Life Cycle Assessment of Home Textiles of Organic Cotton

Commissioner: Mørkegaard A/S in collaboration with Salling Group A/S

Product brand: Nord Harmony

LCA practitioner: Better Green ApS

Critical reviewer: Bureau Veritas Solutions Denmark A/S

Date and version: 2025-04-22 (v1.0)

LIFE CYCLE ASSESSMENT (LCA) INFORMATION	
Commissioner	Mørkegaard A/S in collaboration with Salling Group A/S
Product brand	Nord Harmony
LCA practitioner	Better Green ApS Julie Kathrine Lyager
Critical reviewer	Bureau Veritas Solutions Denmark A/S Waldemar C. Hemdrup - Sustainability specialist
LCA standard	ISO 14040/44
Products (and declared unit)	Bedlinen (1 x duvet cover, 1 x pillow cover) Envelope sheets (1 x sheet) Bath towels (1 x towel) Hand towels (2 x towel (2-pack)) Washcloth (5 x washcloth (5-pack)) Bath mat (1 x bath mat) Bathrobe (1 x bathrobe) Hair turban (1 x hair turban)
Life cycle scope	Cradle-to-grave
Temporal scope	Production data collected covers 2024
Geographical scope	Raw materials: Pakistan and Türkiye Production: Pakistan Use and end-of-life: Denmark
Background database	ecoinvent v3.10 (cut-off)
Software	SimaPro 9.6.0.1
Modeling/allocation approach	Attributional LCA and physical allocation in phase 3 (production)
LCIA method	Environmental Footprint 3.1
Impact categories	Climate change; Climate change – Biogenic; Climate change – Fossil; Climate change - Land use and LU change; Ecotoxicity, freshwater; Particulate matter; Eutrophication, marine; Eutrophication, freshwater; Eutrophication, terrestrial; Human toxicity, cancer; Human toxicity, non-cancer; Ionising radiation; Land use; Ozone depletion; Photochemical ozone formation; Resource use, fossils; Resource use, minerals and metals; Water use
Date and version:	2025-04-22 (v1.0)

1 Summary

Goal and scope: A life cycle assessment (LCA) was carried out to investigate the environmental impacts arising in the full life cycle of five *Nord Harmony* bedlinen products and 12 *Nord Harmony* towel products. The life cycle phases included in the LCA are:

1) Raw materials: Production of organic cotton yarn and polyester thread
2) Raw material transport: Transport of raw materials to the factory
3) Production: Transformation of yarn and thread into final products incl. packaging. The products are produced at two factories in Pakistan - bedlinen products at one factory and the towel products at another factory.
4) Distribution: Transport to Denmark, warehouse, retail, disposal of transport packaging, and transport to the consumer home.
5) Use phase: Washing and drying cycles in the whole product life time and disposal of consumer packaging.
6) End-of-life: Disposal of the products through mixed waste for incineration and through textile sorting scheme for recycling.

The goal of the assessment was to get a deeper understanding of the environmental impacts of the products, and to label the product packaging with the climate change impact of the products (kg CO2e/product).

Data collection and data quality: Data was collected to represent the six life cycle phases of the LCA. Primary data was collected from the two factories in Pakistan to fully represent the production phase, and additional information about the supply chain of the raw materials was also collected from the factories. The life cycle phases before and after production generally rely on secondary data. The data quality in the study is generally good, although a significant limitation in the data collection was the lack of country-specific data for organic cotton cultivation.

Results and conclusions: The environmental impact of the products was evaluated across 19 impact categories according to the EF3.1 LCIA method. The climate change impact of all 17 products is shown in Table 1.

Table 1 – Climate change impact of the 17 products evaluated in the life cycle assessment (LCA) – total across the six life cycle phases.

LCA ID	Product name	Climate change impact (kg CO2e)
BL1	Bedlinen 200 cm (one set)	13,1
BL2	Bedlinen 220 cm (one set)	13,8
ES1	Envelope sheet 90 cm (one piece)	5,5
ES2	Envelope sheet 140 cm (one piece)	9,5
ES3	Envelope sheet 180 cm (one piece)	12,6

LCA ID	Product name	Climate change impact (kg CO2e)
BT1	Bath towel, bleached and dyed (one piece)	14,8
BT2	Bath towel, unbleached (one piece)	12,7
HT1	Hand towel, bleached and dyed (two-pack)	15,0
HT2	Hand towel, unbleached (two-pack)	12,9
WC1	Washcloth, bleached and dyed (five-pack)	7,0
WC2	Washcloth, unbleached (five-pack)	6,0
BM1	Bath mat, bleached and dyed (one piece)	12,2
BM2	Bath mat, unbleached (one piece)	10,5
BR1	Bathrobe, bleached and dyed (one piece)	31,6
BR2	Bathrobe, unbleached (one piece)	27,2
HA1	Hair turban, bleached and dyed (one piece)	2,0
HA2	Hair turban, unbleached (one piece)	1,7

A contribution analysis for the climate change impact revealed that 'Phase 4 - use of product' is the most contributing life cycle phase across all products (34-69%) mainly due to the electricity and detergent used for washing and drying the textiles in their whole life cycle – see Figure 1. The climate change impact of washing and drying textiles was found to decrease by more than 54% when air drying the textiles instead of machine drying them.

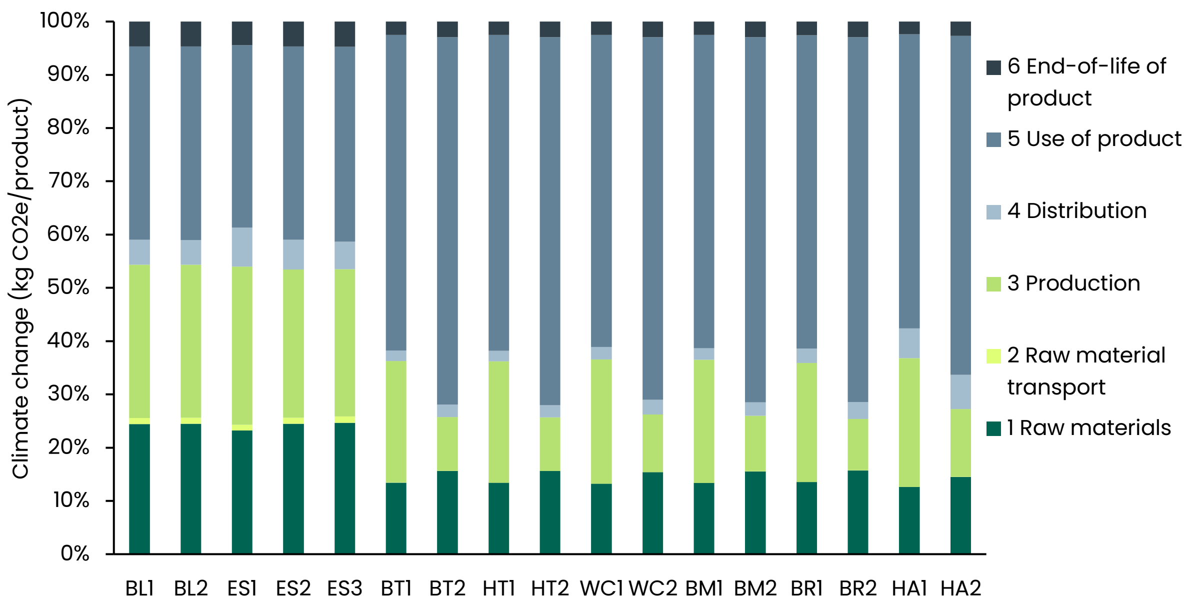

Figure 1 – Contribution analysis for the climate change impact for each product

The bedlinen products (BL1 and BL2) are designed using cotton laces for closing the bed sheet instead of a zipper. The effect of using a polyester zipper instead of cotton laces was analyzed, and it was found that the zipper had 3 times higher climate change impact in the raw material phase than the cotton laces, and 2 times higher climate change impact in the end-of-life of product phase. Looking at the overall climate change impact of the products, the change between cotton laces and zipper was almost negligible. However, the potential benefits of increased recyclability of the bed sheets when using cotton laces were not included in the analysis.

Critical review: The LCA study was carried out by Better Green ApS and critically reviewed by an independent third-party from Bureau Veritas Solutions Denmark A/S. The review took place post-study and the LCA study was updated to accommodate suggestions and comments for improvement from the third-party reviewer. The review took place between March 18 and April 22, 2025.

2 Contents

List of abbreviations

Abbreviation	Full expression
A&FW	Apparel and Footwear
BL1	LCA ID for 'Bedlinen 200 cm'
BL2	LCA ID for 'Bedlinen 220 cm'
BM1	LCA ID for 'Bath mat, bleached and dyed'
BM2	LCA ID for 'Bath mat, unbleached'
BR1	LCA ID for 'Bathrobe, bleached and dyed'
BR2	LCA ID for 'Bathrobe, unbleached'
BT1	LCA ID for 'Bath towel, bleached and dyed'
BT2	LCA ID for 'Bath towel, unbleached'
DK	Denmark
DPP	digital product passport
DQR	Data quality rating
DST	Danmarks Statistik
EF	Environmental Footprint
ES1	LCA ID for 'Envelope sheet 90 cm'
ES2	LCA ID for 'Envelope sheet 140 cm'
ES3	LCA ID for 'Envelope sheet 180 cm'
ESPR	Ecodesign for Sustainable Products Regulation
EU	European Union
GLO	Global
HA1	LCA ID for 'Hair turban, bleached and dyed'
HA2	LCA ID for 'Hair turban, unbleached'
HT1	LCA ID for 'Hand towel, bleached and dyed'
HT2	LCA ID for 'Hand towel, unbleached'
IN	India
IVL	Swedish Environmental Research Institute
LCA	Life cycle assessment
LCI	Life cycle inventory
LCIA	Life cycle impact assessment
N.D.	No date
PEF	Product Environmental Footprint
PEFCR	Product Environmental Footprint Category Rules
PEF-RF	Product Environmental Footprint Representative Product
PES	Polyester
PK	Pakistan
RER	Europe
RoW	Rest of World
TR	Türkiye
WC1	LCA ID for 'Washcloth, bleached and dyed'
WC2	LCA ID for 'Washcloth, unbleached'

3 Goal of the study

3.1 Reasons for carrying out the study

Mørkegaard A/S is preparing for the expected future requirements related to the EU Ecodesign for Sustainable Products Regulation (ESPR), which entered into force on July 18, 2024. One of the planned requirements of the ESPR is the digital product passport (DPP) - a digital identity card for products, components, and materials - which will store relevant information to support product sustainability, circularity, and compliance. The DPP requirements are still being developed for various product categories.

Mørkegaard A/S is carrying out a DPP pilot project for one of their collections of home textiles produced in the first half of 2025. This LCA study will evaluate the environmental impact of these home textile products, and the results will be included in the DPP pilot project.

An equally important goal of the LCA study is to give Mørkegaard A/S a deep understanding of the environmental impact drivers in the life cycle of the assessed products. This will inform future product design and operational decisions for Mørkegaard A/S aiming to minimize the environmental impact of their products and business.

3.2 Intended applications

The results of this LCA study are intended to be communicated to the business partners of Mørkegaard A/S (i.e., retail partners). Furthermore, the results will be communicated to the consumer of the home textile products by:

1) labelling the products with their climate change impact (kg CO2e per product)
2) labelling the products with a QR code which links to a simplified digital product passport containing a summary of the findings in this LCA including the LCIA results and the external review statement

3.3 Target audience

The target audience of this LCA study is the business partners of Mørkegaard A/S (retail partners) and the end consumer of the products. The whole LCA report will be shared with relevant business partners of Mørkegaard A/S, while a summary of the LCA report will be shared with the end consumer. The full LCA study may be shared with the end consumer upon request.

3.4 Comparative claims

Although this LCA study includes an environmental impact assessment of several different products, the study does not intend to compare two or more products or make any claims of one product's environmental superiority over another product. The purpose of including several products in the same LCA is to increase the efficiency of the LCA work.

