3.4 *EUTROPHICATION POTENTIAL*

Eutrophication describes the buildup of excessive nutrients in a body of water. These nutrients are typically nitrogen or phosphorus compounds. The eutrophication potential of Bank and Vogue repurposed denim is 0.0026 kg PO_4e per m², as shown in Figure 13. The contribution to eutrophication potential by each stage, 54% of eutrophication impact is from the transportation stage, also shown in Table 9. Ocean transport contributes 93% to the transportation eutrophication. Cleaning chemicals also contribute nutrients to bodies of water leading to an additional 24% of eutrophication impact.

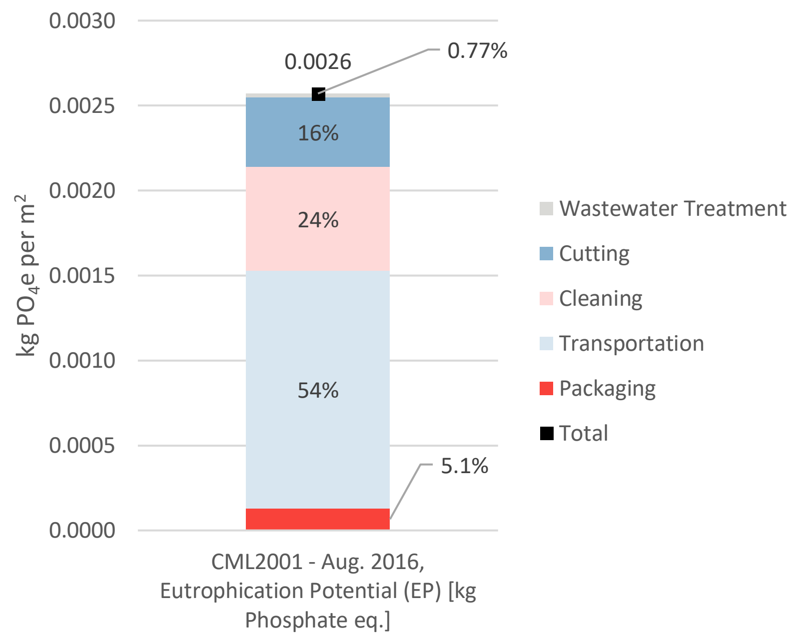

Figure 13: Eutrophication potential impacts per m² of Bank and Vogue repurposed denim

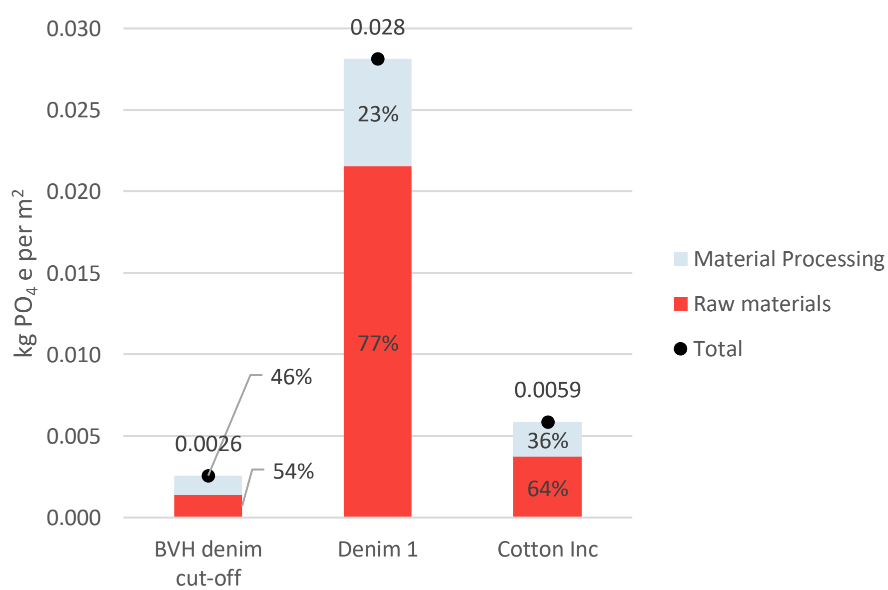

Figure 14: Eutrophication potential of repurposed denim and comparative products.

