LIFE CYCLE ASSESSMENT (LCA)

FOR UNSPUN’S 3D WOVEN PANTS (PHASE 2)

unspun

GreenStory

DECEMBER 2023

TITLE	LIFE CYCLE ASSESSMENT (LCA) OF UNSPUN'S 3D WOVEN PANTS (PHASE 2)
REPORT VERSION	1.0
REPORT DATE	DECEMBER 2023
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

HIGHLIGHTS

Unspun aims to revolutionize fashion and textile by adopting innovative techniques for woven pant production in their supply chain. They intend to do this by using the 3D weaving technique as a sustainable alternative for air-jet/synthetic weaving technique used for producing woven pants. Additionally, they also aim to develop a cleaner supply chain by producing pants on-demand and thus surpassing a huge problem of inventory waste. Unspun has commissioned Green Story (GS) to conduct Life Cycle Assessment (LCA).

This study quantifies and compares the environmental impacts of a pair of Unspun's 3D woven pants that are made on-demand (and therefore have a 100% sell-through rate), versus the similar pants (baseline product) made using air jet/ synthetic weaving technique in a large order quantity product run that has a 70% sell-through rate (30% of unsold finished-goods inventory across the fashion industry). Scenarios were built using two more sell through rates: 60%, and 80%, to investigate the varied effects these scenarios have on the global warming potential (GWP) impacts of 3D woven pants. Scenario analysis results are graphically represented in Figure 1.

This study marks the second phase of the project, incorporating two key modifications compared to Phase 1.

(1) Inventory data from GS confidential industry sources/literature used to model melt spinning, ring spinning air jet weaving, and synthetic weaving processes are replaced with more recent/updated versions in this phase.

(2) Finishing and cut-and sew of the air-jet/synthetically woven fabric encompassing electricity, steam, and fabric loss is modelled in this phase unlike phase 1 where only attachment of accessories was modelled in case of baseline product.

This LCA study is an ISO 14040/14044 cradle to gate analysis of Unspun's 3D woven pants made from two different fibers: (1) conventional cotton and (2) virgin polyester. The Functional Unit (FU) of this study is 'production of 1 pair of Unspun's 3D woven pants produced on demand'. The scope of this study includes cultivation (for conventional cotton pants), fiber/ granulate (for polyester pants) production, yarn production, yarn dyeing, fabric production (3D weaving), and finishing (attachment of accessories). Transport between the life cycle stages is also considered.

Life cycle impact assessment (LCIA) was carried out using characterization factors programmed into GaBi® (Life Cycle Assessment: GaBi Software, 2023). Three impact categories were quantified: Global Warming Potential (GWP), Primary Energy Demand (PED) and Blue Water Consumption (BWC). The PEFCR Guidance (EC, 2018) was used as a reference to perform the hotspot analysis.

The following conclusions are drawn from this study:

- Unspun's 3D woven conventional cotton & polyester pants produced on-demand (100% sell-through rate) show approximately 53% and 42% GWP impact savings compared to similar pants made using air-jet/synthetic weaving technique with 70% sell-through rate.
- The main reason why 3D woven pants exhibit savings in all three impact categories is that they are created on demand, which prevents the production of deadstock inventory and, consequently, avoids excessive input consumption (energy, raw material, etc.).
- Note that GWP reductions realised by 3D woven pants in phase 2 over phase 1 of the project have increased by 29% and 23% for conventional cotton and virgin polyester pants, respectively. This demonstrates the benefits of on-demand production quite clearly.
- Additionally, in case of 3D weaving, the fabric waste generated at cut & sew is considerably eliminated as the pants are directly woven from yarn, with a very high process efficiency (almost 99%). In contrast, 14% of the fabric is lost during the cutand- sew process for pants made using air jet/synthetic weaving.
- Furthermore, air-jet weaving used in case of baseline conventional cotton pants has a 2.5% fabric loss, which is less efficient than 3D weaving, which generates only 1% fabric waste. The amount of fabric waste (1%), produced by 3D weaving and synthetic weaving, is almost similar in the case of Unspun and baselined polyester pants.
- This again clearly demonstrates that main source of savings for 3D woven pants is on demand production, with some amount of savings also resulting from considerable elimination of cut-and-sew step.
- Scenario analysis results clearly indicate GWP impacts are found to be inversely correlated with 3D woven pants sell-through rates, meaning that as sell-through rates decrease, the environmental impacts increase.

1. INTRODUCTION

The production of any product has beneficial and adverse effects on the environment and subsequent generations (Chen et al., 2021). The comprehensive examination of these implications is referred to as the product's Life Cycle Assessment (LCA). LCA is compilation and evaluation of the inputs, outputs, and the potential environmental impacts of a product system throughout its life cycle. The systematic life cycle approach aids stakeholders to compare products/processes and identify hotspots in a manufacturing process. According to ISO standards 14040 and 14044, LCA consists of four phases: goal and scope definition, life cycle inventory (LCI) analysis, life cycle impact assessment (LCIA), and interpretation.