4 Scope of the study

4.1 Description of the products

This study assesses multiple home textile products from the brand Nord Harmony, which are produced at two different factories in Pakistan. Two bedroom textile product types (bedlinen and envelope sheets) are produced in one factory (referred to as *the bedlinen factory*), while six bathroom textile product types (bath towels, hand towels, washcloth, bath mats, bathrobes, and hair turbans) are produced in another factory (referred to as *the towel factory*). The products assessed from the bedlinen factory are shown in Table 2. The products assessed from the towel factory are shown in Table 3. Some of the products come in several sizes/dimensions and several designs/colors. Some of the variations are grouped together, meaning that one set of LCA results will represent several product variations, because the level of detail of the collected data does not allow for distinction between the product variations (i.e., two different printing designs). The number of LCA results is 17 (five sets of LCA results for bedroom textile products, 12 sets of LCA results for bathroom textile products, respectively).

Table 2 – Bedroom textile products assessed in the LCA study incl. size and design variations. These products are produced at the bedlinen factory in Faisalabad, Pakistan.

Product	Size/dimensions	Design/color	LCA ID
Bed linen	140x200 cm + 60x63 cm	Bleached and printed, Design A	BL1*
	140x200 cm + 60x63 cm	Bleached and printed, Design B	
	140x220 cm + 60x63 cm	Bleached and printed, Design A	BL2*
	140x220 cm + 60x63 cm	Bleached and printed, Design B	
Envelope sheet	90x200+8 cm	Bleached white	ES1
	140x200+8	Bleached white	ES2
	180x200+8	Bleached white	ES3

** Product variations grouped together because the level of detail of the life cycle inventory does not enable differentiating between these design/color variations.*

Table 3 – Bathroom textile products assessed in the LCA study incl. size and design variations. These products are produced at the towel factory in Karachi, Pakistan.

Product	Size/dimensions	Design/color	LCA ID
Bath towel	70x140 cm	Bleached and dyed state gray	BT1*
	70x140 cm	Bleached and dyed dust rose	
	70x140 cm	Unbleached	BT2
Hand towel	50x100 cm	Bleached and dyed state gray	HT1*
	50x100 cm	Bleached and dyed dust rose	
	50x100 cm	Unbleached	HT2
Washcloth	30x30 cm	Bleached and dyed state gray	WC1*

Product	Size/dimensions	Design/color	LCA ID
	30x30 cm	Bleached and dyed dust rose	
	30x30 cm	Unbleached	WC2
Bath mat	50x80 cm	Bleached and dyed state gray	BM1*
	50x80 cm	Bleached and dyed dust rose	
	50x80 cm	Unbleached	BM2
Bathrobe	S/M	Bleached and dyed state gray	BR1**
	L/XL	Bleached and dyed state gray	
	S/M	Unbleached	BR2**
	L/XL	Unbleached	
Hair turban	24x67 cm	Bleached and dyed state gray	HA1*
	24x67 cm	Bleached and dyed dust rose	
	24x67 cm	Unbleached	HA2

** Product variations grouped together because the level of detail of the life cycle inventory does not enable differentiating between these design/color variations.*

*** Product variations grouped together and represented by the size L/XL as a conservative estimate, since it is impractical to label different environmental profiles for different sizes of clothing.*

The actual products with their packaging were not photographed at the time of writing this report. Products of the same type and with the same type of packaging are shown in Section 10.1 (Appendix).

4.2 Functional or declared unit

In line with the purpose of the LCA, which is to inform the consumer of the environmental impact of the product they are purchasing, the LCA results will be declared based on the product package that the consumer will see in the store. Depending on the product, one product package may contain one or more products. The configuration of the product package for each product is listed in Table 4.

Table 4 – Declared unit per product in the LCA

LCA ID	Product name	Declared unit
BL1	Bedlinen 200 cm	One set (one duvet cover and one pillow cover)
BL2	Bedlinen 220 cm	One set (one duvet cover and one pillow cover)
ES1	Envelope sheet 90 cm	One sheet
ES2	Envelope sheet 140 cm	One sheet
ES3	Envelope sheet 180 cm	One sheet
BT1	Bath towel, bleached and dyed	One towel
BT2	Bath towel, unbleached	One towel
HT1	Hand towel, bleached and dyed	Two towels (one 2-pack)
HT2	Hand towel, unbleached	Two towels (one 2-pack)
WC1	Washcloth, bleached and dyed	Five washcloths (one 5-pack)

LCA ID	Product name	Declared unit
WC2	Washcloth, unbleached	Five washcloths (one 5-pack)
BM1	Bath mat, bleached and dyed	One bath mat
BM2	Bath mat, unbleached	One bath mat
BR1	Bathrobe, bleached and dyed	One bathrobe
BR2	Bathrobe, unbleached	One bathrobe
HA1	Hair turban, bleached and dyed	One hair turban
HA2	Hair turban, unbleached	One hair turban

4.3 System boundary

The life cycle of this LCA is cradle-to-grave and has been divided into the following life cycle phases: (1) Raw materials, (2) Transport of raw materials, (3) Production, (4) Distribution, (5) Use of product, and (6) End-of-life of product. In Table 5 the activities included in each life cycle phase are presented.

Table 5 – Life cycle phases declared in this LCA and the activities included per life cycle phase.

Life cycle phase	Activities included:
1) Raw materials	• Cotton cultivation • Transport from cotton farm to gin • Cotton ginning • Transport from gin to spinning mill • Cotton yarn spinning • Polyester (PES) fiber production • Transport from PES fiber factory to spinning mill • PES thread production
2) Transport of raw materials	• Transport of cotton yarn to textile mill • Transport of PES thread to textile mill
3) Production	• Energy consumption • Water consumption • Chemicals consumption • Lubricant consumption • Waste and wastewater treatment • Packaging for products • Other materials consumption
4) Distribution	• Transport of product to warehouse • Warehouse energy consumption • Transport of product from warehouse to retail • Retail energy consumption • Waste treatment of freight packaging • Transport to consumer home
5) Use	• Washing and drying of products • Waste treatment of consumer packaging
6) End-of-life	• Waste treatment of products after end-of-life

A flow diagram for the life cycle phases in this LCA is shown in Figure 2.

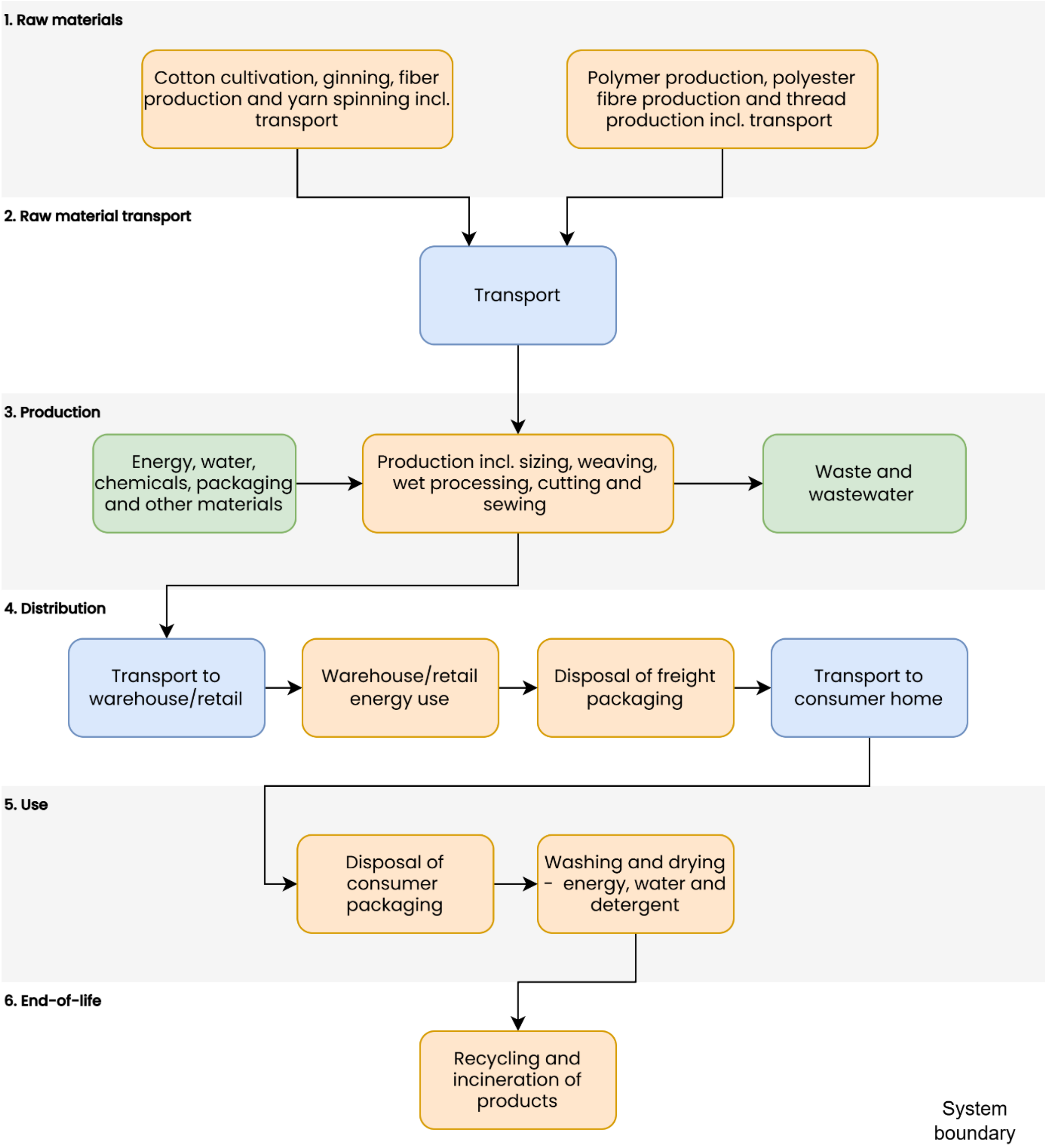

Figure 2 – Flow diagram for life cycle phases in this LCA

4.4 Modelling approach

4.4.1 LCA standard

This LCA follows the DS/EN ISO 14040:2008 and DS/EN ISO 14044:2008 standards for life cycle assessment. ISO 14040 provides the principles and framework for conducting a Life Cycle Assessment (LCA), while ISO 14044 specifies the requirements and guidelines for carrying out each phase of an LCA, including goal definition, inventory analysis, impact assessment, and interpretation. These LCA standards were followed since they are widely recognized international standards. For assumptions the study has been inspired by the Product Environmental Footprint (PEF) Method from the European Union (PEF, 2021), and the specific rules for apparel and footwear, which are still under development.

4.4.2 Database and software

The ecoinvent 3.10 database ("cut-off by classification") has been used for background LCI datasets. The software SimaPro 9.6 and Microsoft Excel have been used for LCA modelling.

4.4.3 LCA method

This is an attributional LCA, meaning the LCA models the environmental impacts of the activities includes in the life cycle of the product. This LCA method is commonly adopted for LCA of single products and is the LCA method adopted by the European Union "Product Environmental Footprint". In this type of LCA the background system uses "average" processes. An alternative LCA method called consequential LCA models the environmental impact related to the decision of buying the product. This method requires the LCA model to account for long-term market trends and market constraints. In this type of LCA the background system uses "marginal" processes.

4.4.4 Handling of multifunctional processes

According to ISO 14044 allocation should be avoided wherever possible by (1) dividing multifunctional processes into multiple sub-processes and collecting input and output data for these sub-processes, or (2) by system expansion. If not avoidable ISO 14040/44 prioritizes physical allocation, and economic allocation if a physical relationship is not established.

In this LCA, for the foreground system (Phase 3: Production) the data is collected as far as possible for single processes in the factory (i.e., using submeters) and if that is not possible the data is collected for the whole factory. Data at the process level is distributed to each product by means of mass allocation (kg of material resulting from each process, and kg of material used in each product). Data at the factory level is also distributed to each product by means of mass allocation (kg of final products leaving the factory).