Repurposed denim eutrophication potential is 91% lower than that of conventional denim and 56% lower than that of cotton fabric, as shown in Figure 14. The majority of eutrophication impacts for conventional denim and conventional cotton is from the fertilizer run-off on field, which drives the impacts in the raw materials stage.

Eutrophication impacts are mostly from fabric production (68%) in conventional denim. Fertilizer run-off during cotton cultivation causes is the largest contributor to eutrophication impacts within fabric production. Similarly, for cotton fabric, there is run-off from cotton fields (64%) and chemical run-off from fabric production (35%) that lead to excessive nutrient accumulation in freshwater systems, leading to higher eutrophication.

Table 9: Eutrophication potential of repurposed denim by life cycle stage.

Impact Category	Packagin g	Transportation	Cleaning	Cutting	Wastewater treatment	Total
Eutrophication Potential, CML2001 (EP) [kg Phosphate eq.]	0.00013	0.0014	0.00061	0.00041	0.000020	**0.0026**
	5.1%	54%	24%	16%	0.77%	

4.3.5 *TOXICITY*

The USEtox methodology was used to calculate ecotoxicity, which is generated based on the fate of the chemical and the extent of exposure to the chemical. There are no toxicity related impacts reported with conventional denim, but the cotton fabric study reports toxicity related impacts using the USEtox model. These results are not compared since many of the exposure and fate factors were customized for the cotton fabric study. The uncertainty of these characterizing factors can be in the hundreds, which makes comparative assessments meaningless.

Table 10 shows the breakdown of contribution to toxicity impacts from each stage of denim repurposing. The cleaning stage is the largest driver of ecotoxicity and non-cancerous human toxicity, with impacts from electricity contributing the most within the cleaning stage. Electricity production releases toxic chemicals into the air, water, and soil which contribute to toxicity impacts. In the case of cancerous toxicity, the largest contributor is the combustion of diesel during cutting and the combustion of fuel oil in cargo ships releases cancer causing chemicals, leading to larger contributions from the cutting stage and the transportation stage. Note that these toxicity impacts have been known to have a large uncertainty range. Therefore, using these results for comparative purposes is not recommended and these results be interpreted with caution.

Table 10: Toxicity impacts of repurposed denim by life cycle stage.

Impact Category	Packaging	Transportation	Cleaning	Cutting	Wastewater treatment	Total
Ecotoxicity, USEtox 2.12 [CTUe]	0.0045	0.0017	0.00051	0.00050	0.00023	**0.0075**
	60%	23%	6.9%	6.7%	3.1%	

4.4 LIMITATIONS

The source material for Bank and Vogue repurposed denim is post-consumer apparel, primarily from thrift stores and charities in Canada. Collection of post-consumer apparel is a complex process and primary data on the portion of this supply chain from the consumer to the aggregation point in Canada was unavailable. Due to this gap in supply chain data and uncertainty in the difference between these missing processes and conventional waste collection operations, this study does not attempt to model denim collection stages between consumers and the aggregation point outside of a sensitivity analysis.

Other limitations of this work include the use of proxy chemical datasets to model certain chemicals used on-site, such as the anti-scalent, which increase the uncertainty of the results. As identified by the data quality assessment, the data have an average representative score of 2 to 3, with large variations between the life cycle stages and several instances of low representativeness. Identifying these limitations will help inform stakeholders on how the model can be improved to be more representative in future iterations.

It is also critical to understand the limitations of certain impact categories while interpreting the results. Toxicity results in LCAs are based on characterization factors, which describe the likelihood of harm to humans or ecosystems from the release of a chemical to the environment. These characterization factors have very low precision, with a range of 100× to 1000× for human health and 10× to 100× for freshwater ecotoxicity (Rosenbaum, et al., 2008). Low precision in characterization factors leads to high uncertainty in LCA results. This can render results unusable for comparisons, since both the product and the comparative products have a large range of potential impact. There are also significant limitations with regards to impact categories for the conventional denim comparative product. The conventional cotton study only reports primary energy demand is different from the abiotic fossil fuel depletion but these two impact categories still represent direct and indirect energy in non-renewable energy sources.