2. GOAL OF THE STUDY

The goals of this study are:

- To quantify and compare the environmental impacts of a pair of Unspun's 3D conventional cotton & virgin polyester woven pants that are made on-demand (and therefore have a 100% sell-through rate), versus the similar pants made using air jet/synthetic weaving technique in a large order quantity product run that has a 70%* sell-through rate, accounting for a 30% inventory waste. (* - Sell-through rate measures the amount of inventory that is sold within a given period relative to the amount of inventory received within the same period (CFI). After a comprehensive literature survey, it was found that most of the global fashion brands have an average sell-through rate of 70% and was therefore used for this analysis).
- To build scenarios with two additional sell-through rates: 60%, and 80%, to investigate the varied effects these scenarios have on the global warming potential (GWP) impacts of 3D woven pants.

3. SCOPE OF THE STUDY

The product system to be analyzed is Unspun's finished 3D woven pants produced ondemand (therefore with 100% sell-through rate). Two types of 3D woven pants are produced using two different fibers: (1) 100% virgin polyester hereinafter referred to as polyester (SC1); (2) 100% conventional cotton hereinafter referred to as cotton (SC2). The scope of the study is 'cradle to gate', starting from the cotton cultivation/polyester granulate production to finishing (attachment of accessories).

3.1 System Boundary

The system boundary of the present study is from 'cradle to gate'. Figure 1 illustrates the production process flow of Unspun's 3D woven pants.

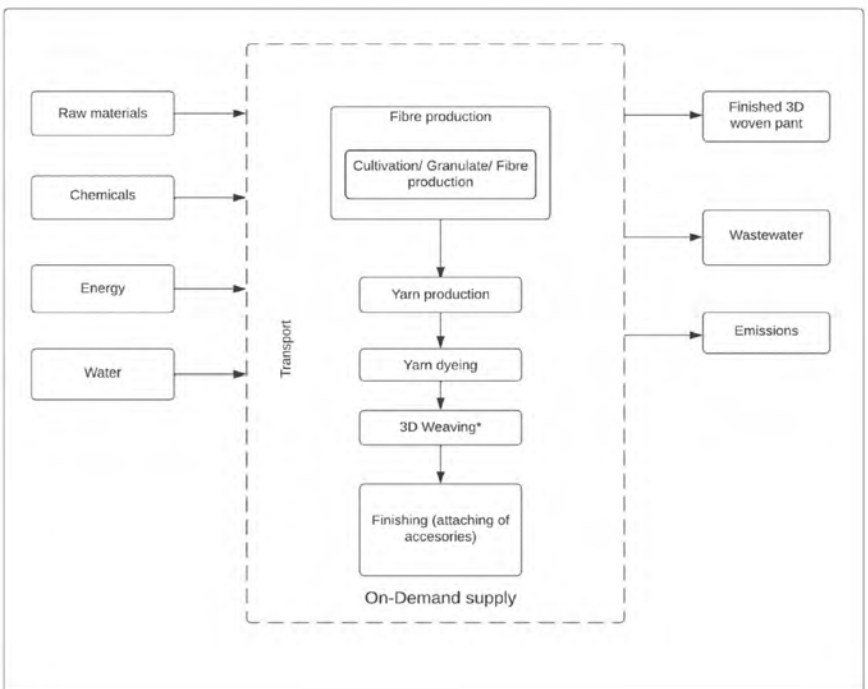

FIGURE 1: SYSTEM BOUNDARY – LIFE CYCLE OF UNSPUN'S 3D WOVEN PANTS

(Note: Manufacturing starts with cultivation in case of cotton pants. While for polyester pants, manufacturing starts with granulate/fiber production. For baselined cotton pants, 3D weaving step is replaced with air-jet weaving and softener finishing, cut-and-sew processes are added. In case of baselined polyester pants 3D weaving is replaced with synthetic weaving and antistatic finishing, cut-and-sew processes are added. Transportation to warehouse is considered only for both the baselined products)

3.2 Product system description

The process starts with cultivation for cotton pants and with fiber production for polyester pants, followed by yarn production, yarn dyeing, fabric production and finishing (attachment of accessories). More details on the 3D weaving can be found in the Phase 1 report. The production of accessories such as brass zipper and button, rivets, sewing threads, lining fabric, woven fusible interfacing, their packaging, and their affixation to the pants are all included in the finishing process.

3.3 Functional Unit

The Functional Unit (FU) of this study is production of 'one pair of Unspun's 3D woven pants on demand' made from two different fibers and produced in two different supply chains mentioned in this study. The corresponding reference flow is one pair of 3D woven pants that weights 0.8 kg (refer Table 7).