For the background system, the ecoinvent 3.10 system model “cut-off by classification” was used. This system model handles multifunctionality by economic allocation (i.e., allocation based on price) with few exceptions, such as for energy, for which allocation is based on exergy.

4.4.5 Cut-off criteria

In this Life Cycle Assessment (LCA), a cut-off threshold is set at a maximum of 5%, meaning that the cumulative exclusion of mass and energy inputs must not exceed this limit. This approach ensures that all significant inputs are considered while allowing minor contributions to be omitted to streamline the analysis.

4.5 Temporal and geographical scope

The temporal and geographical scope of this LCA is presented in Table 6.

The temporal scope of the production is 2025, which is the year where the products studied in this LCA will be manufactured. Data for the production is however collected for 2024, which is considered representative for the production of similar products in 2025.

Table 6 – Temporal and geographical scope of this LCA per life cycle phase

Scope	Raw materials	Transport of raw materials	Production	Distribution	Use of product	End-of-life of product
Temporal	2024-2025	2025	2025	2025	2025-2027/28	2027-2028
Geographical	Türkiye/Pakistan	International	Pakistan	Denmark	Denmark	Denmark

4.6 Data quality requirements

4.6.1 Temporal representativeness

Data collected for the LCA should reflect the temporal scope of the LCA as far as possible. For upstream processes the background datasets should be as recent and up-to-date as possible. For the production process, primary data should be collected for the most recently completed year (2024). For the distribution phase the background datasets should be as recent and up-to-date as possible. For the use phase and end-of-life phase that may take place until 2-3 years in the future, it is assumed that no major differences to current practices will occur, meaning the background datasets should be as recent and up-to-date as possible.

4.6.2 Geographical representativeness

Data collected for the LCA should reflect the geographical scope of the LCA as far as possible. Country-specific background datasets should be prioritized over regional and global datasets, when they are available. If they are not available, the geographical representativeness can be improved by adapting the datasets, i.e. by exchanging the electricity mix.

4.6.3 Technological Representativeness

Data collected for the LCA should reflect the technologies used in the value chain of the products. For the production phase, this is ensured through collection of primary data. For upstream processes it is ensured by collecting information about the different technologies used in the factories' supply chains, i.e. farming method for cotton or yarn-spinning method. The downstream processes can vary a lot based on the consumer behavior. The most commonly used technologies should be assumed downstream.

4.7 Critical review

This LCA has undergone a critical review by Waldemar C. Hemdrup, Sustainability specialist from Bureau Veritas Solutions Denmark A/S. The critical review took place between March 18 and April 22, 2025, and included written feedback and a review meeting. The study was adapted based on the comments from the critical reviewer. See dialogue between the reviewer and the LCA practitioner during the review process in section 10.6 (appendix).

5 Life cycle inventory analysis (LCI)

5.1 Phase 1: Raw materials

Phase 1 "Raw materials" is divided into three sections:

1) Cotton supply chain for bedlinen factory
2) Cotton supply chain for towel factory
3) Polyester supply chain for both factories

Relevant supply chain information regarding cotton and polyester for each factory is summarized in Table 7. The activity data, background data and data quality are described further in the following sections.

Table 7 – Supply chain information for cotton and polyester for the bedlinen and the towel factory.

Parameter	Bedlinen factory	Towel factory
Cotton cultivation method	Organic	Organic
Cotton cultivation location	Türkiye (assumed Şanlıurfa)	Punjab, Pakistan (assumed Faisalabad)
Ginning location	Unknown (assumed Şanlıurfa, Türkiye)	Unknown (assumed Faisalabad, Pakistan)
Transport cotton farm to gin	15 km by truck included in secondary ginning dataset	15 km by truck included in secondary ginning dataset
Yarn spinning method	Ring spinning	Ring spinning
Yarn spinning mill location	Sindh region, Pakistan (assumed Karachi)	Sindh region, Pakistan (assumed Karachi)
Transport gin to yarn mill	Leg 1: Şanlıurfa – Tripoli truck 520 km Leg 2: Tripoli – Karachi ship 6660 km Leg 3: Karachi-Karachi truck 50 km	Leg 1: Faisalabad-Karachi 1120 km
Polyester fiber production location	Punjab region, Pakistan (assumed Faisalabad)	Sindh region, Pakistan (assumed Karachi)
Polyester thread production location	Punjab region, Pakistan (assumed Faisalabad)	Sindh region, Pakistan (assumed Karachi)
Transport between polyester fiber and thread production	Same location assumed (No transport)	Same location assumed (No transport)

In Table 8 the composition of the products can be seen. The amount of raw materials used per product takes into account the losses in each processing step including the textiles factories.

Table 8 – Product composition (grams)

LCA ID	Product name	Main fabric (cotton)	Care label (cotton)	Thread (polyester)	Fabric bag/ribbon (cotton)	Total***
BL1	Bedlinen 200 cm	815	1,5	2	5	823
BL2	Bedlinen 220 cm	865	1,5	2	6	874
ES1	Envelope sheet 90 cm	319	1,5	2	4	326
ES2	Envelope sheet 140 cm	589	1,5	2	5	597
ES3	Envelope sheet 180 cm	794	1,5	2	6	803
BT1	Bath towel, bleached and dyed	490	10	4	-	504
BT2	Bath towel, unbleached	490	10	4	-	504
HT1	Hand towel, bleached and dyed*	500	10	3	-	513
HT2	Hand towel, unbleached*	500	10	3	-	513
WC1	Washcloth, bleached and dyed**	225	10	1	-	236
WC2	Washcloth, unbleached**	225	10	1	-	236
BM1	Bath mat, bleached and dyed	400	10	3	-	413
BM2	Bath mat, unbleached	400	10	3	-	413
BR1	Bathrobe, bleached and dyed	1050	10	12	10	1082
BR2	Bathrobe, unbleached	1050	10	12	10	1082
HA1	Hair turban, bleached and dyed	56	6	1	-	63
HA2	Hair turban, unbleached	56	6	1	-	63

* 2-pack
** 5-pack
*** Total weight may deviate slightly from the sum of weight of each component due to decimal rounding.

5.1.1 Cotton supply chain – bedlinen factory

5.1.1.1 Activity data

The bedlinens assessed in this LCA (BL1, BL2, ES1, ES2, and ES3) consist of a main fabric of cotton, a care label of cotton, thread of polyester and a self-fabric bag of cotton. Although the self-fabric bag is part of the product packaging, it is treated as a part of the product in this LCA, since it is made of the same materials as the main fabric. That means the bedlinens consist of 99,0-99,4% cotton and 0,6-1% polyester. The main fabric and self-fabric bag have the same cotton supply chain (growing in Türkiye and spinning in Pakistan), while the care label has another supply chain (growing and spinning in Pakistan). Since the care label accounts for 0,4% or less of the total cotton in the bedlinens, its supply chain is not modelled, and instead it is assumed to come from the same supply chain as the main fabric.

The cotton for the bedlinen is grown using organic farming methods in Türkiye. The exact growing region is unknown to the bedlinen factory but for estimation of transport distances, it is assumed that the cotton is grown in Sanliurfa, Southeastern Anatolia, which is the largest cotton-growing region in Türkiye.

The next step, ginning of seed-cotton to obtain cotton fiber, usually takes place in the same region as the cotton growing. Therefore, it is assumed in this LCA that the ginning also takes place in Sanliurfa, Türkiye. The transport distance from cotton farm to gin is assumed to be 15 km, which is the distance used by ecoinvent in the datasets for cotton ginning.

The next step is yarn spinning, which takes place in the Sindh region in Pakistan (ring spinning). The exact location of the spinning mill is not known by the bedlinen factory. For estimation of transport distances, it is assumed that the spinning mill is located near Karachi. The transport routes and distances are estimated with the EcoTransit online tool as follows:

1) 517 km by truck from Sanliurfa to the port in Tripoli, Lebanon
2) 6660 km by container ship from Tripoli to the port in Karachi, Pakistan
3) 50 km by truck from Karachi port to the yarn spinning mill in Karachi

5.1.1.2 Background data

The organic cultivation of cotton is modelled with secondary data, since the bedlinen factory does not have primary data for their supply chain. A literature search for LCI datasets for organic cotton cultivation was carried out, but it was not possible to find a suitable LCI dataset representing organic cotton growing in Türkiye. Therefore, an Indian dataset from ecoinvent 3.10 for cultivation of organic cotton was used (Seed-cotton, organic {IN-OR}| seed-cotton production, organic | Cut-off, U). The cotton cultivation has a large influence on the LCIA results for the products, and the lack of region-specific data is a limitation of this LCA study. The Indian dataset was selected instead of a global dataset, which was also available in the ecoinvent database. This was done for transparency reasons, because the global dataset in ecoinvent was based solely on the Indian dataset.

The ginning process was modelled with an ecoinvent 3.10 dataset for ginning in India, where the electricity mix was changed from India (IN) to Türkiye (TR) (Fibre, cotton {IN}| fibre production, cotton, ginning | Cut-off, U – adapted to TR). Furthermore, the seed-cotton input and its transport were removed from the dataset, since seed-cotton is modelled separately and its transport to the gin is included in the seed-cotton dataset.

The yarn spinning process was modelled with an ecoinvent 3.10 dataset for cotton yarn spinning globally, where the electricity mix was changed from Global (GLO) to Pakistan (PK) (Yarn, cotton {GLO}| yarn production, cotton, ring spinning, for weaving | Cut-off, U – adapted to PK). Furthermore, the cotton fiber input was removed from the dataset, since the cotton growing and ginning is modelled separately.

The truck transport in Türkiye and Pakistan was modelled with an ecoinvent 3.10 dataset for unspecified truck in the 'Rest of World' (RoW) geography (Transport, freight, lorry, unspecified {RoW}| market for transport, freight, lorry, unspecified | Cut-off, U). The ship transport was modelled with an ecoinvent 3.10 dataset for global container shipping (Transport, freight, sea, container ship {GLO}| transport, freight, sea, container ship | Cut-off, U).

See overview of LCI data for phase 1 (Raw materials) in Table 12 and Table 13.

5.1.1.3 Data quality

Information about the cotton supply chain for the bedlinen was collected from the bedlinen factory and has a good accuracy since the country and regions for the supply chain steps are known. Nonetheless, secondary LCI data for the supply chain steps are not available for the actual countries and regions. Cotton cultivation is a very location specific process, since it is significantly affected by environmental factors such as temperature, rainfall, soil conditions etc. Therefore, the lack of a cotton cultivation dataset for Türkiye makes the geographical representativity low. The other processing steps (ginning and spinning) are not location specific, and it was possible to adapt the available datasets to the actual locations to increase the geographical representativeness. See Table 9 for data quality rating (DQR).

Table 9 – Data quality rating (DQR) for bedlinen cotton supply chain. Accuracy is rated for the activity data. Geographical, temporal and technological representativeness is rated for the secondary data used to represent the activity data. DQR based on UN Environment Global Guidance on LCA database development with the following scale: 'very good', 'good', 'fair', 'poor', and 'very poor'.

Activity	Accuracy	Geography	Time	Technology
Cotton growing	Good	Very poor	Fair	Very good
Ginning	Good	Fair	Fair	Very good
Spinning	Good	Fair	Fair	Very good
Transport	Good	Good	Poor	Good

5.1.2 Cotton supply chain – towel factory

5.1.2.1 Activity data

The towel factory products assessed in this LCA (BT1, BT2, HT1, HT2, WC1, WC2, BM1, BM2, BR1, BR2, HA1, and HA2) consist of a main fabric of cotton, a care label of cotton and thread of polyester. The bedlinens consist of 98,4-99,6% cotton and 0,4-1,6% polyester. The main fabrics' cotton supply chain (growing in Punjab, Pakistan and spinning in Sindh, Pakistan) is different from the care label's cotton supply chain (growing in Sindh, Pakistan, and spinning in Sindh, Pakistan). The care label accounts for 1-10% of the total cotton in the towel products, but since the supply chains are very similar, the care label's supply chain is not modelled, and instead it is assumed to come from the same supply chain as the main fabric.