4.5 DESCRIPTION OF PRACTITIONER VALUE CHOICES

The practitioner value choices have been limited to the selected LCIA and the allocations procedures described in the relevant sections of this report. All results are presented on a midpoint basis using the methods noted in Section 4.1; normalization and weighting are not used. Other impact categories have been excluded from the results because they do not answer the questions defined as the goal and scope for the intended audience in Section 1 of this report.

4.6 STATEMENT OF RELATIVITY

LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins, or risks. No grouping of impact categories has been performed; all impacts are presented at the midpoint level. LCIA impacts presented in this report are based on midpoint characterization factors (e.g., kg CO_2e for GWP), and this study does not refer to the ultimate damage to human health and the environment. For example, GWP and water consumption may have a negative or a positive environmental impact depending on the conditions in locations where emissions or resource consumption occur, or where the effects are ultimately felt. Since this study does not present end-point results, it does not draw any conclusions about the relative impact (positive or negative) for the categories considered by the study.

5 LIFE CYCLE INTERPRETATION

5.1 IDENTIFICATION OF RELEVANT FINDINGS

Producing one m^2 of Bank and Vogue repurposed denim generates 3.9 kg CO_2e, consumes 20 L of blue water, and generates 0.0040 kg PO_4 of eutrophication potential (among other assessed impacts, summarized in Table 11). Processing, cleaning, and cutting of post-consumer denim at the Bank and Vogue facility is the leading source of all environmental impacts except eutrophication due to a high proportion of energy sourced from the highly coal-dependent Indian electric grid. The use of rooftop solar photovoltaic power by Bank and Vogue mitigates these impacts.

Sourcing of post-consumer denim is also an important source of environmental impact. Transportation of denim bales from the Canadian aggregation site to the Bank and Vogue facility in India generates 23% of GWP, 27% of fossil fuel depletion, and 56% of eutrophication potential from repurposed denim. Additional upstream collection and processing stages not included in this study could increase these impacts.

The GWP of repurposed denim is 56% to 73% lower than conventional first-use denim and conventional cotton fabric (Table 11). This is due primarily to the much higher GWP of fabric weaving and dyeing in conventional systems, although the collection of post-consumer denim may also have lower GHG emissions than agricultural production of cotton fiber. Blue water consumption by repurposed denim is 98% to 99% lower than first-use cotton due to the high water demand from many agricultural cotton production systems and the relatively minor water consumption by the repurposing process.

Bank and Vogue repurposed denim also reduces GWP including biogenic carbon by 63% and fossil fuel depletion by 61% compared to first-use cotton fabric and has 55% to 86% lower eutrophication potential than first-use denim. Although there was insufficient data available on first-use denim to compare repurposed denim in all the selected impact categories, it is clear that repurposed denim has substantially lower environmental impacts in many impacts related to fossil energy use and agricultural production.

Table 11: Repurposed denim impacts per m^2 and differences when compared to conventional denim and cotton fabric.

Impact Category	Repurposed denim	Conventional denim	Conventional cotton fabric
GWP, IPCC AR5 GWP100 excl biogenic carbon [kg CO_2 eq.]	2.5	14	5.8
		-83%	-57%
GWP, IPCC AR5 GWP100, incl biogenic carbon [kg CO_2 eq.]	2.5		5.1
			-52%
Blue water consumption [kg]	13	3400	750
		-99%	-98%
Water scarcity, AWARE [m^3 world equiv.]	0.55		
Fossil fuel depletion, CML2001 (ADP fossil) [MJ]	27		70
			-62%
Eutrophication Potential, CML2001 (EP) [g PO_4 eq.]	2.6	28	5.9
		-91%	-56%
Ecotoxicity, USEtox 2.12 [CTUe]	0.0075		

5.2 SENSITIVITY ANALYSIS

Three sensitivity analyses were done: an assessment of the model's sensitivity to renewable energy, an assessment of the model's sensitivity to transportation of post-consumer denim from the consumer to the storage facility in Maple Ridge, BC and a comparison of model results using alternative allocation methods.