3.4 Baseline Methodology

To evaluate the impacts or savings of Unspun's 3D woven cotton/polyester pants, baseline products was modelled. For baselining, 70% sell through was considered, 3D weaving was replaced with air-jet/synthetic weaving. For both Unspun and the baseline products, all processes up to yarn dyeing including packaging of dyed yarn, and accessories production & attachment mirrored those outlined for the Unspun's 3D woven pants. In case of baseline cotton pants, the 3D weaving process was replaced with air-jet weaving, and additional softener finishing and cut-and sew steps were considered. In case of baseline polyester pants, the 3D weaving process was replaced with synthetic weaving, and additional antistatic finishing and cut-and sew steps were considered.

3D weaving and finishing (attaching of accessories) steps were modelled using primary foreground data. Air-jet/ synthetic weaving processes, and finishing (softener and antistatic finishing) steps were modelled using secondary data. More details about the exact datasets and sources can be found in Section 4.2. It should be noted that the baselined results could be influenced by the quality of the secondary data used in the LCA study. Data quality refers to the technological/ geographical/time representativeness, reliability & completeness of the data used.

3.5 Software and Database

The LCA models are created using the GaBi 10.6.1 software system for life cycle engineering, developed by Sphera (Life Cycle Assessment: GaBi Software, 2023). The 6 ecoinvent 3.8 and Sphera databases provide the life cycle inventory data for many downstream processes and all upstream processes.

4. LIFE CYCLE INVENTORY

The Life Cycle Inventory (LCI) provides a detailed account of all the flows entering and leaving the studied product system. It consists of all the inputs (raw materials, energy, water, chemicals, etc.) required as per the FU and the outputs (final product (3D woven pant), cutting waste, wastewater, and emissions) leaving the system. First, we distinguished between primary foreground data (collected from Unspun) and secondary foreground data (mainly from publicly available data sources, scientific literature, GS confidential industry sources). All upstream (background) processes were modelled using data taken from ecoinvent and Sphera (refer Annexure 8.3).

4.1 What's new in Phase 2?

- 1. The ring spinning process in case of baseline cotton pants in phase 1 was modelled based on inventory data taken from GS confidential industrial sources. In this phase, is replaced with a complete and reliable ecoinvent 3.8 dataset.
- 2. The melt spinning process in case of baseline polyester pants in phase 1 was modelled based on inventory data taken from Van der Veldon (2014). In this phase, is replaced with a more recent data taken from Sandin, G. (2019).
- 3. The air-jet and synthetic weaving processes in case of baseline cotton and polyester pants respectively, in phase 1 was modelled based on inventory data taken from GS confidential industrial sources. In this phase, is replaced with complete and more reliable ecoinvent 3.8 datasets.
- 4. In phase 1, softener finishing in case of baseline cotton, antistatic finishing in case of polyester pants, and cut-and-sew for both baselined pants, were not considered. In Phase 2 (1) inventory data from Beton et al. 2014 for electricity, steam and fabric loss was used to model the cut-and-sew process, and (2) Ecoinvent/Sphera datasets were used to model the softener and antistatic finishing p rocesses respectively.

4.2 Data Collection Procedure

TABLE 1: DESCRIPTION OF PRIMARY FOREGROUND, SECONDARY FOREGROUND AND BACKGROUND DATA USED IN THE STUDY

Sr. No.	Type Of Data	Source
Primary Foreground Data	Product details like product type and product weight. Accessory details like type, weight of accessory, material used for making the accessory. Packaging information for yarn like, weight and type of packaging used and packaging waste treatment methods. Supplier locations (for 3D weaving process) for calculating transport distance.	Data collected from Unspun
Secondary Foreground Data	Energy, steam requirements and fabric loss during cut and sew of the baseline products.	Beton et al 2014
	Cotton cultivation and fiber production processes.	ICAC
	Fiber production (virgin polyester granulates), ring spinning, yarn dyeing, air-jet/synthetic weaving, softener finishing.	ecoinvent 3.8 and GS confidential sources
	Melt spinning	Sandin, G. (2019)
	Antistatic finishing	Sphera
Background data	Gabi 10.6.1 and ecoinvent 3.8 databases were used to model all the upstream processes like fuel production, electricity generation, chemical production, extraction, and production of raw materials and transportation.	ecoinvent 3.8