The cotton for the towel products is grown using organic farming methods in Punjab, Pakistan. The exact growing location is unknown to the towel factory but for estimation of transport distances, it is assumed that the cotton is grown near Faisalabad, Punjab, which is a major textile industry hub in Pakistan.

The next step, ginning of seed-cotton to obtain cotton fiber, usually takes place in the same region as the cotton growing. Therefore, it is assumed in this LCA that the ginning also takes place in Faisalabad, Punjab. The transport distance from cotton farm to gin is assumed to be 15 km, which is the distance used by ecoinvent in the datasets for cotton ginning.

The next step is yarn spinning, which takes place in the Sindh region in Pakistan (ring spinning). The exact location of the spinning mill is not known by the towel factory. For estimation of transport distances, it is assumed that the spinning mill is located near Karachi, Sindh. The transport route and distance are estimated with the EcoTransit online tool as follows:

1) 1120 km by truck from Faisalabad to Karachi

5.1.2.2 *Background data*

The organic cultivation of cotton is modelled with secondary data, since the towel factory does not have primary data for their supply chain. A literature search for LCI datasets for organic cotton cultivation was carried out, but it was not possible to find a suitable LCI dataset representing organic cotton growing in Pakistan. Therefore, an Indian dataset from ecoinvent 3.10 for cultivation of organic cotton was used (Seed-cotton, organic {IN-OR}| seed-cotton production, organic | Cut-off, U). The cotton cultivation has a large influence on the LCIA results for the products, and the lack of region-specific data is a limitation of this LCA study. The Indian dataset was selected instead of a global dataset, which was also available in the ecoinvent database. This was done for transparency reasons, because the global dataset in ecoinvent was based solely on the Indian dataset.

The ginning process was modelled with an ecoinvent 3.10 dataset for ginning in India, where the electricity mix was changed from India (IN) to Pakistan (PK) (Fibre, cotton {IN}| fibre production, cotton, ginning | Cut-off, U – adapted to PK). Furthermore, the seed-cotton input and its transport were removed from the dataset, since seed-cotton is modelled separately and its transport to the gin is included in the seed-cotton dataset.

The yarn spinning process was modelled with an ecoinvent 3.10 dataset for cotton yarn spinning globally, where the electricity mix was changed from Global (GLO) to Pakistan (PK) (Yarn, cotton {GLO}| yarn production, cotton, ring spinning, for weaving | Cut-off, U – adapted to PK). Furthermore, the cotton fiber input was removed from the dataset, since the cotton growing and ginning is modelled separately.

The truck transport in Pakistan was modelled with an ecoinvent 3.10 dataset for unspecified truck in the 'Rest of World' (RoW) geography (Transport, freight, lorry, unspecified {RoW}| market for transport, freight, lorry, unspecified | Cut-off, U).

See overview of LCI data for phase 1 (Raw materials) in Table 12 and Table 13.

5.1.2.3 *Data quality*

Information about the cotton supply chain for the towel products was collected from the towel factory and has a good accuracy since the country and regions for the supply chain steps are known. Nonetheless, secondary LCI data for the supply chain steps are not available for the actual countries and regions. Cotton cultivation is a very location specific process, since it is significantly affected by environmental factors such as temperature, rainfall, soil conditions etc. Therefore, the lack of a cotton cultivation dataset for Pakistan makes the geographical representativity low. The other processing steps (ginning and spinning) are not location specific, and it was possible to adapt the available datasets to the actual locations to increase the geographical representativeness. See Table 10 for data quality rating (DQR).

Table 10 – Data quality rating (DQR) for towel product cotton supply chain. Accuracy is rated for the activity data. Geographical, temporal and technological representativeness is rated for the secondary data used to represent the activity data. DQR based on UN Environment Global Guidance on LCA database development with the following scale: 'very good', 'good', 'fair', 'poor', and 'very poor'.

Activity	Accuracy	Geography	Time	Technology
Cotton growing	Good	Very poor	Fair	Very good
Ginning	Good	Fair	Fair	Very good
Spinning	Good	Fair	Fair	Very good
Transport	Good	Good	Poor	Good

5.1.3 Polyester supply chain – both factories

5.1.3.1 Activity data

The products contain less than 2% polyester thread.

The polyester thread used for bedlinen products and towel products is produced in Pakistan (fiber production in Pakistan and thread production in Pakistan). No transport is modelled between the processing steps, assuming they take place in the same factory. Transport of PET granules to the polyester fiber production is included with global average distances in the applied ecoinvent datasets.

5.1.3.2 Background data

The polyester fiber production is modelled with secondary data since the factories do not have primary data for their supply chain. The process was modelled with an ecoinvent 3.10 dataset for polyester fiber production in India, where regional inputs (surface water and electricity) were changed from India (IN) to Pakistan (PK) (Fibre, polyester {IN}| polyester fibre production, finished | Cut-off, U – adapted to PK).

There was no dataset available for polyester thread spinning in the ecoinvent 3.10 database. As a proxy, the polyester thread production was modelled with an ecoinvent 3.10 dataset for cotton yarn spinning globally, where the electricity mix was changed from Global (GLO) to Pakistan (PK) (Yarn, cotton {GLO}| yarn production, cotton, ring spinning, for weaving | Cut-off, U – adapted to PK).

See overview of LCI data for phase 1 (Raw materials) in Table 12 and Table 13.

5.1.3.3 Data quality

Information about the polyester supply chain for the bedlinen and towel products was collected from the respective factories and has a good accuracy since the country and regions for the supply chain steps are known. Nonetheless, secondary LCI data for the supply chain steps are not available for the actual countries and regions. The processing steps (fiber production and spinning) are not location specific, and it was possible to adapt the available datasets to the actual locations to increase the geographical representativeness. There was no polyester spinning dataset available, so a dataset for cotton yarn spinning was used instead, meaning the technological representativeness is deemed 'fair'. See Table 11 for data quality rating (DQR).

Table 11 – Data quality rating (DQR) for towel product cotton supply chain. Accuracy is rated for the activity data. Geographical, temporal and technological representativeness is rated for the secondary data used to represent the activity data. DQR based on UN Environment Global Guidance on LCA database development with the following scale: 'very good', 'good', 'fair', 'poor', and 'very poor'.

Activity	Accuracy	Geography	Time	Technology
Fiber production	Good	Fair	Fair	Fair
Spinning	Good	Fair	Fair	Fair

5.1.4 Phase 1 – unit process overview

Table 12 – Unit processes in phase 1 – raw materials.

Unit process name	Unit process unit	Input	Input unit	ecoinvent dataset	Comment
1.1 Cotton cultivation incl. transport to gin GLO	kg seed-cotton	1	kg	Seed-cotton, organic {GLO}| market for seed-cotton, organic | Cut-off, U	
1.2 Cotton ginning TR	kg cotton fiber	1	kg	Fibre, cotton {IN}| fibre production, cotton, ginning | Cut-off, U – adapted to TR	Background dataset adapted from India to Türkiye.
1.3 Cotton ginning PK	kg cotton fiber	1	kg	Fibre, cotton {IN}| fibre production, cotton, ginning | Cut-off, U – adapted to PK	Background dataset adapted from India to Pakistan.
1.4 Polyester fiber PK	kg polyester fiber	1	kg	Fibre, polyester {IN}| polyester fibre production, finished | Cut-off, U – adapted to PK	Background dataset adapted from India to Pakistan.
1.5 Cotton fiber transport to spinning Sanliurfa to Karachi	kg cotton fiber	0,52	tkm	Transport, freight, lorry, unspecified {RoW}| market for transport, freight, lorry, unspecified | Cut-off, U	520 km by truck
		6,66	tkm	Transport, freight, sea, container ship {GLO}| transport, freight, sea, container ship | Cut-off, U	6660 km by ship
1.6 Cotton fiber transport to spinning Faisalabad to Karachi	kg cotton fiber	1,12	tkm	Transport, freight, lorry, unspecified {RoW}| market for transport, freight, lorry, unspecified | Cut-off, U	1120 km by truck
1.7 Yarn spinning PK	kg yarn/thread	1	kg	Yarn, cotton {GLO}| yarn production, cotton, ring spinning, for weaving | Cut-off, U – adapted to PK	Background dataset adapted from Global to Pakistan.

Table 13 – Amount of unit processes per product in phase 1 – raw materials.

Unit process name	Unit	BL1	BL2	ES1	ES2	ES3	BT1	BT2	HT1	HT2	WC1	WC2	BM1	BM2	BR1	BR2	HA1	HA2
1.1 Cotton cultivation incl. transport to gin	kg seed-cotton	1,990	2,114	0,786	1,443	1,943	1,218	1,218	1,243	1,243	0,573	0,573	0,999	0,999	2,607	2,607	0,151	0,151
1.2 Cotton ginning TR	kg ginning	1,004	1,067	0,397	0,729	0,981	-	-	-	-	-	-	-	-	-	-	-	-
1.3 Cotton ginning PK	kg ginning	-	-	-	-	-	0,615	0,615	0,627	0,627	0,289	0,289	0,504	0,504	1,316	1,316	0,076	0,076
1.4 Polyester fiber PK	kg polyester fiber	0,002	0,002	0,002	0,002	0,002	0,005	0,005	0,004	0,004	0,001	0,001	0,004	0,004	0,014	0,014	0,001	0,001
1.5 Cotton fiber transport to spinning Sanliurfa to Karachi	kg cotton fiber	1,004	1,067	0,397	0,729	0,981	-	-	-	-	-	-	-	-	-	-	-	-
1.6 Cotton fiber transport to spinning Faisalabad to Karachi	kg cotton fiber	-	-	-	-	-	0,615	0,615	0,627	0,627	0,289	0,289	0,504	0,504	1,316	1,316	0,076	0,076
1.7 Yarn spinning PK	kg spinning	0,857	0,910	0,340	0,622	0,837	0,528	0,528	0,537	0,537	0,247	0,247	0,432	0,432	1,133	1,133	0,066	0,066

5.2 Phase 2: Transport of raw materials

Phase 2 “Raw materials” includes the raw material transport from the last processing step (spinning mill) to the two factories (bedlinen factory and towel factory). See relevant information about phase 2 in Table 14. The activity data, background data and data quality are described further in the following sections.

Table 14 – Information about the transport routes from spinning mill to textile factories.

Parameter	Bedlinen factory	Towel factory
Spinning location	Sindh, Pakistan (assumed Karachi)	Sindh, Pakistan (assumed Karachi)
Factory location	Faisalabad, Punjab, Pakistan	Karachi, Sindh, Pakistan
Transport yarn spinning mill to textile factory	Leg 1: Karachi-Faisalabad truck 1120 km	Leg 1: Karachi-Karachi 50 km (estimated distance)
Transport secondary dataset	Transport, freight, lorry, unspecified {RoW}| market for transport, freight, lorry, unspecified | Cut-off, U	Transport, freight, lorry, unspecified {RoW}| market for transport, freight, lorry, unspecified | Cut-off, U

5.2.1 Activity data

The bedlinen factory is located in Faisalabad, Punjab, and cotton yarn comes from Sindh, Pakistan (assumed Karachi). The transport distance by truck is estimated to 1120 km using the EcoTransit online tool. The bedlinen factory sources thread from Punjab (assumed Faisalabad), and a distance of 50 km is assumed.

The towel factory is located in Karachi, Sindh, and cotton yarn comes from Sindh, Pakistan (assumed Karachi). The transport distance by truck is assumed to be 50 km. The thread comes from Sindh (assumed Karachi), and a distance of 50 km is assumed.

5.2.2 Background data

The truck transport in Pakistan was modelled with an ecoinvent 3.10 dataset for unspecified truck in the ‘Rest of World’ (RoW) geography (Transport, freight, lorry, unspecified {RoW}| market for transport, freight, lorry, unspecified | Cut-off, U).

See overview of LCI data for phase 2 (Transport of raw materials) in Table 16 and Table 17.

5.2.3 Data quality

The activity data is of good quality because the factories know which region the materials come from. The specific locations are assumed in order to estimate transport distances. See

Table 15 for data quality rating (DQR).