5.2.1 *SENSITIVITY TO RENEWABLE ENERGY*

Bank and Vogue had already indicated that photovoltaic panels are used on the production facility to supplement electricity from the local electric grid. The sensitivity assessment models the impacts of one square meter of repurposed denim if 100% of the electricity consumed for cutting and leaning was sourced from rooftop-scale solar power. Table 12 presents the results of this scenario. The use of solar power to power all cleaning and cutting operations leads to a reduction in environmental impacts in every assessed category, with an effect between 1% and 95%, depending on the impact category.

The lack of direct emissions and the lower embodied impacts of solar panels leads to lower GHG emissions, water, and energy impacts. There is also reduction in eutrophication impacts, but the reduction achieved is lower since the contribution from grid electricity to eutrophication is lower.

Table 12: Renewable energy scenario impacts on LCA results for repurposed denim.

Impact Category	Cut-Off Approach	Cut-off + Renewable energy	% reduction
GWP, excl biogenic carbon [kg CO_2 eq.]	2.5	0.74	70%
GWP, incl biogenic carbon [kg CO_2 eq.]	1.8	0.094	95%
Blue water consumption [kg]	13	6.1	54%
Water scarcity, AWARE [m^3 world equiv.]	0.55	0.34	38%
Fossil fuel depletion [MJ]	27	9	65%
Eutrophication potential (EP) [kg Phosphate eq.]	0.0026	0.0017	32%
Ecotoxicity [CTUe]	0.0075	0.0074	1%

5.2.2 *SENSITIVITY TO POST-CONSUMER DENIM COLLECTION*

The baseline model of repurposed denim in this study includes transportation of post-consumer denim jeans from a collection facility in Maple Ridge, BC Canada to the BVH processing facility in Gandhidham, India, but does not include collection activities further upstream. Consumer transport stages of a supply chain can have high environmental impacts due to the inefficiency of transporting small quantities of goods by passenger car. To assess the potential impact of the full post-consumer denim collection supply chain in the absence of primary data, a scenario was developed using the following assumptions:

- Consumers deliver 5.0 kg loads of goods to a secondhand store by passenger car, traveling 5.6 km each direction (based on consumer-to-supermarket distance reported by (Clifton, et al., 2013))
- 15% of goods are rejected at the secondhand store (sent to landfill; based on an article from The Seattle Times (Doughton, 2021))

- Postconsumer denim jeans are moved by truck from major metropolitan areas in western Canada to the collection facility in Maple Ridge, BC
- Truck transportation to Maple Ridge was estimated using the population-weighted average distance from the metropolitan areas of Vancouver, BC, Victoria BC, Calgary AB, and Edmonton AB to Maple Ridge BC
- Sea ferry transportation from Victoria to Tsawwassen was included based on a gross truck vehicle weight of 15,900 kg (35,000 lbs) and truck freight weight of 11,300 kg (25,000 lbs) and using the same population weighting method as truck transportation

Total upstream transportation elements added in this scenario included, per m^2 of repurposed denim:

- 1.34 km by passenger car
- 0.30 t*km by truck
- 0.0071 t*km by sea ferry

Results of this assessment show that including consumer delivery of denim to local secondhand stores and bulk delivery by truck from secondhand stores throughout western Canada to the processing facility in Maple Ridge does increase the environmental impacts of repurposed denim by roughly 5% to 11% across most impact categories (see Table 13). These increases are notable, but do not substantially affect the interpretation of results.

Table 13: Post-consumer denim collection scenario impacts on LCA results for repurposed denim.