NOTE: FOR DETAILED DATASET NAMES REFER ANNEXURE 8.3

TABLE 2: KEY DATASETS USED AND THEIR SOURCES

Supply Chain	Process Name	Dataset Used	Source
SC1- Virgin polyester	Fiber production	RER: polyethylene terephthalate production, granulate, amorphous	ecoinvent 3.8
	Yarn Production	Polyester yarn	Sandin et al 2019
	Yarn Dyeing	RoW: bleaching and dyeing, yarn	ecoinvent 3.8
	Packaging	Packaging	Unspun
	EoL (for packaging)	Packaging end-of-life	Unspun
	Weaving	3D weaving	Unspun
	Finishing (accessories)	US: Fabric Finishing	Unspun
SC2- Conventional Cotton	Cultivation & Fiber production	US: Conventional Cotton (ICAC)	ICAC
	Yarn Production	RoW: Cotton ring spinning	ecoinvent 3.8
	Yarn Dyeing	GLO: Yarn dyeing light shade	GS confidential
	Packaging	Packaging	Unspun
	EoL (for packaging)	Packaging end-of-life	Unspun
	Weaving	3D weaving	Unspun
	Finishing (accessories)	US: Fabric Finishing	Unspun

4.3 Assumptions and data quality

Based on the data provided by Unspun, we have made certain general assumptions while modelling, and are transparently documented in this section.

- 1. After a comprehensive literature survey, it was found that most of the global fashion brands have an average sell-through rate of 70% and was therefore assumed for this analysis.
- 2. For baselining, a 70% sell-through rate was considered, meaning the remaining 30% of inventory is assumed to be wasted. This waste was assumed to be sent to incineration (15%) or landfilling (85%) with energy recovery. System expansion was 10 applied, which means credits are given for the electricity production are avoided. For the avoided electricity production, "US: market group for electricity, low voltage ecoinvent 3.8" was used.
- 3. Locations for cultivation, fiber production, yarn production and yarn dyeing were not provided by Unspun. The location of 3D weaving and finishing unit was provided as US, hence it was assumed that the other manufacturing processes like cotton cultivation, polyester fiber production, yarn production, yarn dyeing, also take place in US for both SCs 1 and 2. Transportation between these life cycle stages was assumed to be 30 km by truck. All upstream were modelled using US datasets.
- 4. Waste from the 3D weaving process was assumed to be mechanically recycled to produce cotton/polyethylene terephthalate (PET) fiber, based on the product type. System expansion was applied, which means credits are given for the cotton/PET fiber production that is avoided because of the recovered fibers, by looping back into the system.
- 5. The plastic material used for packaging of yarn is assumed as high-density polyethylene (HDPE). The spools used for yarn packaging are assumed to be made from virgin corrugated board. These assumptions are taken based on general industry practices used for packaging of yarn.
- 6. According to Unspun, packaging wastes was sent to 100% recycling, but end use of the recovered waste was not provided. So, an avoided burden approach also known as end-of-life or 0:100 method was used to model the end of life of both the packaging materials. So recycled waste was assumed to be used in the manufacturing of a similar packages (closed loop recycling). The credits achieved from the recycling of both the packaging materials was considered in this study.
- 7. According to Unspun recycled kraft paper was used for packaging the finished 3D woven pants. In the absence of this specific dataset, closest alternative, recycled graphic paper dataset was used.
- 8. The electricity bills provided by Unspun are for both the 3D weaving and finishing units. Data validation was not carried out in this study, and the collected data was assumed to be accurate. Also split between electricity demands for 3D weaving and finishing could not be calculated, so all the electricity numbers provided were assumed to be for 3D weaving. So, going forward, Green Story recommends data validation for these processes.
- 9. Unspun informed that 100% renewable energy is used in their units, but due to lack of renewable energy certificates, US electricity grid mix was used.
- 10. The weight of the sewing thread is taken from GS confidential source.
- 11. There was no information provided on the material used for production of rivets, hence was assumed that rivets made from brass are used.

5. LIFE CYCLE IMPACT ASSESSMENT (LCIA) & INTERPRETATION

This section presents the baselined results and hotspots for Unspun's 3D woven pants produced on-demand (100% sell through rate) in SCs 1 and 2, as per the defined FU.

5.1 Baselined LCIA results

LCIA results for Unspun's 3D woven pants with 100% sell through rate versus baselined products with 70% sell through rate are presented in Table 3. Savings are observed in all the three categories for Unspun's 3D woven pants with 100% sell through rate. The reasons for the savings are listed below:

- The Unspun's 3D woven pant is manufactured on-demand, and therefore with 100% sell through rate and creates zero inventory deadstock. In contrast, the baseline products produced using air-jet/synthetic weaving technique are assumed to have only 70% sell through rate thereby incurring 30% deadstock in inventory. This heightened deadstock percentage contributes to an augmented production of pants, necessitating increased input quantities of raw materials, energy, water, etc., thereby amplifying the overall impacts from the entire manufacturing process.

