

Life Cycle Assessment of Bags Made from Primary and Recycled Materials (Haze Bag)

Introduction

The fashion industry has long been a cornerstone of global culture and economy, but in recent years, discussions have increasingly focused on transitioning to more sustainable fashion practices. A significant part of this transition involves addressing the environmental challenges associated with textile production, particularly through the use of recycled materials.

In 2023, synthetic fibers accounted for approximately 67% of global textile fiber production ¹, with polyester being the most dominant contributor. Polyester production, however, is associated with significant energy and water consumption, extensive fossil fuel use, and substantial carbon emissions, all of which raise major environmental concerns, particularly in contributing to global warming.

The textile industry has seen notable advances, with a growing adoption of recycled materials and the rise of more sustainable fashion brands. Interest in sustainable fashion has surged by 1,116.67% between 2008 and 2024 ², reflecting the increasing importance and awareness of sustainability in the fashion sector. At Kintobe, sustainability is at the heart of our mission. The brand is committed to designing sustainable bags, striving to use 100% recycled materials—whether pre- or post-consumer—for all products. Currently, we are exploring innovative materials, such as bio-based leather, to incorporate into new designs as part of our efforts to align with carbon reduction goals and ensure the brand's sustainable growth.

The purpose of this analysis is to compare the environmental impacts of bags made from primary materials versus the Haze bag, which is made from recycled materials. The focus is on key environmental impact categories relevant to the textile industry, with the aim of informing sustainable design strategies and contributing to the broader shift toward sustainability in fashion.

Methods

Life Cycle Assessment Approach

This analysis conducts a Life Cycle Assessment (LCA) (from raw material production/recycling process to fiber production) to compare the environmental impacts of the virgin bag (made from primary materials) and the HAZE bag (made from recycled materials). The four phases of LCA—goal and scope definition, life cycle inventory analysis, impact assessment, and interpretation—are systematically carried out in this analysis. For the majority of the analysis, an attributional modeling approach is applied. This method quantifies the direct, average environmental impacts associated with the materials and production processes of the bags using existing data. It does not account for broader market dynamics or indirect effects, consistent with the static and descriptive nature of attributional LCA.

The goal of this analysis is to evaluate the environmental impacts of the HAZE bag to support design improvements and effectively communicate its sustainability performance to consumers.

The scope of the analysis is defined as follows:

- **Functional Unit:** The energy use and emissions per kilogram of one bag.
- **System Boundaries:** The system boundaries for fabrics include the processes of raw material production (or post- or pre-industrial waste collection and processing), chip /recycled chip production, and yarn spinning while excluding the stages and processes beyond yarn spinning (e.g., fabric weaving, fabric finishing (dyeing, coating), bag assembly, bag distribution (retailers), bag usage and bag reuse/ repair). Most water-intensive occur beyond the defined system boundaries, specifically during the fabric finishing and assembly stages. For leather, no specific flow chart is available in the LCA of mushroom provided by the supplier; however, its system boundary is defined from raw material extraction/production to finished leather, which is ready for cutting and downstream application ³.
- The system boundaries for mushroom leather extend slightly further than those of other materials. While mushroom leather is already prepared for the assembly stage ³, the fabric materials still require additional processing, such as fabric or foam production, before reaching the assembly phase. However, since mushroom leather are analyzed individually due to differences in geographical scope and data consistency, the slight variation in system boundaries for

mushroom leather does not pose an issue. This approach ensures clarity and alignment in the analysis.

- The system boundaries are visually represented as the processes within the square in the figure provided.