Impact Category	Cut-Off Approach	Cut-off + Denim Collection	% change
GWP, excl biogenic carbon [kg CO_2 eq.]	2.5	2.8	11%
GWP, incl biogenic carbon [kg CO_2 eq.]	2.5	2.7	11%
Blue water consumption [kg]	13	14	5.1%
Water scarcity, AWARE [m^3 world equiv.]	0.55	0.56	3.3%
Fossil fuel depletion [MJ]	27	31	15%
Eutrophication potential (EP) [kg Phosphate eq.]	0.0026	0.0027	6.0%
Ecotoxicity [CTUe]	0.0075	0.0088	17%

5.2.3 *SENSITIVITY TO ALLOCATION METHOD*

A key factor that influences LCA results is the allocation method that is chosen. In this study the cut-off approach (a.k.a. recycled content approach) is used as the base case. In this case, the cut-off approach provides highly conservative results because all impacts of the production system are assigned to the primary product (repurposed denim) and none to the co-product (cutting scrap). However, both the repurposed denim and cutting scrap are useful and economically valuable products. To more accurately assign environmental impacts to both products, this study includes sensitivity case studies using the mass allocation and system expansion methods. Both of these approaches are approved by the ISO standards for LCA, which prioritize first avoiding allocation through system expansion, or when that is not feasible using a physical allocation parameter, such as mass. Hence both of these approaches are used in this sensitivity assessment. These results are presented in Table 14.

The mass allocated results are 72% lower than the cut-off approach results in every impact category. The difference is consistent because all of the environmental burdens from the denim repurposing system are evenly split between repurposed denim, (28% of product output by mass) and the cutting scraps (72% of output by mass).

The change in environmental impacts using system expansion is less consistent because the difference is based on a change in the system boundary to include the recycling of cutting scraps into cotton fabric and the displacement of first-use cotton fabric in the global market. Even though the cutting skeleton recycling process is modeled using a wood pulp mill process, there are large savings in emissions, excluding biogenic carbon, that are incurred through the quantity of cotton that is no longer produced. The GWP excluding biogenic carbon of repurposed denim are 44% lower while the GWP including biogenic carbon is 173% higher. The GWP including biogenic carbon is higher since production of cotton stores biogenic carbon which no longer occurs. The fossil use impacts are 36% lower when using system expansion than when applying the cut-off approach. This is because fuel and electricity needed to produce cotton is no longer spent. There is also reduction in blue water consumption, water scarcity, and eutrophication potential since water and fertilizers are no longer needed to produce cotton that is replaced by the recycled cutting skeletons. The absolute value of blue water consumption and water scarcity are also negative because there no water withdrawn for cotton production, which mathematically appears as a return. Similarly, eutrophication potential also has a negative value since fertilizer run-off from cotton production is avoided. There is a reduction in ecotoxicity impacts as well, but given the high uncertainty of USEtox characterization factors it is not advised to compare USEtox results between scenarios.

Table 14: Life cycle impact assessment results for repurposed denim by assessment methodology (cut-off, mass allocation, and system expansion).

Impact Category	Cut-Off Approach	Mass Allocation	System Expansion
GWP, excl biogenic carbon [kg CO_2 eq.]	2.5	0.70	1.4
GWP, incl biogenic carbon [kg CO_2 eq.]	2.5	0.070	6.7
Blue water consumption [kg]	13	3.8	-764
Water scarcity, AWARE [m^3 world equiv.]	0.55	0.15	-44
Fossil fuel depletion [MJ]	27	7.6	172
Eutrophication potential (EP) [kg Phosphate eq.]	0.0026	0.00073	-0.028
Ecotoxicity [CTUe]	0.0075	0.0021	-16

5.3 DATA QUALITY ASSESSMENT

The quality of fit, or representativeness, of model inputs will be evaluated across five indicator categories: reliability, completeness, temporal correlation, geographical correlation, and technological correlation. For each indicator, a score from 1 to 5 was assigned to each model input, where 1 indicates high representativeness of the product system and 5 indicates low representativeness (Table 15). The assessment was completed across life cycle stages for a final average score (rounded to the nearest whole number) in each indicator (Table 16).