- The air-jet/synthetically woven pants produced from conventional cotton and polyester SCs incur 16.5% and 15% loss respectively, from fabric production and cutand- sew stages. In particular, 14% fabric loss happens during cut-and-sew, 2.5% during air-jet weaving and 1% during synthetic weaving. In contrast, fabric loss in 3D weaving process is only 1%. The difference in loss percentage conveys that process efficiency of 3D weaving process is higher and therefore results in impact savings for 3D woven pants.

- Note that, in 3D weaving, the fabric waste generated at cut & sew is considerably eliminated as the pants are directly woven from yarn. Fabric loss at cut-and-sew, airjet/ synthetic weaving determines the amount of fiber needed in the cultivation stage and the process energy/materials needed in the yarn/3D weaving/finishing (apparel production) processes. So higher fabric waste means lower process efficiency, more fiber and process energy/materials are needed to produce the required output, resulting in higher environmental impacts across the life cycle of the pants.

TABLE 3: BASELINED LCIA RESULTS: PERCENTAGE SAVINGS FOR UNSPUN'S 3D WOVEN PANTS WITH 100% SELL THROUGH RATE AGAINST BASELINED PANTS WITH 70% SELL THROUGH RATE

Supply Chain details	Difference in GWP (kg CO2 eq.)	Difference in PED (MJ)	Difference in BWC (kg)
100% conventional virgin polyester woven pants (SC 1)	-42.18%	-36.89%	-31.32%
100% conventional cotton woven pants (SC 2)	-53.34%	-49.37%	-38.91%

NOTE: -VE INDICATES IMPACT SAVINGS

5.2 Scenario Analysis

In addition to the on demand (100% sell through) and 70% sell through (baselined products), two more scenarios were built to understand the influence of two additonal sell through rates: 60%, and 80%, on the GWP impacts of Unspun's 3D woven pants. Results are graphically represented in Figure 2.

FIGURE 2: SCENARIO ANALYSIS: GWP IMPACTS FOR DIFFERENT SELL-THROUGH RATES

GWP impacts are found to be inversely correlated with 3D woven pants' sell-through rates, meaning that as sell-through rates decrease, the impacts increase. This is because, a greater sell through causes more waste in terms of deadstock inventory which increases the demand for virgin yarn production and related fiber production, as a result has increased environmental impacts. Similar trends can be observed for PED and BWC impacts.

5.3 Hotspots based on top two contributing life cycle stages

The top two contributing (1) life cycle stages, (2) process within those life cycle stages and (3) elementary or inventory flows with those processes are identified as hotspots for the Unspun's 3D woven pant produced from polyester and cotton and presented in Table 4 and Table 5 respectively. As a comprehensive summary of all the by-stage impacts are already provided in 'Phase 1 report', only the hotspots are listed here.

100% polyester 3D woven pants production is broken into the following life cycle stages: Granulate production, melt extrusion, yarn production, yarn dyeing, 3D weaving, and finishing (attachment of accessories).

TABLE 4: HOTSPOTS (TOP 2 CONTRIBUTING PROCESSES AND INVENTORY FLOWS) FOR UNSPUN'S 3D WOVEN POLYESTER PANT, FOR ALL THREE IMPACT CATEGORIES: GWP, PED AND BWC.

	Hotspots		
SC number	**SC 2 Conventional Cotton**		
Impact Category	**GWP**	**PED**	**BWC**
Life cycle stage	**1. 3D weaving (30%)** **2. Cotton cultivation & fiber Production (28%)**		**1. Cotton cultivation & fiber Production (94%)**
Processes	**1.1 Terephthalic Acid production** **1.2 Ethylene glycol production** **2.1 Use of Electricity**		**1.1 Cotton lining fabric production (accessory)** **1.2 Cotton woven fusible interfacing production (accessory)** **2.1 Use of electricity**
Elementary flows	**2.1.1 Heavy reliance on natural gas (37%) and coal (22%) in the US grid mix results in significant impacts**		**1.1.1 & 1.2.1 Irrigation that is the water supplied to plants during cotton cultivation and water evaporated or infiltrated.**

TABLE 5: HOTSPOTS (TOP 2 CONTRIBUTING PROCESSES AND INVENTORY FLOWS) FOR UNSPUN'S 3D WOVEN COTTON PANT, FOR ALL THREE IMPACT CATEGORIES: GWP, PED AND BWC

	Hotspots		
SC number	**SC 2 Conventional Cotton**		
Impact Category	**GWP**	**PED**	**BWC**
Life cycle stage	**1. 3D weaving (30%)** **2. Cotton cultivation & fiber Production (28%)**		**1. Cotton cultivation & fiber Production (94%)**
Processes	**1.1 Use of Electricity** **2.1 Cotton cultivation**		**1.1 Cotton cultivation**
Elementary flows	**1.1.1 Heavy reliance on natural gas (37%) and coal (22%) in the US grid mix results in significant impacts** **2.1.1 Energy required for pumping of water used in irrigation**		**1.1.1 Irrigation, that is the water supplied to plants during cultivation and water evaporated or infiltrated**

6. KEY INSIGHTS

Key insights relevant to on-demand production of Unspun's 3D woven pants is presented here, as is the main focus of this phase of the project. Relevant findings from the hotspots identified within the production of 3D of cotton/polyester woven pants can be found in the 'Phase 1 report'.