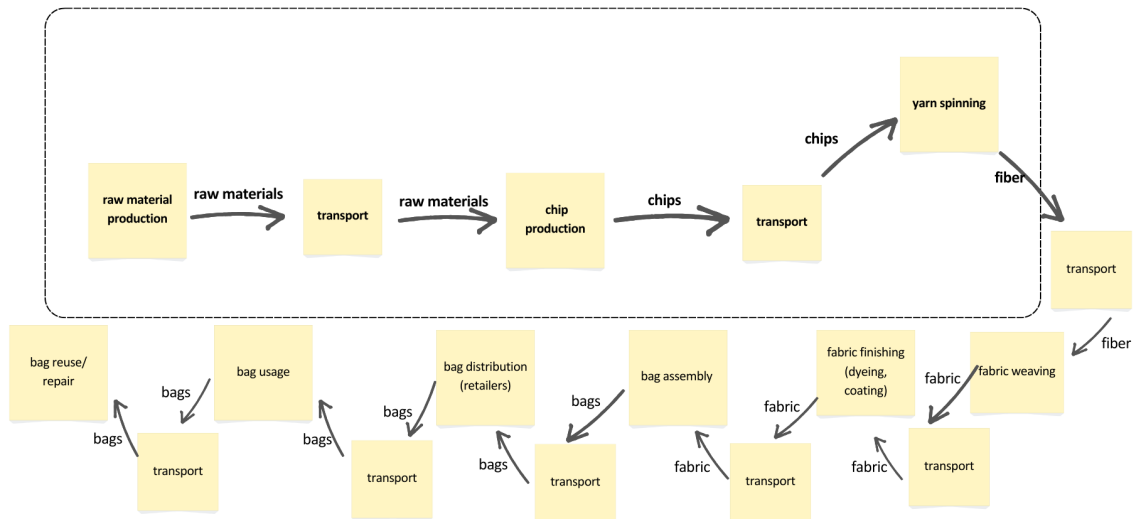


Figure1. Flow chart of the fabric of virgin bag production

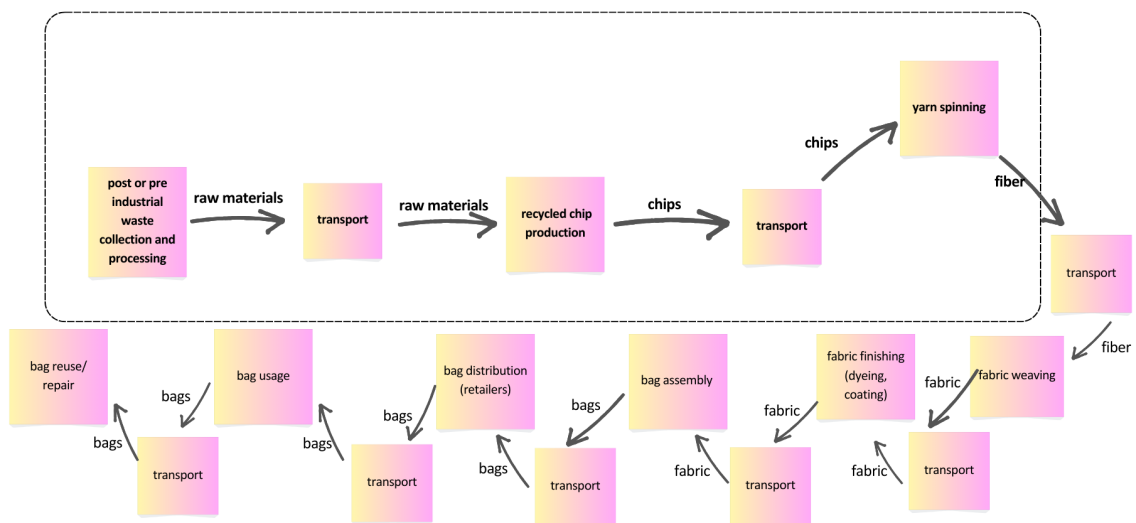


Figure 2. Flow chart of the fabric of Haze bag production

Assumptions

Due to the lack of supplier data and limited access to datasets, we have made several assumptions throughout the analysis to simplify the calculations. These assumptions are discussed later in the discussion section, detailing their reasonableness.

1. To simplify the calculations, the analysis selected five parts of the package (body fabric, lining, straps, zipper tape and label) to represent one bag based on the weight of each part (assuming that the higher the weight, the greater the environmental impact).
2. Due to missing supplier data, this analysis used industry average data instead of actual material density ⁴.
3. Due to missing supplier data, the OpenLCA calculation uses data from Ecoinvent's EF3.1 database and Sphera's EF3.1pt2 database (based on the GaBi database). Both systems' calculation uses data from Ecoinvent and Sphera to calculate the environmental impact of the entire process from raw materials production (or recycling process) to chip production to yarn production. Because of the limited access of database, the transport of nylon and polyester from chip to yarn is ignored in the Virgin bag production system; and the transport of polyester and polypropylene from chip to yarn is ignored in the Haze bag production system.
4. Due to missing supplier data, the analysis uses industry averages instead of actual production loss rates for each material from chip (granulate) to yarn (fiber) and from yarn (fiber) to fabric production ⁵.
5. Due to the limited number of databases that are freely available, no data could be found for yarn production for polypropylene, so process data for polyester thread is used instead.