Developing pedigree matrices for the comparative products was not feasible due to a lack of visibility into the background data and inventory processes selected for the cited studies.

Table 15: Pedigree matrix category definitions, adapted from the U.S. Environmental Protection Agency

Data Quality Indicator	Highest Confidence 1	2	3	4	Lowest Confidence 5
Reliability	Primary data from Bank and Vogue, measured data	Primary data from Bank and Vogue, estimated data	Data obtained from literature with an exact proxy match	Data obtained from literature with a proxy match	Data obtained from online sources and not an exact match, limited documentation
Completeness	Representative data from >80% of the relevant market, over an adequate period	Representative data from 60-79% of the relevant market, over an adequate period **or** representative data from >80% of the relevant market, over a shorter period of time	Representative data from 40-59% of the relevant market, over an adequate period **or** representative data from 60-79% of the relevant market, over a shorter period of time	Representative data from <40% of the relevant market, over an adequate period **or** representative data from 60-79% of the relevant market, over a shorter period of time	Unknown **or** data from a small number of sites and from shorter periods
Temporal correlation	Less than 3 years of difference	Less than 6 years of difference	Less than 10 years of difference	Less than 15 years of difference	Age of data unknown or more than 15 years
Geographical correlation	Data from same resolution **and** same area of study	Within one level of resolution **and** a related area of study	Within two levels of resolution **and** a related area of study	Outside of two levels of resolution but related area of study	From a different or unknown area of study
Technological correlation	All technology categories are equivalent	Three of the technology categories are equivalent	Two of the technology categories are equivalent	One of the technology categories is equivalent	None of the technology categories are equivalent

Source: **(Edelen & Ingwersen, 2016)**

Geographical resolution has seven levels of resolution: global, continental, sub-region, national, province/state/region, county/city, and site-specific (Edelen & Ingwersen, 2016). The sub-region level refers to regional descriptions (e.g., UAE), and the site-specific level, the most granular level, and includes the physical address of the site. The geographical correlation is scored based on the level of the input data and the level of the dataset that is available.

Technological correlation is represented using four categories: process design, operational conditions, material quality, and scalability. Process design refers to the set of conditions in a process that affect the product. Operational conditions refer to variable parameters such as heat, temperature, and pressure needed to make the product. Material quality refers to the type and quality of feedstock material. Scale refers to output per unit time or per line needs to be described.

Table 16: Pedigree matrix assessment

Data Quality Indicator	Data quality description by phase	Average
Reliability	Input data for the production of the repurposed denim was primary measured data collected on the production site. The measured data were modeled using datasets from ecoinvent and Sphera. Exact matches for materials and energy flows were identified for 80% of inputs, with proxies used for the remaining 20%. Overall the data from Bank and Vogue is highly reliable, and the datasets identified were of average reliability. The overall reliability score is a 2.	**2**
Completeness	All input and output flows from the repurposed denim system are quantified in this model based on measured data from the complete set of production runs for the repurposed denim product. The overall completeness of the model representing the production system is excellent and has a completeness score of 1.	**1**
Temporal correlation	The measured data provided represents the entire production cycle for the denim manufactured for Tapestry in 2023. Life cycle inventory datasets used from ecoinvent and Sphera are up to date and reflect industrial processes within three years of the study period. The temporal correlation score is 1.	**1**
Geographical correlation	Measured, primary data were provided for the production process, including energy, water, and chemicals at a specific site in the western region of India. The data sets used to model all the input and outputs are either at the national level (electric grid dataset) or at the global level (packaging and chemical datasets). Due to the large difference in resolution between the provided data and proxy datasets, the geographical correlation is conservatively scored as a 4.	**4**
Technological correlation	The technologies modeled reflect primary data on the system boundary and processes used for denim repurposing by Bank and Vogue. This study therefore represents repurposed denim at equivalent process design, operational conditions, and scale of the product under study. The material quality of some inventory proxies may not completely match the actual chemicals in use, and therefore the technological correlation score is 2.	**2**

5.4 CONCLUSIONS AND RECOMMENDATIONS

This study demonstrates that Bank and Vogue repurposed denim has lower environmental impacts than conventional denim and conventional cotton in several categories related to energy use and agricultural production. Table 17 summarizes the difference in impact between repurposed denim and the two comparative products. While data across all impact categories were not publicly available for a comparison, it is clear that repurposed denim has lower GHG emissions, fossil use, blue water consumption, and eutrophication potential when compared to conventional denim and conventional cotton fabric.