- In the GWP category, Unspun's 3D woven pants produced on-demand has approximately 42% and 53% savings in SC1 (polyester) and SC2 (cotton) respectively, over baselined products with 70% sell through.
- In PED impact category, Unspun's 3D woven pants produced on demand demonstrate savings of about 37% and 50% in SCs1 and 2 respectively, and for the BWC impact category, savings are approximately 32% and 39% in SCs1 and 2 respectively.
- The main reason why 3D woven pants exhibit savings in all three impact categories is that they are created on demand, which prevents the production of deadstock inventory and, consequently, avoids excessive input consumption (energy, raw material, etc.).
- Note that GWP reductions realised by 3D woven pants in phase 2 over phase 1 of the project have increased by 29% and 23% for cotton and polyester pants, respectively. This demonstrates the benefits of on-demand production quite clearly.
- Additionally, in case of 3D weaving, the fabric waste generated at cut & sew is considerably eliminated as the pants are directly woven from yarn, with a very high process efficiency (almost 99%). In contrast, 14% of the fabric is lost during the cutand- sew process for pants made using air jet/synthetic weaving.
- Air-jet weaving used in case of baselined cotton pants, has a 2.5% fabric loss, which is less efficient than 3D weaving, which has 1% fabric loss. The amount of fabric waste (1%), produced by 3D weaving and synthetic weaving, is almost similar in the case of Unspun and baselined polyester pants.
- This again clearly demonstrates that main source of savings for 3D woven pants is on demand production, with some amount of savings also resulting from considerable elimination of cut-and-sew step.
- Note that savings that come from on demand production vs 70% sell through and 3D weaving vs air-jet/synthetic weaving is similar for both cotton and polyester 17 pants. Still GWP and BWC savings realised by 3D woven cotton pants is higher than polyester pants. This is because, the cotton fiber and yarn production impacts are per se higher than that of polyester and therefore, the savings realised are also higher for 3D woven cotton pants.
- Scenario analysis results clearly indicate GWP impacts are found to be inversely correlated with 3D woven pants sell-through rates, meaning that as sell-through rates decrease, the impacts increase.

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8. ANNEXURE

8.1 Selection of impact categories

The life cycle inventory data are analysed based on the following three impact categories (Table 6) chosen after discussion with Unspun.

TABLE 6: ENVIRONMENTAL IMPACT CATEGORIES ANALYZED IN THIS STUDY

Indicator	Description	Reference
Global warming potential (kg CO2 eq.)	Potential for climate change based on the radiative forcing of chemicals. The GWP is expressed in kg or tons CO2 equivalents in proportion to CO2. Converts LCI data to carbon dioxide (CO2) equivalents by adding the emissions of greenhouse gases (CO2, N2O, CH4, and VOCs) multiplied by their appropriate GWP factors.	IPCC 2013
Primary energy demand (MJ)	PED is expressed in MJ energy equivalents and indicates the entire amount of primary energy (renewable and nonrenewable) utilized during the life cycle of a product, including all direct and indirect energy usage.	Sphera, 2022
Blue water consumption (Liters)	Blue water is defined as water sourced from surface or groundwater resources. Irrigated agriculture, industry and domestic water use can each have a blue water footprint. Only blue water consumption is used and not blue water use, as it measures the water removed from its source that cannot be replaced, leading to water scarcity.	Sphera, 2022

8.2 Products included in scope of the study

TABLE 7: AVERAGE WEIGHT OF THE PANTS PRODUCED AT UNSPUN MANUFACTURING UNIT

Product Name	Average weight (kgs)
Virgin polyester pant	0.8
Conventional cotton pant	