Data Quality and Relevance

The data quality and relevance of this analysis are ensured through adherence to temporal, geographical, and technological considerations, alongside comprehensive, consistent, and transparent integration of diverse data sources, all aligned with the EU Environmental Footprint (EF) 3.1 standards for robust and regulation-compliant assessments.

1. Temporal Relevance: The datasets from Ecoinvent and Sphera are valid until 12/31/2024, ensuring alignment with current production practices and reflecting recent developments in material production.
2. Geographical Relevance: The selected datasets represent global averages, chosen due to the lack of region-specific supplier data. While this provides a generalized perspective, it offers a robust foundation for analyzing global supply chains while maintaining relevance to diverse production conditions. The geographical relevance of mushroom leather data is tied to their site-specific locations. The impact results for the mushroom leather LCA are provided by the supplier and are based on site-specific data. For mushroom leather, while the specific geographical range is not explicitly stated, it is likely tied to the location of its manufacturing facilities.
3. Technological Relevance: The datasets accurately represent standard industrial processes for material production, aligning with the assumed technologies for the materials analyzed.

This ensures the technological relevance of the results to contemporary and commonly used production methods.

4. **Completeness and Consistency:** Ecoinvent's inventory data comprehensively covers material production, including resource extraction, energy use, and emissions. By integrating material-specific data such as area, density, and thickness with Ecoinvent datasets, the calculations are consistent across life cycle stages, minimizing discrepancies and improving reliability.
5. **Transparency and Compliance:** This report ensures transparency by clearly documenting all data sources, including Ecoinvent, Sphera, Matweb, supplier-provided data, and manual measurements. These sources are referenced throughout the report to enable traceability and reproducibility. Additionally, this study adheres to the methodological requirements of the EU Environmental Footprint (EF) 3.1 standards, ensuring compliance with European regulations. The alignment with EU standards demonstrates a commitment to producing reliable, regulation-compliant, and scientifically rigorous assessments suitable for decision-making within the European context. However, the impact results of mushroom LCAs are not geographically representative of a global scale, leading to some inconsistencies with the rest of the data. As a result, their impacts cannot be directly integrated into the overall impact calculations for the bags. To ensure transparency, the impacts of mushroom materials are presented separately from those of other fabrics, with their results and interpretations analyzed individually.

Impact Assessment Method:

The data source of the analysis is Ecoinvent and Sphera, using the EF3_1 Plastics, EF3_1 Others, EF3_1PT2_Official dataset with a global (GLO) scope, and analyzed under the Product Environmental Footprint (PEF) method. PEF covers 16 environmental impact categories but emphasizes focusing on the most relevant ones for practical implementation. This report incorporates both primary data, such as supplier-specific material area and thickness measurements, and secondary data, including global averages from the EF3 database. For the textile industry, the Apparel and Footwear PEF Category Rules (PEFCR) highlight several key categories that align with the environmental hotspots associated with textile production processes ⁶. Based on this guidance and resource considerations, the following impact categories have been selected for this analysis:

1. **Climate Change (GHG Emissions):** Textile production, particularly fiber manufacturing, dyeing, and finishing, is energy-intensive and a major source of greenhouse gas emissions. Recognized as a priority across industries, climate change is emphasized in the PEFCR as a key environmental hotspot for textiles.

2. Water Use (Water Scarcity): Processes like dyeing, finishing, and natural fiber cultivation in textiles consume significant water, often in water-scarce regions. The PEFCR highlights water use as critically important due to its strain on freshwater resources.
3. Resource Use, Fossils (Energy and Fuel Depletion): Synthetic fiber production, fabric processing, and transportation heavily rely on fossil fuels, depleting resources and causing energy-related impacts. The PEFCR identifies fossil fuel depletion as a vital focus for textile impact assessments.