Table 15 – Data quality rating (DQR) for transport of raw materials. Accuracy is rated for the activity data. Geographical, temporal and technological representativeness is rated for the secondary data used to represent the activity data. DQR based on UN Environment Global Guidance on LCA database development with the following scale: 'very good', 'good', 'fair', 'poor', and 'very poor'.

Activity	Accuracy	Geography	Time	Technology
Transport by truck	Good	Good	Poor	Good

5.2.4 Phase 2 – unit process overview

Table 16 – Unit processes in phase 2 – transport of raw materials.

Unit process name	Unit process unit	Input	Input unit	ecoinvent dataset	Comment
2.1 Cotton yarn transport to textile factory Karachi-Faisalabad	kg cotton yarn	1,12	tkm	Transport, freight, lorry, unspecified {RoW}| market for transport, freight, lorry, unspecified | Cut-off, U	1120 km by truck
2.2 Cotton yarn transport to textile factory Karachi-Karachi	kg cotton yarn	0,05	tkm	Transport, freight, lorry, unspecified {RoW}| market for transport, freight, lorry, unspecified | Cut-off, U	50 km by truck
2.3 Polyester yarn transport to textile factory	kg polyester yarn	0,05	tkm	Transport, freight, lorry, unspecified {RoW}| market for transport, freight, lorry, unspecified | Cut-off, U	50 km by truck

Table 17 – Amount of unit processes per product in phase 2 – transport of raw materials.

Unit process name	Unit	BL1	BL2	ES1	ES2	ES3	BT1	BT2	HT1	HT2	WC1	WC2	BM1	BM2	BR1	BR2	HA1	HA2
2.1 Cotton yarn transport to textile factory Karachi-Faisalabad	kg cotton yarn	0,855	0,908	0,338	0,620	0,835	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
2.2 Cotton yarn transport to textile factory Karachi-Karachi	kg cotton yarn	0,000	0,000	0,000	0,000	0,000	0,523	0,523	0,534	0,534	0,246	0,246	0,429	0,429	1,120	1,120	0,065	0,065
2.3 Polyester yarn transport to textile factory	kg polyester yarn	0,002	0,002	0,002	0,002	0,002	0,004	0,004	0,003	0,003	0,001	0,001	0,003	0,003	0,013	0,013	0,001	0,001

5.3 Phase 3: Production

5.3.1 Production inputs and outputs

5.3.1.1 Activity data – bedlinen factory

The bedlinen products included in this LCA can be divided into two groups: (1) bleached and printed products, and (2) bleached products. The products BL1 and BL2 belong to group (1) and the products ES1, ES2, and ES3 belong to group (2). In Figure 3 a process diagram for the production is shown for the two groups.

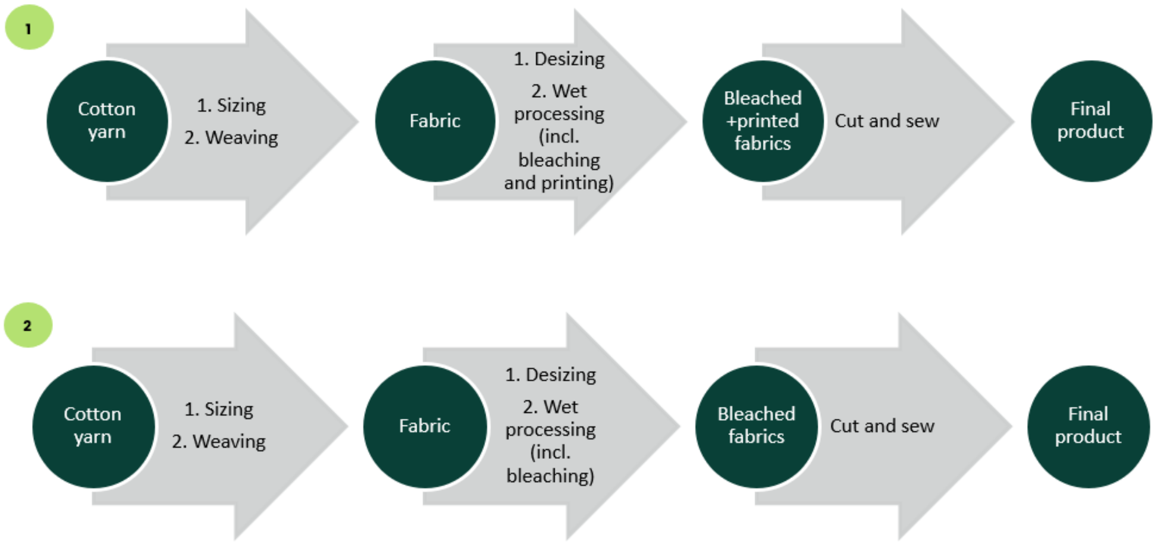

Figure 3 – Process diagrams for (1) bleached and printed products and for (2) bleached products.

In the weaving process there is a loss of 1%, while in the cut and sew process there is a loss of 3%. Overall, this means that 1,04 kg of yarn input to the factory is needed to produce 1 kg of product.

Data from the factory has been collected on:

- input of energy and consumables
- output of waste and wastewater
- product flows

The product flows (in kg) at different processing steps in the factory have been used for allocation of the inputs and outputs to the single products. In the bedlinen factory in 2024:

- 1.517.529 kg fabric was woven
- 12.302.165 kg fabric underwent bleaching (wet processing)
- 4.149.603 kg fabric underwent dyeing (wet processing)

- 4.509.466 kg fabric underwent printing (wet processing)
- 4.866.310 kg fabric underwent cut and sew

A large amount of pre-woven fabric is processed commercially in the factory (i.e. bleached, dyed, printed, cut and sewn). None of the bedlinen products included in this LCA undergo dyeing, therefore the inputs and outputs related to dyeing are excluded from this LCA. Inputs of energy, water, materials and chemicals per kg of product in group 1 and group 2, respectively, are listed in Table 18. Outputs of waste and wastewater per kg of product in group 1 and group 2, respectively, are listed in Table 19.

Table 18 – Energy and consumables per kg of final product

Input	Unit	/kg of group 1	/kg of group 2	Source
Electricity from grid	kWh	2,48	2,48	Primary data (allocated)
Electricity from solar	kWh	0,16	0,16	Primary data (allocated)
Steam from biomass	tons	0,014	0,014	Primary data (allocated)
Natural gas	m3	0,099	0,099	Primary data (allocated)
Clean water	m3	0,069	0,069	Primary data (allocated)
Lubricants	kg	0,0046	0,0046	Primary data (allocated)
Plastic	kg	0,0075	0,0075	Calculated from mass balance*
Metal	kg	0,012	0,012	Calculated from mass balance*
Paper	kg	0,025	0,025	Calculated from mass balance*
Starch for sizing	kg	0,090	0,090	Primary data
Enzyme for desizing	kg	0,040	0,040	Primary data
Sodium hydroxide for scouring	kg	0,60	0,60	Secondary data**
Hydrogen peroxide for bleaching	kg	0,031	0,030	Primary data
Sodium hydroxide for bleaching	kg	0,41	0,41	Secondary data**
Sodium silicate for bleaching	kg	0,62	0,62	Secondary data**
Pigment agent	kg	0,15	-	Primary data (allocated)

Pl* The amount of plastic, metal and paper waste is assumed to enter the factory i.e., misc. packaging etc.
** CBSE (2014) – laboratory test procedures for pretreatment of textiles.

Table 19 – Waste and wastewater per kg of final product

Input	Unit	/kg of group 1	/kg of group 2	Source
Plastic waste	kg	0,0075	0,0075	Primary data (allocated)
Metal waste	kg	0,012	0,012	Primary data (allocated)
Paper waste	kg	0,025	0,025	Primary data (allocated)
Wastewater	m3	0,083	0,083	Primary data (allocated)
Textile waste	kg	0,041	0,041	Calculated from loss rate

For a more detailed description of how each input or output flow was determined and allocated to 1 kg of each product see Section 10.2 (Appendix).

5.3.1.2 Activity data – towel factory

The towel products included in this LCA can be divided into two groups: (1) bleached and dyed products, and (2) unbleached (and undyed) products. The products BT1, HT1, WC1, BM1, BR1 and HA1 belong to group (1) and the products BT2, HT2, WC2, BM2, BR2 and HA2 belong to group (2). In Figure 4 a process diagram for the production is shown for the two groups.

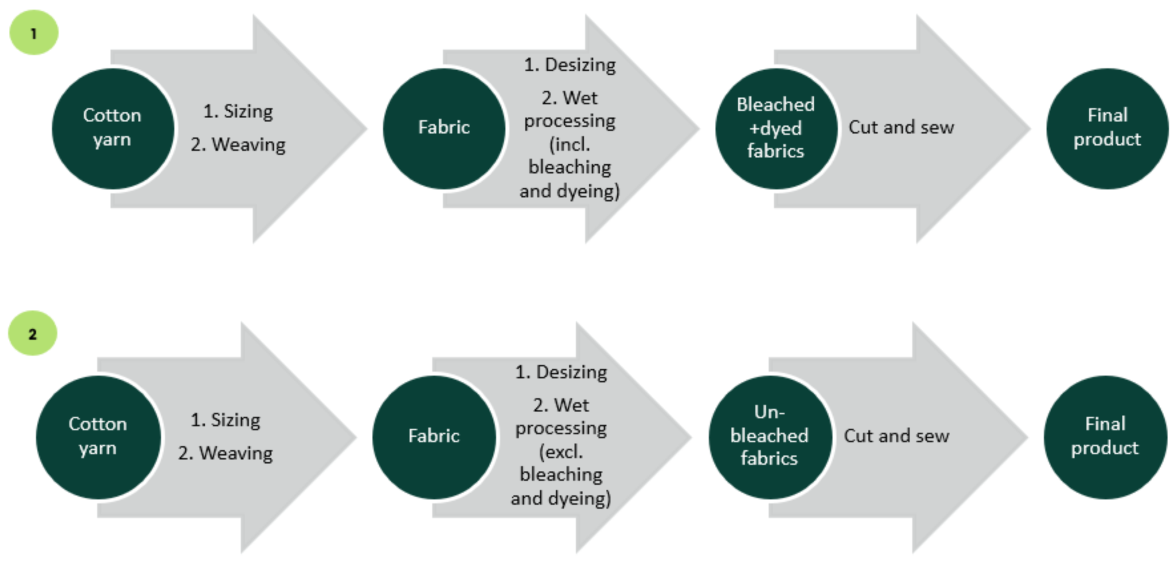

Figure 4 – Process diagrams for (1) bleached and dyed products and for (2) unbleached products.

In the weaving process there is a loss of 3,5%, while in the cut and sew process there is a loss of 1%. Overall, this means that 1,047 kg of yarn input to the factory is needed to produce 1 kg of product.

Data from the factory has been collected on:

- input of energy and consumables
- output of waste and wastewater
- product flows

The product flows (in kg) at different processing steps in the factory have been used for allocation of the inputs and outputs to the single products. In the bedlinen factory in 2024:

- 1.691.492 kg fabric was woven
- 676.596 kg fabric underwent bleaching (wet processing)
- 1.014.895 kg fabric underwent dyeing (wet processing)

- 1.556.173 kg fabric underwent cut and sew (final products)

Inputs of energy, water, materials and chemicals per kg of product in group 1 and group 2, respectively, are listed in Table 20. Outputs of waste and wastewater per kg of product in group 1 and group 2, respectively, are listed in Table 21.