Across most of these impact categories, electricity used in cutting and cleaning was the main driver of impacts. While there is solar power on site, most of power is drawn from the Indian electric grid, which is dependent on fossil fuels like coal and natural gas. Shifting all cleaning and cutting electricity to solar power was built out as a scenario. This led to a 70% reduction in GHG emissions, 54% reduction in blue water consumption, and 65% reduction in fossil fuel use.

Since 72% of the denim entering the denim repurposing system becomes cutting scraps, a co-product used in downstream recycling processes, allocation is highly influential in determining the results of this study. Three different allocation methods were employed as a sensitivity assessment. The baseline analysis employed the cut-off approach, where all impacts were assigned to the Tapestry products. Results were generated using mass allocation and system expansion as scenarios for comparison, as summarized in Table 17. Mass allocation results were 72% lower than the baseline results since all burdens were distributed between the weight of material used for Tapestry products as well as the weight of material in denim skeletons. In the case of system expansion, difference in impact varied between -8100% and 170%. The reduction in impacts achieved for GWP without biogenic carbon, blue water consumption, water scarcity, fossil fuel use, eutrophication, and ecotoxicity are due to avoided production of cotton. The cotton that would have been produced is now replaced by the recycled denim product in the market. The increased impact for GWP emissions including biogenic carbon is also due to the avoided cotton production. Cotton, while it is produced, stores biogenic carbon. This no longer happens and hence there is an increase in GWP including biogenic carbon. Fossil fuel use impacts were higher by 59% under system expansion. GHG emissions and eutrophication impacts under system expansion scenarios were lower by 9% and 1800%, respectively. The increases in impacts are due to the higher fossil use during the recycling process to convert cutting scraps to cotton fabric, while the reduction in impacts is due to avoided GHG emissions and chemical use during virgin cotton production. Comparing cut-off approach results and system expansion results are not recommended for the toxicity results, due to the inherent variance in toxicity characterization factors.

Table 17: Summary of results for repurposed denim and differences in impact compared to conventional denim and conventional cotton fabric.

Impact Category	Repurposed denim	Conventional denim	Conventional cotton fabric
GWP, excl biogenic carbon, $kgCO_2e$	2.5	14 (-83%)	5.8 (-57%)
GWP, incl biogenic carbon, $kgCO_2e$	2.5		5.1 (-52%)
Blue Water Consumption, L	13	3351 (~-100%)	750 (-98%)
Water Scarcity (AWARE), m^3e	0.55		
Fossil fuel depletion, MJ	27		70 (-62%)
Eutrophication Potential, $kgPO_4e$	0.0026	0.028 (-91%)	0.0059 (-56%)
Ecotoxicity, CTUe	0.0075		

Based on this study, it is recommended that Bank and Vogue consider the following actions to reduce GHG emissions, water impacts, energy impacts, eutrophication, and toxicity impacts of repurposed denim. First, increase the proportion of energy use from renewable energy. The solar energy-based scenario results show that environmental impacts in all assessed categories can be reduced by using solar electricity generation, particularly GHG emissions, blue water consumption, fossil fuel depletion, and ecotoxicity. Second, consider diversifying the sourcing of post-consumer denim jeans to include more local sources to reduce the substantial GHG emissions, fossil fuel depletion, and eutrophication impacts associated with sourcing raw materials for repurposed denim. Third, continue to identify high-value uses for cutting scraps from the denim repurposing process. The baseline results for repurposed denim in this study conservatively assume that all of the energy, water, and materials used in material sourcing and the repurposing process are assigned to the repurposed denim product, and not to the cutting scraps which are sent for recycling. The sensitivity analyses presented in this study demonstrate that alternative accounting methods substantially reduce the environmental impact of the repurposed denim. Maintaining the value chain for recycling of cutting scraps, reducing the energy and materials intensity of the cutting scrap recycling process, and other approaches that demonstrate the circularity and efficiency of this postconsumer textiles supply chain would all support the use of less conservative allocation methods that would assign a smaller proportion of the environmental burdens of Bank and Vogue's processes to the repurposed denim product that is the focus of this study.