Life Cycle Inventory

The fabric usage (from the BOM list) combined with the assumed density values is used to calculate the material weight for each component.

bag part	length	width	thickness	density	weight(kg)	material
body fabric (the HAZE)	0,316 yd	58"	0.2mm	1,14g/cc	0,097	recycled nylon 6
body fabric (the virgin)	0,316 yd	58"	0.2mm	1,15g/cc	0,098	primary nylon 6
lining (the HAZE)	0,446yd	58"	0.2mm	1,36g/cc	0,163	recyled polyester
lining (the virgin)	0,446yd	58"	0.2mm	1,36g/cc	0,163	primary polyester
straps (the HAZE)	1,505m	38mm	1mm	0,950g/cc	0,05433	recycled polypropylene
straps (the virgin)	1,505m	38mm	1mm	0,905g/cc	0,05174	primary polypropylene
zipper tape 1 (the HAZE)	0,423m	3mm	1mm	1,36g/cc	0,00173	recycled polyester
zipper tape 1 (the virgin)	0,423m	3mm	1mm	1,36g/cc	0,00173	primary polyester
zipper tape 2 (the HAZE)	0,330m	5mm	1mm	1,36g/cc	0,00224	recycled polyester
zipper tape 2 (the virgin)	0,330m	5mm	1mm	1,36g/cc	0,00224	primary polyester
label (the HAZE)	3,5cm*3,5cm					mushroom
label (the virgin)	3,5cm*3,5cm					primary leather

Table 1. The fabric use amount for producing 1 bag.

(The impact of the mushroom leather is calculated using area-based data, consistent with both the ecoinvent dataset and the supplier-provided LCA data. This approach is appropriate because the process data normalizes the impact per unit area, aligning with the functional use of leather. For materials like leather, area is often more relevant than weight in most applications, making this methodology both practical and accurate.)

fabric use	amount (kg) (cm2)	fabric use	amount (kg) (cm2)
primary nylon 6	0,098	recycled nylon 6	0,097
primary polyester	0,16697	recyled polyester	0,16697
primary polypropylene	0,05174	recycled polypropylene	0,05433
primary leather	3.5*3.5cm	Mushroom leather	3.5*3.5cm

Table 2. The weight of each material used for 1 bag.

Assumptions of efficiency of granulates and fabric production

process efficiency	efficiency from granulate to fiber	efficiency from fiber to fabric
primary nylon 6	95%	93%
primary polyester	98%	93%
primary polypropylene	95%	
recycled nylon 6	90%	
recyled polyester	90%	93%
recycled polypropylene	90%	93%

Table 3. The loss/ efficiency rate of each material's process from granulate to fiber and from fiber to fabric.

Input:

Fiber (or thread) input	Amount (kg)	Granulates input	Amount(kg)
Primary nylon 6 fiber	0,105376344	primary nylon 6 granulate	0,1109
Primary polyester thread	0,179537634	primary polyester granulate	0,1832
Primary polypropylene fiber	0,054463158	primary polypropylene granulate	
Recycled nylon 6 fiber	0,107777778	recycled nylon 6 granulate	
Recyled polyester fiber	0,179537634	recyled polyester granulate	0,1995
Recycled polypropylene fiber	0,058419355	recycled polypropylene granulate	0,0649

Table 4. The granulate and fiber amount used for producing 1 bag.

Results

Impact results

Name	Impact assessment result (the Virgin bag)	Impact assessment result (the HAZE)	Unit
Acidification	0,02179	0,01344	mol H+ eq
Climate change	3,64471	1,62486	kg CO2 eq
Climate change-Biogenic	0,01278	0,01606	kg CO2 eq
Climate change-Fossil	3,62815	1,60605	kg CO2 eq
Climate change-Land use and land use change	0,00377	0,00275	kg CO2 eq
Ecotoxicity, freshwater	1,15272	0,83354	CTUe
Eutrophication marine	0,00533	0,00317	kg N eq
Eutrophication, freshwater	7,65469E-05	7,27696E-05	kg P eq
Eutrophication, terrestrial	0,05395	0,03412	mol N eq
Human toxicity, cancer	6,65147E-08	5,64953E-08	CTUh
Human toxicity, non-cancer	1,10547E-07	6,52625E-08	CTUh
Ionising radiation, human health	0,07049	0,02668	kBq U-235 eq
Land use	6,65236	4,97461	Pt
Ozone depletion	4,90456E-09	3,80816E-09	kg CFC11 eq
Particulate Matter	4,13812E-07	2,83932E-07	disease inc.
Photochemical ozone formation - human health	0,01634	0,01076	kg NMVOC eq
Resource use, fossils	72,09852	28,89429	MJ
Resource use, minerals and metals	1,42104E-05	1,25472E-05	kg Sb eq
Water use	0,11315	0,00000	m3 depriv.