Table 20 – Energy and consumables per kg of final product

Input	Unit	/kg of group 1	/kg of group 2	Source
Electricity from grid	kWh	6,23	6,23	Primary data (allocated)
Natural gas	m3	1,051	0,083	Primary data (allocated)
Clean water	m3	0,035	0,0044	Primary data (allocated)
Lubricants	kg	0,0010	0,0010	Primary data (allocated)
Plastic	kg	0,0015	0,0015	Calculated from mass balance*
Metal	kg	0,0012	0,0012	Calculated from mass balance*
Paper	kg	0,00071	0,00071	Calculated from mass balance*
Starch for sizing	kg	0,086	0,086	Primary data
Acid for desizing	kg	0,0051	0,0051	Primary data
Sodium hydroxide for scouring	kg	0,61	0,61	Secondary data**
Hydrogen peroxide for bleaching	kg	0,030	-	Primary data
Sodium hydroxide for bleaching	kg	0,40	-	Secondary data**
Sodium silicate for bleaching	kg	0,61	-	Secondary data**
Dye	kg	0,076 for BT1, HT1 and WC1 (500 gsm) 0,091 for BM1 (1000 gsm) 0,066 for BR1 and HA1 (350 gsm)	-	Primary data

* The amount of plastic, metal and paper waste is assumed to enter the factory i.e., misc. packaging etc.
** CBSE (2014) – laboratory test procedures for pretreatment of textiles.

Table 21 – Waste and wastewater per kg of final product

Input	Unit	/kg of group 1	/kg of group 2	Source
Plastic waste	kg	0,0015	0,0015	Primary data (allocated)
Metal waste	kg	0,0012	0,0012	Primary data (allocated)
Paper waste	kg	0,00071	0,00071	Primary data (allocated)
Wastewater	m3	0,039	0,0049	Estimated (110% of water input)
Textile waste	kg	0,047	0,047	Calculated from loss rate

For a more detailed description of how each input or output flow was determined and allocated to 1 kg of each product see Section 10.3 (Appendix).

5.3.1.3 Background data

The electricity consumption from the grid was modelled with an ecoinvent 3.10 dataset for electricity in Pakistan (PK) (Electricity, medium voltage {PK}| market for electricity, medium voltage | Cut-off, U).

The electricity consumption from solar energy (only used in bedlinen factory) was modelled with an ecoinvent 3.10 dataset for solar electricity in the geography 'Rest of World' (RoW) (Electricity, low voltage {RoW}| electricity production, photovoltaic, 3kWp flat-roof installation, multi-Si | Cut-off, U).

The steam from biomass (only used in bedlinen factory) was modelled with an ecoinvent 3.10 dataset for heat from wood chips in the geography 'Rest of World' (RoW) (Heat, central or small-scale, other than natural gas {RoW}| heat production, wood chips from industry, at furnace 50kW | Cut-off, U). 1600 MJ of that dataset was used for 1 ton of steam, based on low pressure saturated steam according to TSE (N.D).

The natural gas for heating was modelled with an ecoinvent 3.10 dataset for heat production from natural gas in the geography 'Rest of World' (RoW) where the electricity mix was changed from various geographies to Pakistan (PK) (Heat, central or small-scale, natural gas {RoW}| heat production, natural gas, at boiler modulating <100kW | Cut-off, U – adapted to PK). This unit for this dataset is MJ, while the natural gas consumption in the factory is defined in mmBTU. Conversion from mmBTU to m3 natural gas was carried out (28,26 m3 natural gas per mmBTU). Then the amount of m3 natural gas needed to produce 1 MJ heat was taken from within the dataset (0,029 m3 natural gas/MJ) to define the amount of the dataset required to represent the consumption of 1 m3 natural gas in the factory.

The water consumption was modelled with an ecoinvent 3.10 dataset for tap water in the geography 'Rest of World' (RoW) (Tap water {RoW}| market for tap water | Cut-off, U).

The consumption of lubricants was modelled with an ecoinvent 3.10 dataset for lubricating oil the geography 'Rest of World' (RoW) (Lubricating oil {RoW}| market for lubricating oil | Cut-off, U).

Starch for sizing was modelled with an ecoinvent 3.10 dataset for maize starch in the geography 'Global' (GLO) (Maize starch {GLO}| market for maize starch | Cut-off, U).

Enzyme for desizing (only used in bedlinen factory) was modelled with an ecoinvent 3.10 dataset for enzymes in the geography 'Global' (GLO) (Enzymes {GLO}| market for enzymes | Cut-off, U).

Acid for desizing (only used in towel factory) was modelled with an ecoinvent 3.10 dataset for acetic acid in the geography 'Global' (GLO) (Acetic acid, without water, in 98% solution state {GLO}| market for acetic acid, without water, in 98% solution state | Cut-off, U).

Sodium hydroxide for scouring and for bleaching was modelled with an ecoinvent 3.10 dataset for sodium hydroxide in the geography 'Rest of World' (RoW) (Sodium hydroxide, without water, in 50% solution state {RoW}| market for sodium hydroxide, without water, in 50% solution state | Cut-off, U).

Hydrogen peroxide (H_2O_2) for bleaching was modelled with an ecoinvent 3.10 dataset for hydrogen peroxide in the geography 'Rest of World' (RoW) (Hydrogen peroxide, without water, in 50% solution state {RoW}| hydrogen peroxide production, product in 50% solution state | Cut-off, U).

Sodium silicate for bleaching was modelled with an ecoinvent 3.10 dataset for sodium silicate in the geography 'Rest of World' (RoW) (Sodium silicate, without water, in 48% solution state {RoW}| market for sodium silicate, without water, in 48% solution state | Cut-off, U).

Pigment and dye were modelled with an ecoinvent 3.10 dataset for generic organic chemicals in the geography 'Global' (GLO) (Chemical, organic {GLO}| market for chemical, organic | Cut-off, U).

The disposal of plastic waste was modelled with an ecoinvent 3.10 dataset for disposal of waste polyethylene in the geography 'Rest of World' (RoW) (Waste polyethylene {RoW}| market for waste polyethylene | Cut-off, U).

The disposal of metal waste was modelled with an ecoinvent 3.10 dataset for disposal of scrap steel in the geography 'Rest of World' (RoW) (Scrap steel {RoW}| market for scrap steel | Cut-off, U).

The disposal of paper waste was modelled with an ecoinvent 3.10 dataset for disposal of paperboard in the geography 'Rest of World' (RoW) (Waste paperboard {RoW}| market for waste paperboard | Cut-off, U).

The disposal of textile waste was modelled with an ecoinvent 3.10 dataset for disposal of soiled textile in the geography 'Rest of World' (RoW) (Waste textile, soiled {RoW}| market for waste textile, soiled | Cut-off, U).

The disposal of dye-polluted wastewater was modelled with an ecoinvent 3.10 dataset for disposal of soiled textile in the geography 'Global' (GLO) (Wastewater from textile production {GLO}| market for wastewater from textile production | Cut-off, U).

The input of plastics to the factory was modelled with an ecoinvent 3.10 dataset for LDPE film in the geography 'Global' (GLO) (Packaging film, low density polyethylene {GLO}| market for packaging film, low density polyethylene | Cut-off, U).

The input of metals to the factory was modelled with an ecoinvent 3.10 dataset for low-alloyed steel in the geography 'Global' (GLO) (Steel, low-alloyed {GLO}| market for steel, low-alloyed | Cut-off, U).

The input of paper to the factory was modelled with an ecoinvent 3.10 dataset for woodfree paper in the geography 'Rest of World' (RoW) (Paper, woodfree, uncoated {RoW}| market for paper, woodfree, uncoated | Cut-off, U).

See overview of LCI data for phase 3 (production) in Table 25 and Table 26.

5.3.1.4 Data quality

The data quality rating for the production phase can be seen in Table 22. Overall, the data accuracy and technological representativeness of background data is good, while the geographical and temporal representativeness is poor.

Table 22 – Data quality rating (DQR) for production. Accuracy is rated for the activity data. Geographical, temporal and technological representativeness is rated for the secondary data used to represent the activity data. DQR based on UN Environment Global Guidance on LCA database development with the following scale: 'very good', 'good', 'fair', 'poor', and 'very poor'.

Activity	Accuracy	Geography	Time	Technology
Electricity from grid	Good	Very good	Very good	Very good
Electricity from solar	Good	Poor	Fair	Very good
Steam from biomass	Good	Poor	Fair	Fair
Natural gas	Good	Poor	Poor	Good
Clean water	Good	Poor	Poor	Good
Lubricant	Good	Poor	Poor	Good
Starch for sizing	Good	Poor	Poor	Good
Enzyme for desizing	Good	Poor	Good	Fair
Acid for desizing	Good	Poor	Poor	Good
Sodium hydroxide for scouring	Poor	Poor	Poor	Very good
Hydrogen peroxide for bleaching	Good	Poor	Good	Very good
Sodium hydroxide for bleaching	Poor	Poor	Poor	Very good
Sodium silicate for bleaching	Poor	Poor	Poor	Very good
Dye/pigment	Good	Poor	Poor	Poor
Plastic waste	Good	Poor	Poor	Good
Metal waste	Good	Poor	Poor	Good
Paper waste	Good	Poor	Poor	Good
Wastewater treatment	Good	Poor	Poor	Good
Plastic input	Fair	Poor	Poor	Good
Metal input	Fair	Poor	Poor	Good
Paper input	Fair	Poor	Poor	Good
Packaging – printed cardboard	Good	Poor	Poor	Good
Packaging – unprinted cardboard	Good	Poor	Poor	Good

Activity	Accuracy	Geography	Time	Technology
Packaging - LDPE	Good	Poor	Poor	Good

5.3.2 Product packaging

5.3.2.1 Activity data

The amount of packaging per product can be seen in Table 23. Furthermore, BL1, BL2, ES1, ES2 and ES3 have a self-fabric bag, but these bags are treated as part of the actual product in this LCA and have therefore been included in Phase 1 and 2. For BR1 and BR2 there is a cotton ribbon around the products, which has similarly been included in Phase 1 and 2.

Table 23 Product packaging composition (grams)

LCA ID	Product name	Consumer packaging		Freight packaging	
		Stiffener (cardboard)	Belly band (printed cardboard)	Polybag (LDPE)	Box (cardboard)
BL1	Bedlinen 200 cm	110	20	1	125
BL2	Bedlinen 220 cm	110	21	1	125
ES1	Envelope sheet 90 cm	90	18	1	200
ES2	Envelope sheet 140 cm	90	20	1	200
ES3	Envelope sheet 180 cm	90	21	1	267
BT1	Bath towel, bleached and dyed	-	13	3	83
BT2	Bath towel, unbleached	-	13	3	83
HT1	Hand towel, bleached and dyed*	-	12	3	78
HT2	Hand towel, unbleached*	-	12	3	78
WC1	Washcloth, bleached and dyed**	-	8	2	75
WC2	Washcloth, unbleached**	-	8	2	75
BM1	Bath mat, bleached and dyed	-	9	3	100
BM2	Bath mat, unbleached	-	9	3	100
BR1	Bathrobe, bleached and dyed	-	8	3	103
BR2	Bathrobe, unbleached	-	8	3	103
HA1	Hair turban, bleached and dyed	-	6	1	50
HA2	Hair turban, unbleached	-	6	1	50

* 2-pack
** 5-pack

5.3.2.2 Background data

The stiffener cardboard and freight box were modelled with an ecoinvent 3.10 dataset for cardboard box in the 'Rest of World' (RoW) geography (Corrugated board box {RoW}| market for corrugated board box | Cut-off, U).

The bellyband which is printed was modelled with an ecoinvent 3.10 dataset for printed carton board in the 'Global' (GLO) geography (Carton board box production, with offset printing {GLO}| market for carton board box production, with offset printing | Cut-off, U).

The poly bag was modelled with an ecoinvent 3.10 dataset for LDPE packaging film in the 'Global' (GLO) geography (Packaging film, low density polyethylene {GLO}| market for packaging film, low density polyethylene | Cut-off, U).

See overview of LCI data for phase 3 (production) in Table 25 and Table 26.

5.3.2.3 Data quality

The accuracy of the activity data is very good. The geographical and temporal representativeness is poor-very poor and the technological representativeness is good. See Table 24 for data quality rating (DQR).

Table 24 – Data quality rating (DQR) for product packaging. Accuracy is rated for the activity data. Geographical, temporal and technological representativeness is rated for the secondary data used to represent the activity data. DQR based on UN Environment Global Guidance on LCA database development with the following scale: 'very good', 'good', 'fair', 'poor', and 'very poor'.