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7 CRITICAL REVIEW STATEMENT

Review of "ISO 14044-Conformant Comparative LCA Report – Bank and Vogue Repurposed Denim, Conventional Denim and Conventional Cotton Fabric – Tapestry"

Commissioned by: Tapestry, Inc.

Conducted by: WSP

Reviewers: Arpad Horvath – Consultant (Chair)
Bill Flanagan – Aspire Sustainability
Corinne Scown - Consultant

Date of completion of review: September 9, 2024

References: ISO 14044:2006 – Environmental Management – Life CycleAssessment – Requirements and Guidelines

ISO 14067:2018 Greenhouse gases – Carbon Footprint of Products – Requirements and Guidelines for Quantification

ISO/TS 14071:2014 — Environmental management — Life cycle assessment — Critical review processes and reviewer competencies:Additional requirements and guidelines to ISO 14044:2006

Scope of the Critical Review

The Critical Review Panel was commissioned to review a comparative LCA report of Bank and Vogue repurposed denim, conventional denim, and conventional cotton fabric.

In accordance with ISO 14044:2006, section 6.1, the goal of the Critical Review was to assess whether:

- the methods used to carry out the LCA are consistent with the standards ISO 14040 and ISO 14044,
- the methods used to carry out the LCA are scientifically and technically valid,

- the data used are appropriate and reasonable in relation to the goal of the study,
- the interpretations reflect the limitations identified and the goal of the study, and
- the study report is transparent and consistent.

This review statement is only valid for the specific report titled "ISO 14044-Conformant Comparative LCA Report – Bank and Vogue Repurposed Denim, Conventional Denim and Conventional Cotton Fabric – Tapestry," dated September 2024, thus it does not apply to any other report versions, derivative reports, excerpts, press releases, and similar documents.

The review was performed exclusively on the LCA study report. No software models were shared or requested during the review.

Critical Review Process

The review was conducted by exchanging comments and responses using an Excel spreadsheet based on Annex A of ISO/TS 14071:2014.

The critical review was carried out between April 16, 2024 (receipt of the draft LCA report) and September 9, 2024 (delivery of the final review statement). There were four formal rounds of comments on the original and three revised versions of the report. A copy of the review spreadsheet containing all written comments and responses has been provided to Tapestry along with this review statement.

The review was conducted in a constructive manner. All comments were addressed and all open issues were resolved. There were no dissenting opinions held by any of the involved parties upon finalization of the review.

General Evaluation

The study was found to be well-scoped and the analysis capable of supporting the goals of the study. The report shows a high level of technical knowledge and methodological proficiency.

Conclusion

Based on the final LCA report, it can be concluded that the methods used to carry out the LCA are consistent with the ISO 14044 standard, that they are scientifically and technically valid, that the data used are appropriate and reasonable in relation to the goals of the study, and that the interpretations reflect the limitations identified and the goal of the study. The LCA report is considered sufficiently transparent and consistent.

When communicating results to third parties, ISO 14044, section 5.2 requires that a third-party report be made available to any such parties. The third-party report shall be made available by the study commissioner and should contain all required information as specified in ISO 14044, section 5.2. Any confidential or otherwise sensitive contents can be removed or blacked out prior to sharing the report with third parties.

The reviewers sign this review statement as independent experts. Their signatures do not constitute an endorsement of the study's scope or results.

Bill Flanagan	Corinne Scown	Arpad Horvath

Valid as of September 9, 2024