Table 5. The impacts results of producing 1 Haze bag and 1 virgin bag.

Note: The water use impact for the Haze bag is reported as 0 m³ depriv. due to two main reasons:

- 1. Exclusion of water-intensive processes: Water-intensive stages, such as fabric production and assembly, fall outside the defined system boundaries of this analysis.*
- 2. Definition of the “m³ depriv.” indicator: This metric does not measure the actual volume of water used but rather the potential for water scarcity. It represents the equivalent amount of water that would affect availability in areas with varying water scarcity. For example, the same volume of water used in a water-scarce region would result in a higher m³ depriv.*

value compared to usage in a water-abundant region. However, both systems use global geographical data, making the results comparable.

Since the actual water usage within the defined system boundaries is minimal, the result is 0 m³ depriv., indicating that the water consumption in these processes has no significant impact on water availability for people or ecosystems.

The 3 impact categories are selected to compare (for fabrics): Climate change; Resource use, fossils; and water use.

Name	Impact assessment result (1 HAZE bag)	Impact assessment result (1 Virgin bag)	reduced	reduced percentage
Climate change (kg CO2 eq)	1,62486	3,64471	2,02	55,42%
Resource use, fossils (MJ)	28,89429	72,09852	43,20	59,92%
Water use (m3 depriv.)	0,00000	0,11315	0,11	100,00%

Table 6. The environmental impacts avoided by 1 Haze bag.