Activity	Accuracy	Geography	Time	Technology
Unprinted cardboard	Very good	Very poor	Poor	Good
Printed cardboard	Very good	Very poor	Poor	Good
LDPE bag	Very good	Very poor	Poor	Good

5.3.3 Phase 3 – unit process overview

Table 25 – Unit processes in phase 3 – production.

Unit process name	Unit process unit	Input	Input unit	ecoinvent dataset	Comment
3.01 Electricity from grid	kWh	1	kWh	Electricity, medium voltage {PK}| market for electricity, medium voltage | Cut-off, U	
3.02 Electricity from solar	kWh	1	kWh	Electricity, low voltage {RoW}| electricity production, photovoltaic, 3kWp flat-roof installation, multi-Si | Cut-off, U	
3.03 Steam from biomass	tons	2600	MJ	Heat, central or small-scale, other than natural gas {RoW}| heat production, wood chips from industry, at furnace 50kW | Cut-off, U	Assuming low pressure saturated steam at 100 C, which requires 2.6 GJ/ton (TSA, N.D).
3.04 Natural gas	m3	35	MJ	PK Heat, central or small-scale, natural gas {RoW}| heat production, natural gas, at boiler modulating <100kW | Cut-off, U	0,028888889 m3 natural gas/MJ according to dataset. 1/0,02888=34,615 MJ/m3 natural gas
3.05 Water consumption	m3	1000	kg	Tap water {RoW}| market for tap water | Cut-off, U	
3.06 Lubricant	kg	1	kg	Lubricating oil {RoW}| market for lubricating oil | Cut-off, U	
3.07 Chemicals for sizing, desizing, scouring 1 kg bedlinens	kg fabric	0,09	kg	Maize starch {GLO}| market for maize starch | Cut-off, U	
		0,04	kg	Enzymes {GLO}| market for enzymes | Cut-off, U	
		0,6	kg	Sodium hydroxide, without water, in 50% solution state {RoW}| market for sodium hydroxide, without water, in 50% solution state | Cut-off, U	
3.08 Chemicals for sizing, desizing, scouring 1 kg towel products	kg fabric	0,085	kg	Maize starch {GLO}| market for maize starch | Cut-off, U	
		0,005	kg	Acetic acid, without water, in 98% solution state {GLO}| market for acetic acid, without water, in 98% solution state | Cut-off, U	

Unit process name	Unit process unit	Input	Input unit	ecoinvent dataset	Comment
		0,6	kg	Sodium hydroxide, without water, in 50% solution state {RoW}| market for sodium hydroxide, without water, in 50% solution state | Cut-off, U	
3.09 Chemicals for bleaching 1 kg fabric	kg fabric	0,03	kg	Hydrogen peroxide, without water, in 50% solution state {RoW}| hydrogen peroxide production, product in 50% solution state | Cut-off, U	
		0,4	kg	Sodium hydroxide, without water, in 50% solution state {RoW}| market for sodium hydroxide, without water, in 50% solution state | Cut-off, U	
		0,6	kg	Sodium silicate, without water, in 48% solution state {RoW}| market for sodium silicate, without water, in 48% solution state | Cut-off, U	
3.10 Pigment/dye	kg	1	kg	Chemical, organic {GLO}| market for chemical, organic | Cut-off, U	
3.11 Plastic waste	kg	1	kg	Waste polyethylene {RoW}| market for waste polyethylene | Cut-off, U	
3.12 Metal waste	kg	1	kg	Scrap steel {RoW}| market for scrap steel | Cut-off, U	
3.13 Paper waste	kg	1	kg	Waste paperboard {RoW}| market for waste paperboard | Cut-off, U	
3.14 Textile waste	kg	1	kg	Waste textile, soiled {RoW}| market for waste textile, soiled | Cut-off, U	
3.15 Wastewater dye-polluted	m3	1	m3	Wastewater from textile production {GLO}| market for wastewater from textile production | Cut-off, U	
3.16 Packaging - printed cardboard	kg	1	kg	Carton board box production, with offset printing {GLO}| market for carton board box production, with offset printing | Cut-off, U	

Unit process name	Unit process unit	Input	Input unit	ecoinvent dataset	Comment
3.17 Packaging - unprinted cardboard	kg	1	kg	Corrugated board box {RoW}| market for corrugated board box | Cut-off, U	
3.18 Packaging - LDPE	kg	1	kg	Packaging film, low density polyethylene {GLO}| market for packaging film, low density polyethylene | Cut-off, U	
3.19 Other material inputs - plastic	kg	1	kg	Packaging film, low density polyethylene {GLO}| market for packaging film, low density polyethylene | Cut-off, U	
3.20 Other material inputs - metal	kg	1	kg	Steel, low-alloyed {GLO}| market for steel, low-alloyed | Cut-off, U	
3.21 Other material inputs - paper	kg	1	kg	Paper, woodfree, uncoated {RoW}| market for paper, woodfree, uncoated | Cut-off, U	

Table 26 – Amount of unit processes per product in phase 3 – production.

Unit process name	Unit	BL1	BL2	ES1	ES2	ES3	BT1	BT2	HT1	HT2	WC1	WC2	BM1	BM2	BR1	BR2	HA1	HA2
3.01 Electricity from grid	kWh	2,044	2,171	0,811	1,484	1,996	3,140	3,140	3,196	3,196	1,470	1,470	2,573	2,573	6,741	6,741	0,392	0,392
3.02 Electricity from solar	kWh	0,135	0,143	0,054	0,098	0,132	-	-	-	-	-	-	-	-	-	-	-	-
3.03 Steam from biomass	tons	0,011	0,012	0,004	0,008	0,011	-	-	-	-	-	-	-	-	-	-	-	-
3.04 Natural gas	m3	0,081	0,086	0,032	0,059	0,079	0,529	0,042	0,539	0,043	0,248	0,020	0,434	0,034	1,137	0,090	0,066	0,005
3.05 Water consumption	m3	0,057	0,060	0,023	0,041	0,055	0,018	0,002	0,018	0,002	0,008	0,001	0,015	0,002	0,038	0,005	0,002	0,000
3.06 Lubricant	kg	0,0038	0,0040	0,0015	0,0027	0,0037	0,0005	0,0005	0,0005	0,0005	0,0002	0,0002	0,0004	0,0004	0,0011	0,0011	0,0001	0,0001
3.07 Chemicals for sizing, desizing, scouring 1 kg bedlinens	kg product	0,848	0,901	0,337	0,616	0,828	-	-	-	-	-	-	-	-	-	-	-	-

Unit process name	Unit	BL1	BL2	ES1	ES2	ES3	BT1	BT2	HT1	HT2	WC1	WC2	BM1	BM2	BR1	BR2	HA1	HA2
3.08 Chemicals for sizing, desizing, scouring 1 kg towel products	kg product	-	-	-	-	0,000	0,509	0,509	0,518	0,518	0,238	0,238	0,417	0,417	1,093	1,093	0,064	0,064
3.09 Chemicals for bleaching 1 kg fabric	kg product	0,848	0,901	0,337	0,616	0,828	0,509	-	0,518	-	0,238	-	0,417	-	1,093	-	0,064	-
3.10 Pigment/dye	kg pigment/ dye	0,127	0,135	-	-	-	0,038	-	0,039	-	0,018	-	0,038	-	0,071	-	0,004	-
3.11 Plastic waste	kg waste	0,0062	0,0065	0,0024	0,0045	0,0060	0,0008	0,0008	0,0008	0,0008	0,0004	0,0004	0,0006	0,0006	0,0016	0,0016	0,0001	0,0001
3.12 Metal waste	kg waste	0,0100	0,0106	0,0040	0,0072	0,0097	0,0006	0,0006	0,0006	0,0006	0,0003	0,0003	0,0005	0,0005	0,0013	0,0013	0,0001	0,0001
3.13 Paper waste	kg waste	0,0202	0,0215	0,0080	0,0147	0,0198	0,0004	0,0004	0,0004	0,0004	0,0002	0,0002	0,0003	0,0003	0,0008	0,0008	0,0000	0,0000
3.14 Textile waste	kg waste	0,034	0,036	0,013	0,025	0,033	0,024	0,024	0,024	0,024	0,011	0,011	0,019	0,019	0,051	0,051	0,003	0,003
3.15 Wastewater dye-polluted	kg wastewater	0,068	0,072	0,027	0,049	0,066	0,020	0,002	0,020	0,002	0,009	0,001	0,016	0,002	0,042	0,005	0,002	0,000
3.16 Packaging - printed cardboard	kg cardboard	0,020	0,021	0,018	0,020	0,021	0,013	0,013	0,012	0,012	0,008	0,008	0,009	0,009	0,008	0,008	0,006	0,006
3.17 Packaging - unprinted cardboard	kg cardboard	0,235	0,235	0,290	0,290	0,357	0,083	0,083	0,078	0,078	0,075	0,075	0,100	0,100	0,103	0,103	0,050	0,050
3.18 Packaging - LDPE	kg LDPE	0,001	0,001	0,001	0,001	0,001	0,003	0,003	0,003	0,003	0,002	0,002	0,003	0,003	0,003	0,003	0,001	0,001
3.19 Other material inputs - plastic	kg plastic	0,0062	0,0065	0,0024	0,0045	0,0060	0,0008	0,0008	0,0008	0,0008	0,0004	0,0004	0,0006	0,0006	0,0016	0,0016	0,0001	0,0001
3.20 Other material inputs - metal	kg metal	0,0100	0,0106	0,0040	0,0072	0,0097	0,0006	0,0006	0,0006	0,0006	0,0003	0,0003	0,0005	0,0005	0,0013	0,0013	0,0001	0,0001
3.21 Other material inputs - paper	kg paper	0,0202	0,0215	0,0080	0,0147	0,0198	0,0004	0,0004	0,0004	0,0004	0,0002	0,0002	0,0003	0,0003	0,0008	0,0008	0,0000	0,0000

5.4 Phase 4: Distribution

Phase 4 "Distribution" is divided into four sections:

1) Transport to retail in Denmark
2) Warehouse and retail
3) Disposal of freight packaging
4) Transport to consumer

The products are sold in stores all over Denmark. The distribution phase is based on a representative scenario, where the products are sold at a retail store in Odense, Denmark. Odense was selected because the city has a central location in Denmark.

Relevant information regarding distribution is summarized in Table 27. The activity data, background data and data quality are described further in the following sections.

Table 27 Relevant information regarding distribution of bedlinen and towel products

Parameter	Information
Transport from factory to retail in Denmark	Leg 1: 1120 km by truck for bedlinen products (Factory in Faisalabad, Pakistan to port in Karachi, Pakistan), 30 km by truck for towel products (Factory in Karachi, Pakistan to port in Karachi, Pakistan). Leg 2: 12.200 km by ship from port in Karachi, Pakistan to port in Copenhagen, Denmark. Leg 3: 50 km truck transport from port in Copenhagen, Denmark to warehouse in Køge, Denmark. Leg 4: 140 km truck transport from warehouse in Køge, Denmark, to retail in Odense, Denmark.
Warehouse	Ambient storage in warehouse located in Køge. The products are assumed to take up four times the space of their actual volume. The products are expected to spend 4 weeks in the warehouse. Total warehouse capacity in 'm3-weeks' is estimated based on PEF standard scenarios. Electricity and heating included based on the capacity taken up by each product.
Retail	Ambient storage in retail store located in Odense. The products are assumed to take up four times the space of their actual volume. The products are expected to spend 5 weeks in the retail store. Total retail store capacity in 'm3-weeks' is estimated based on PEF standard scenarios. Electricity included based on the capacity taken up by each product.
Transport to consumer	5 km by small passenger car assumed

5.4.1 Transport to retail in Denmark

5.4.1.1 Activity data

The products are transported from the respective factories to the Karachi port in Pakistan by truck (1120 km for bedlinen products from factory in Faisalabad and 30 km by truck for towel products from factory in Karachi). From the port in Karachi, the products are transported by container ship to the port in Copenhagen (12200 km). From the port in Copenhagen, the products are transport by truck to the warehouse in Køge (50 km). From the warehouse in Køge, the products are transported to a retail store in Odense, Denmark (140 km). The truck transport distances are estimated using the EcoTransit online tool. The sea distance was calculated using the searates.org online tool, since EcoTransit would not estimate the specific sea route.