8.3 Datasets, Literature used for modelling Unspun’s 3D woven pant

TABLE 8: DATASETS USED FOR UNSPUN’S VIRGIN POLYESTER PANT PRODUCTION PROCESSES

POLYESTER GRANULATE PRODUCTION			
RER- VIRGIN PET PRODUCTION- MODELLED FROM THE ECOINVENT DATASET "RER: POLYETHYLENE TEREPHTHALATE PRODUCTION, GRANULATE, AMORPHOUS ECOINVENT 3.8 <U-SO>.			
Inputs	Dataset/Flows used in Gabi	Data sources	Assumptions made
Ethylene glycol	GLO: market for ethylene glycol	ecoinvent 3.8	
Purified terephthalic acid	GLO: market for purified terephthalic acid	ecoinvent 3.8	
Electricity, medium voltage	US: market for electricity, medium voltage	ecoinvent 3.8	
Heat, district or industrial, natural gas	GLO: market group for heat, district or industrial, natural gas	ecoinvent 3.8	
Heat, district or industrial, other than natural gas	GLO: market group for heat, district or industrial, natural gas	ecoinvent 3.8	
Nitrogen, liquid	DE: Nitrogen (liquid)	Sphera	
Steam, in chemical industry	RER: market for steam, in chemical industry	ecoinvent 3.8	
Waste plastic, mixture	RoW: market for waste plastic, mixture	ecoinvent 3.8	
Municipal solid waste	RER: market for municipal solid waste	ecoinvent 3.8	
Output			
Polyethylene terephthalate, granulate, amorphous	To yarn production		

YARN PRODUCTION, MELT SPINNING (SYNTHETIC FIBERS)			
YARN PRODUCTION FOR SYNTHETIC FIBERS IS MODELLED FROM SANDIN G, 2019 DATA			
Inputs	**Dataset/Flows used in Gabi**	**Data sources**	**Assumptions made**
Polyethylene terephthalate, granulate	From polyester granulate production		
Lubricating oil	RoW: market for lubricating oil		
Antimony	GLO: market for antimony	ecoinvent 3.8	
Electricity	US: market group for electricity, low voltage	ecoinvent 3.8	Country specific dataset to be selected
Toluene diisocyanate	RoW: market for toluene diisocyanate		
Heat	RoW: market for heat, district or industrial, other than natural gas		
Output			
Polyester yarn	To yarn production		
Waste yarn	GLO: market for waste yarn and waste textile		

YARN DYEING			
YARN DYEING MODELLED FROM ECOINVENT DATASET "ROW: BLEACHING AND DYEING, YARN ECOINVENT 3.8, AGG"			
Inputs	**Dataset/Flows used in Gabi**	**Data sources**	**Assumptions made**
Yarn	From yarn production		
Output			
Dyed yarn	To 3D weaving		

3D WEAVING			
WEAVING IS MODELLED BASED ON PRIMARY DATA COLLECTED FROM UNSPUN			
Inputs	**Dataset/Flows used in Gabi**	**Data sources**	**Assumptions made**
Dyed yarn	From yarn dyeing		
Electricity	US: market group for electricity, medium voltage	ecoinvent 3.8	
Output			
Woven fabric	To finishing		
Waste yarn	Mechanical recycling of polyester waste fabric	GS confidential source	
Waste fabric			

FINISHING (ATTACHMENT OF ACCESSORIES)			
FINISHING IS MODELLED BASED ON PRIMARY DATA COLLECTED FROM UNSPUN			
Inputs	**Dataset/Flows used in Gabi**	**Data sources**	**Assumptions made**
Woven fabric	From 3D weaving		
Woven fusible interfacing and Lining fabric	US: Conventional Cotton (ICAC) - Far West	ICAC, 2019-20	
	Cotton Ring Spinning	GS confidential	
	Air jet weaving	GS confidential	
Brass zipper	RoW: market for brass GLO: market for casting, brass	ecoinvent 3.8	
Rivets			
Brass buttons			
Sewing threads	RER: polyethylene terephthalate production, granulate, amorphous,	ecoinvent 3.8	
	Yarn production (Synthetic)	Van der velden, 2014	
	RoW: bleaching and dyeing, yarn	ecoinvent 3.8	
Output			
Finished 3D woven pants			

NOTE: GLO- GLOBAL, US- UNITED STATES OF AMERICA, ROW- REST OF THE WORLD AND DE: GERMANY.

8.3 Datasets, Literature used for modelling Unspun's 3D woven pant

TABLE 9: DATASETS USED FOR UNSPUN'S CONVENTIONAL COTTON PANT PRODUCTION PROCESSES

CONVENTIONAL COTTON FIBER PRODUCTION			
CONVENTIONAL COTTON FIBER PRODUCTION- MODELLED BASED ON DATA FROM ICAC 2021			
Inputs	Dataset/Flows used in Gabi	Data sources	Assumptions made
Cotton Seed	GLO: market for cottonseed, for sowing	ecoinvent 3.8	
Electricity, medium voltage	US: market group for electricity, medium voltage	ecoinvent 3.8	Country specific dataset to be selected
Diesel, burned in agricultural machinery	GLO: diesel, burned in agricultural machinery	ecoinvent 3.8	
Manure, solid, cattle	GLO: manure, solid, cattle, Recycled Content cut-off	ecoinvent 3.8	
Urea, as N	US: market for inorganic nitrogen fertiliser, as N	ecoinvent 3.8	Country specific dataset to be selected
Irrigation	US: market for irrigation	ecoinvent 3.8	Country specific dataset to be selected
Inorganic phosphorus fertiliser, as P2O5	US: market for inorganic phosphorus fertiliser, as P2O5	ecoinvent 3.8	Country specific dataset to be selected
Insecticides, unspecified	RoW: pesticide production, unspecified	ecoinvent 3.8	
Potash magnesia (agriculture)	US: market for inorganic potassium fertiliser, as K2O	ecoinvent 3.8	Country specific dataset to be selected
Output			
IN: Cotton Fiber Bales	To yarn production	ICAC 2021	
IN: Cottons seed from Gin		ICAC 2021	