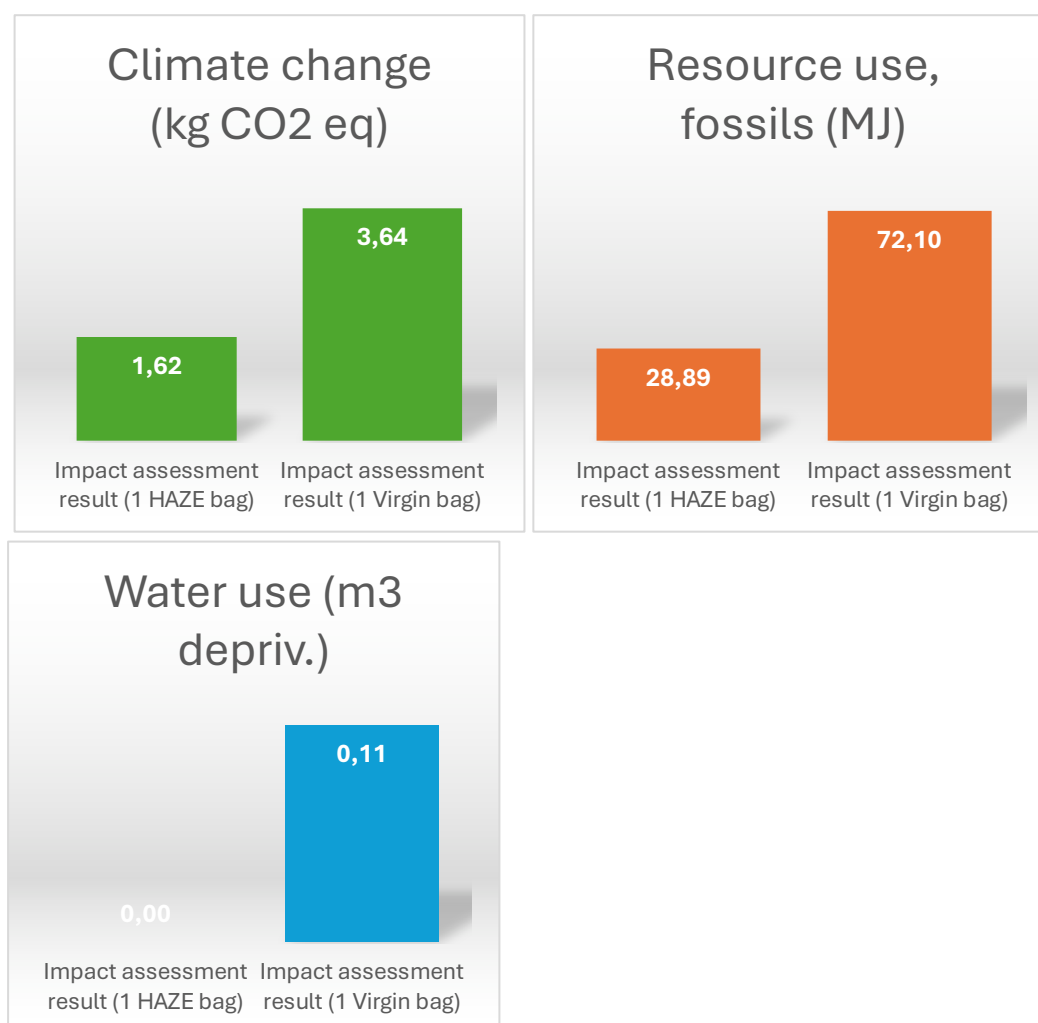


Figure 3. Chart of impacts of 2 bags in 3 categories

Impact results of the label (primary leather/ mushroom leather):

Name	Impact assessment result (1 Haze bag)	Impact assessment result (1 Virgin bag)	reduced	reduced percentage
Climate change (kg CO2 eq)	0,00415275	0,1430908136	0,14	97,10%
Resource use, fossils (MJ)	0,07901250	10,0062851956	9,93	99,21%
Water use (m3 world eq.)	0,00211925	0,2386654907	0,24	99,11%
average reduced percentage				98,47%

Table 7. The environmental impacts avoided by the mushroom leather label.

Discussions

Reasonable explanations of assumptions

To simplify the calculation and focus on the most impactful components of the bag, four parts (body fabric, lining, straps, and zipper tape) were selected to represent the entire bag. This approach assumes that the weight of each part correlates with its environmental impact, as heavier components typically require more material and energy during production. Although lighter components were excluded, the selected parts likely account for the majority of the environmental footprint, ensuring that the analysis remains representative while streamlining the process.

Industry averages were used for material density due to missing supplier data. Material density is a critical factor in weight calculations, which form the basis for assessing environmental impacts. By relying on established averages from reliable sources, the analysis ensures transparency and consistency. While specific supplier data would enhance precision, the use of widely recognized industry averages provides a reasonable and robust foundation for the calculations.

Transport from granulate to fiber was excluded for nylon, polyester, and polypropylene due to limitations in the available databases. Transport impacts, while relevant, are generally smaller compared to the production processes such as raw material extraction and fiber production. The omission simplifies the model without significantly affecting the conclusions, especially since transport modes and distances are assumed to be similar across scenarios. This exclusion is

consistent with standard LCA practices when data is unavailable, provided that it is clearly documented and its potential impact on results is acknowledged.

The analysis also relied on industry average loss rates for material transitions, such as granulate-to-fiber and fiber-to-fabric production, in the absence of supplier-specific data. These averages reflect common practices and typical efficiency levels in textile manufacturing. While actual supplier data might vary slightly, industry averages provide a standardized and reliable baseline, ensuring that the calculations remain robust and comparable across materials and scenarios.

Lastly, polyester thread process data was used as a proxy for polypropylene fiber production due to the lack of specific data. Since polyester and polypropylene share similar production processes⁷, such as melt spinning⁸, this substitution is reasonable and aligns with established LCA practices. The spinning and thread production processes for polyester (PET)⁹ and polypropylene (PP) are highly similar, both involving melt spinning, where the polymer is melted, extruded, drawn, and twisted into threads. While PP requires slightly less energy due to a lower melting temperature (~160–170°C vs. ~260°C for PET) and has a lower material density (~0.91 g/cm³ vs. ~1.38 g/cm³)^{10 11}, polyester thread data can reasonably serve as a proxy for PP, with adjustments for these material differences. Although minor differences in energy use and emissions may exist, they are unlikely to significantly alter the overall analysis. The use of proxy data is a common approach in LCA when direct data is unavailable, and the assumption is transparently documented to maintain the credibility of the study.

These assumptions, while necessitated by data limitations, adhere to recognized LCA methodologies and ensure that the analysis remains robust, transparent, and aligned with best practices. Sensitivity analyses or further data refinement can be conducted in the future to validate the robustness of the results and address any potential uncertainties.

Uncertainty and Sensitivity:

This analysis acknowledges several sources of uncertainty, primarily stemming from the reliance on secondary data (Ecoinvent and Sphera) and the use of industry averages for parameters such as material density and production loss rates. The exclusion of transport processes from granulate to fiber and the use of polyester thread data as a proxy for polypropylene fiber introduce additional uncertainties. These factors, while necessary for simplifying the analysis, may influence the accuracy of the results.

Sensitivity to key assumptions, such as material loss rates and density values, could impact the environmental impact estimates. For example, small variations in loss rates during fiber production could alter the relative impacts of virgin and recycled materials. Although formal sensitivity and uncertainty analyses were not conducted due to data limitations, these discussions highlight areas where future studies could refine the methodology and enhance reliability.

Overall, this analysis provides a robust framework for understanding the environmental impacts of bag production, while emphasizing the need for improved data availability and refinement of assumptions in future assessments.

Conclusions

First, in the category of resource use-fossil, the virgin bag system accounts for 72,10 MJ, while the Haze bag system uses 28,89 MJ, representing a reduction of 43,20 MJ (59,92%). For climate change, the virgin bag system has an impact of 3,64 kg CO₂ eq, compared to 1,62 kg CO₂ eq for the Haze bag system, resulting in a reduction of 2,02 kg CO₂ eq (55,42%). In the category of water use, the virgin bag system contributes 0.11 m³ depriv., whereas the Haze bag system contributes 0 m³ depriv., achieving a 99.99% reduction.

Therefore, within the defined system boundaries, the environmental impact of the Haze bag is significantly lower than that of the virgin bag. Also, processes beyond fiber production, such as fabric weaving, fabric finishing (dyeing, coating), bag assembly, are assumed to have comparable impacts for both systems, as there are no significant differences due to the materials. This supports the conclusion that the environmental impacts of the Haze bag in a full life cycle assessment would remain lower than those of the virgin bag.

Second, mushroom leather stands out as an environmentally friendly material, with an impressive average reduction of 98.47% across three key impact categories: climate change, resource use-fossil, and water use. While the leather label represents only a small portion of the entire bag, and therefore does not significantly influence the bag's overall impact results, it highlights the immense potential of biomass materials. This

inspires further exploration into using mushroom leather more extensively, perhaps even creating fully mushroom leather bags in the future, as a step toward achieving carbon neutrality.

Third, several relatable comparisons can be made to better illustrate the environmental impact reductions achieved by the recycled fabric. For climate change, the reduction of 2020 g CO₂ eq. is equivalent to cleaning the air in 1226 scuba tanks¹². In terms of fossil resource use, the reduction of 43,20 MJ is comparable to the energy consumed during 3000¹³ hours of smartphone use. Regarding water use, the reduction of 0,11 m³ equals approximately 20 flushes of a low-flush toilet¹⁴. If the reductions from producing one Blaze bag are scaled up to 1000 Blaze bags, the total reductions would equate to 392000 scuba tanks of air cleaned, 1057000 hours of smartphone usage offset, and water savings equivalent to 550 bathtub showers¹⁵.

**Three metrics to
express how much
environmental
impacts avoided by
1000 Haze bags:**



1226000 Scuba
tanks of air
cleaned



3000000 hours
of smartphone
use offset



550 times of
bathtub showers

The eco-facts of 1000 Haze bags.

In conclusion, the environmental impacts of the Haze bag are significantly lower than those of the virgin bag, demonstrating its potential to contribute meaningfully to carbon reduction and overall sustainability goals.

References

1. [Statista](#)
2. [AM Custom Clothing](#)
3. Fishwick Environmental, *“Life Cycle Assessment (LCA) of HyphaLite, summary for external parties, August 2023”*
4. [Matweb.com](#)
5. [Textileexchange.org](#)
6. Eunomia, *“Apparel and Footwear PEF Category Rules (PEFCR), The Role of PEF in Policy, October 2022”*
7. [Textile Learner](#)
8. [Online Textile Academy](#)
9. [Textile Triangle - Melt Spinning](#)
10. [SpringerLink](#)
11. [Textile Learner - Polypropylene](#)
12. BLOOM, *“1kg Bloom MB Eco Facts Guide”*
13. [How much power does it take to charge a phone](#)
14. [Council of Churches in Warwickshire](#)
15. [Bathroom Blueprint](#)