YARN PRODUCTION, COTTON, RING SPINNING			
RING SPINNING MODELLED FROM ECOINVENT 3.8 DATASETS "GLO: RING SPINNING COTTON"			
Inputs	Dataset/Flows used in Gabi	Data sources	Assumptions made
Cotton fiber	From fiber production		
Heat	RoW: market for heat, district or industrial, other than natural gas GLO: market for antimony	ecoinvent 3.8	
Building hall	GLO: market for building, hall, steel construction		
Electricity	US: market group for electricity, low voltage		
Output			
Yarn, cotton	To yarn dyeing		
Waste yarn and waste textile			

YARN DYEING			
YARN DYEING IS MODELLED BASED ON GS CONFIDENTIAL INDUSTRY DATA, HENCE LCI IS NOT DISCLOSED			
Inputs	Dataset/Flows used in Gabi	Data sources	Assumptions made
Yarn, cotton	From yarn production		
Output			
Dyed yarn	To 3D weaving		

3D WEAVING			
WEAVING IS MODELLED BASED ON PRIMARY DATA COLLECTED FROM UNSPUN			
Inputs	Dataset/Flows used in Gabi	Data sources	Assumptions made
Dyed yarn	From yarn dyeing		
Electricity	US: market group for electricity, medium voltage	ecoinvent 3.8	Country specific dataset to be selected
Output			
Woven fabric	To finishing		
Waste yarn	Mechanical recycling of cotton waste	GS confidential source	
Waste fabric			

FINISHING (ATTACHMENT OF ACCESSORIES)			
FINISHING IS MODELLED BASED ON PRIMARY DATA COLLECTED FROM UNSPUN			
Inputs	**Dataset/Flows used in Gabi**	**Data sources**	**Assumptions made**
Woven fabric	From 3D weaving		
Woven fusible interfacing and Lining fabric	US: Conventional Cotton (ICAC) - Far West	ICAC, 2019-20	
	Cotton Ring Spinning	GS confidential	
	Air jet weaving	GS confidential	
Brass zipper	RoW: market for brass GLO: market for casting, brass	ecoinvent 3.8	
Rivets			
Brass buttons			
Sewing threads	RER: polyethylene terephthalate production, granulate, amorphous,	ecoinvent 3.8	
	Yarn production (Synthetic)	Van der velden, 2014	
	RoW: bleaching and dyeing, yarn	ecoinvent 3.8	
Output			
Finished 3D woven pants			

NOTE: GLO- GLOBAL, US- UNITED STATES OF AMERICA, ROW- REST OF THE WORLD AND DE: GERMANY.

8.4 Blend Information and Product Categories Analysed

TABLE 10: PRODUCTS PRODUCED BY UNSPUN

SC No.	Blend	Products produced by Unspun
SC 1	100% Virgin polyester	Woven pants
SC 2	100% Conventional Cotton	Woven pants

A3: Energy Mixers

Thermal Energy Mixer

Thermal energy mix is based on IEA statistics for Unites States (IEA 2020). All upstream processes are taken from Sphera

TABLE 11: THERMAL ENERGY MIX DISTRIBUTION

Inputs	Dataset used	Share of thermal energy mix (%)
Thermal energy from natural gas	US: Thermal energy from natural gas	81.2%
Thermal energy from biomass	US: Thermal energy from biomass	8.42%
Thermal energy from oil	US: Thermal energy from heavy fuel oil	3.47%
Thermal energy from hard coal	US: Thermal energy from hard coal	6.93%

ABOUT GREEN STORY

Green Story is a sustainability platform that enables brands to accurately measure and communicate the positive impact of their products and make them carbon neutral.

By combining Life Cycle Assessment methodology with interactive data and impact visuals and a carbon offsetting platform, we enrich the customer experience with your green story throughout the customer lifecycle. Enhancing transparency, increasing engagement and loyalty, and driving revenue.

Partnering with hundreds of sustainable fashion players like ThredUP, Rent the Runway, Threads 4 Thought, Pact, and Hanesbrands, Green Story has a global team of experts working to empower 1 billion people to know their impact and make choices that are better for the planet and the generations to come.