The weight of packaging is included in the transported weight when calculating the ton-kilometers for each mode of transport.

5.4.1.2 Background data

The truck transport in Pakistan was modelled with an ecoinvent 3.10 dataset for unspecified truck in the 'Rest of World' (RoW) geography (Transport, freight, lorry, unspecified {RoW}| market for transport, freight, lorry, unspecified | Cut-off, U).

The ship transport was modelled with an ecoinvent 3.10 dataset for global container shipping (Transport, freight, sea, container ship {GLO}| transport, freight, sea, container ship | Cut-off, U).

The truck transport in Denmark was modelled with an ecoinvent 3.10 dataset for >32 ton, EURO 4 truck in the 'Rest of Europe' (RER) geography (Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U).

See overview of LCI data for phase 4 (distribution) in Table 34 and Table 35.

5.4.1.3 Data quality

The accuracy of activity data is very good since Mørkegaard knows the exact locations of each distribution step until the selected retail store. The geographical representativeness is good overall, with the datasets representing larger regions, where the exact locations fall under. The temporal representativeness is rates as poor-fair, since the original data used for the ecoinvent datasets is a little old, however ecoinvent extrapolates the data yearly to increase the temporal representativeness. The technological representativeness is rated as good. See

Table 15 for data quality rating (DQR).

Table 28 – Data quality rating (DQR) for product transport to Denmark. Accuracy is rated for the activity data. Geographical, temporal and technological representativeness is rated for the secondary data used to represent the activity data. DQR based on UN Environment Global Guidance on LCA database development with the following scale: 'very good', 'good', 'fair', 'poor', and 'very poor'.

Activity	Accuracy	Geography	Time	Technology
Truck transport Pakistan	Very good	Good	Poor	Good
Ship transport	Very good	Good	Poor	Good
Truck transport Denmark	Very good	Good	Fair	Good

5.4.2 Warehouse and retail

5.4.2.1 Activity data

Energy consumption for warehousing and retail is included in the LCA based on standard scenarios defined in the Product Environmental Footprint (PEF) Method (PEF, 2021) and the pilot PEF category rules (PEFCR) (PEFCR, 2018).

Warehousing: According to PEF (2021) the electricity consumption for an average distribution center is 30 kWh/m2/yr, while the heating consumption is 360 MJ/m2/yr. The heating is assumed to come from natural gas. An average distribution center has a size of 30.000 m2 and a storage volume of 60.000 m3 (PEF, 2021; PEFCR, 2018). The total electricity consumption for a year is calculated as 900.000 kWh, and the total heating consumption for a year is calculated as 10.800.000 MJ. The specific storage volume is calculated to be 3.120.000 m3-weeks. The specific electricity consumption is calculated as 0,29 kWh/m3-week, and the specific heating consumption is calculated as 3,46 MJ/m3-week.

Retail: According to PEF (2021) the electricity consumption for an average retail store is 150 kWh/m2/yr. An average retail store center has a size of 2.000 m2 and a storage volume of 2.000 m3 (PEF, 2021; PEFCR, 2018). The total electricity consumption for a year is calculated as 300.000 kWh. The specific storage volume is calculated to be 104.000 m3-weeks. The specific electricity consumption is calculated as 2,88 kWh/m3-week.

The storage occupancy of each product is determined based on its actual volume times four based on PEFCR (2018) guidelines. The specific storage occupancy in m3-weeks is then calculated based on the average time the product spends in storage, which is expected to be four weeks in warehouse and five weeks in the retail store. See specific occupancy of each product in Table 29 for warehousing and in Table 30 for retail.

Table 29 – Occupancy rates for each product in the LCA for warehouse.

LCA ID	Product name	Storage occupancy*** (m3)	Storage time (weeks)	Specific storage occupancy (m3-weeks)
BL1	Bedlinen 200 cm	0,012	4	0,046
BL2	Bedlinen 220 cm	0,012	4	0,046
ES1	Envelope sheet 90 cm	0,012	4	0,046
ES2	Envelope sheet 140 cm	0,012	4	0,046
ES3	Envelope sheet 180 cm	0,012	4	0,046
BT1	Bath towel, bleached and dyed	0,011	4	0,044
BT2	Bath towel, unbleached	0,011	4	0,044
HT1	Hand towel, bleached and dyed*	0,011	4	0,045
HT2	Hand towel, unbleached*	0,011	4	0,045
WC1	Washcloth, bleached and dyed**	0,007	4	0,027
WC2	Washcloth, unbleached**	0,007	4	0,027
BM1	Bath mat, bleached and dyed	0,010	4	0,042
BM2	Bath mat, unbleached	0,010	4	0,042
BR1	Bathrobe, bleached and dyed	0,049	4	0,197
BR2	Bathrobe, unbleached	0,049	4	0,197
HA1	Hair turban, bleached and dyed	0,007	4	0,030
HA2	Hair turban, unbleached	0,007	4	0,030

* 2-pack
** 5-pack
*** Estimated as four times the actual volume of the products

Table 30 – Occupancy rates for each product in the LCA for retail.

LCA ID	Product name	Storage occupancy*** (m3)	Storage time (weeks)	Specific storage occupancy (m3-weeks)
BL1	Bedlinen 200 cm	0,012	5	0,058
BL2	Bedlinen 220 cm	0,012	5	0,058
ES1	Envelope sheet 90 cm	0,012	5	0,058
ES2	Envelope sheet 140 cm	0,012	5	0,058
ES3	Envelope sheet 180 cm	0,012	5	0,058
BT1	Bath towel, bleached and dyed	0,011	5	0,055
BT2	Bath towel, unbleached	0,011	5	0,055
HT1	Hand towel, bleached and dyed*	0,011	5	0,056
HT2	Hand towel, unbleached*	0,011	5	0,056
WC1	Washcloth, bleached and dyed**	0,007	5	0,034
WC2	Washcloth, unbleached**	0,007	5	0,034
BM1	Bath mat, bleached and dyed	0,010	5	0,052
BM2	Bath mat, unbleached	0,010	5	0,052
BR1	Bathrobe, bleached and dyed	0,049	5	0,246
BR2	Bathrobe, unbleached	0,049	5	0,246
HA1	Hair turban, bleached and dyed	0,007	5	0,037
HA2	Hair turban, unbleached	0,007	5	0,037

* 2-pack
** 5-pack
*** Estimated as four times the actual volume of the products

5.4.2.2 Background data

The electricity consumed at the warehouse and the retail store was modelled with an ecoinvent 3.10 dataset for Danish residual electricity mix (Electricity, low voltage {DK}| electricity, low voltage, residual mix | Cut-off, U).

The heating consumed at the warehouse was modelled with an ecoinvent 3.10 dataset for heating from natural gas in Denmark (Heat, district or industrial, natural gas {DK}| heat and power co-generation, natural gas, combined cycle power plant, 400MW electrical | Cut-off, U).

See overview of LCI data for phase 4 (distribution) in Table 34 and Table 35.

5.4.2.3 Data quality

The activity data is of fair quality because this phase is based on a standard scenario, meaning no data was collected for the actual warehouse and retail store that the products go to. The datasets are See

Table 15 for data quality rating (DQR). The geographical representativeness of the secondary is rated as very good, since they are representative for Denmark. See Table 31 for data quality rating (DQR).

Table 31 – Data quality rating (DQR) for warehouse and retail energy consumption. Accuracy is rated for the activity data. Geographical, temporal and technological representativeness is rated for the secondary data used to represent the activity data. DQR based on UN Environment Global Guidance on LCA database development with the following scale: 'very good', 'good', 'fair', 'poor', and 'very poor'.

Activity	Accuracy	Geography	Time	Technology
Electricity for warehouse	Fair	Very good	Good	Very good
Heating for warehouse	Fair	Very good	Good	Good
Electricity for retail	Fair	Very good	Good	Very good

5.4.3 Disposal of freight packaging

5.4.3.1 Activity data

The freight packaging is disposed of after distribution. The amount of freight packaging (cardboard box and LDPE polybag) per product can be seen in Table 23.

5.4.3.2 Background data

The disposal of cardboard box was modelled with an ecoinvent 3.10 dataset for waste paperboard disposal in Denmark (Waste paperboard {DK}| market for waste paperboard | Cut-off, U).

The disposal of LDPE polybag was modelled with an ecoinvent 3.10 dataset for waste polyethylene disposal in Denmark (Waste polyethylene {DK}| market for waste polyethylene | Cut-off, U).

See overview of LCI data for phase 4 (distribution) in Table 34 and Table 35.

5.4.3.3 Data quality

The activity data is of very good quality because the packaging weight is based on the actual packaging designs. The secondary datasets are geographically representative of Denmark and waste fractions very similar to the packaging materials. See Table 32 for data quality rating (DQR).

Table 32 – Data quality rating (DQR) for disposal of freight packaging. Accuracy is rated for the activity data. Geographical, temporal and technological representativeness is rated for the secondary data used to

represent the activity data. DQR based on UN Environment Global Guidance on LCA database development with the following scale: 'very good', 'good', 'fair', 'poor', and 'very poor'.

Activity	Accuracy	Geography	Time	Technology
Cardboard disposal	Very good	Very good	Good	Good
LDPE disposal	Very good	Very good	Good	Good

5.4.4 Transport to consumer

5.4.4.1 Activity data

The transport to the consumer is based on a 5 km round trip in a personal car. It was assumed that the consumer purchased 10 kg of goods, so the 5 km round trip was distributed across that amount of goods.

5.4.4.2 Background data

The transport to consumer home was modelled with an ecoinvent 3.10 dataset for small petrol car in Europe (Transport, passenger car, small size, petrol, EURO 5 {RER}| transport, passenger car, small size, petrol, EURO 5 | Cut-off, U). See overview of LCI data for phase 4 (distribution) in Table 34 and Table 35.

5.4.4.3 Data quality

The activity data for this process is of very low quality since the distances travelled and the amount of goods purchased per trip is highly variable. Therefore, it is based on an estimated scenario. See Table 33 for data quality rating (DQR).

Table 33 – Data quality rating (DQR) for product transport to consumer home. Accuracy is rated for the activity data. Geographical, temporal and technological representativeness is rated for the secondary data used to represent the activity data. DQR based on UN Environment Global Guidance on LCA database development with the following scale: 'very good', 'good', 'fair', 'poor', and 'very poor'.

Activity	Accuracy	Geography	Time	Technology
Car transport	Very low	Good	Good	Fair

5.4.5 Phase 4 – unit process overview

Table 34 – Unit processes in phase 4 – distribution.

Unit process name	Unit process unit	Input	Input unit	ecoinvent dataset	Comment
4.1 Transport of product to retail - Bedlinen factory	kg product incl. packaging	1,12	tkm	Transport, freight, lorry, unspecified {RoW}| market for transport, freight, lorry, unspecified | Cut-off, U	Faisalabad - Karachi port (1120 km)
		12,2	tkm	Transport, freight, sea, container ship {GLO}| transport, freight, sea, container ship | Cut-off, U	Karachi port - Copenhagen port (12200 km)
		0,19	tkm	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Copenhagen port - Køge - Odense (50 km + 140 km)
4.2 Transport of product to retail - Towel factory	kg product incl. packaging	0,03	tkm	Transport, freight, lorry, unspecified {RoW}| market for transport, freight, lorry, unspecified | Cut-off, U	Karachi - Karachi port (30 km)
		12,2	tkm	Transport, freight, sea, container ship {GLO}| transport, freight, sea, container ship | Cut-off, U	Karachi port - Copenhagen port (12200 km)
		0,19	tkm	Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Cut-off, U	Copenhagen port - Køge - Odense (50 km + 140 km)
4.3 Warehouse	m3-weeks	0,29	kWh	Electricity, low voltage {DK}| electricity, low voltage, residual mix | Cut-off, U	
		3,46	MJ	Heat, district or industrial, natural gas {DK}| heat and power co-generation, natural gas, combined cycle power plant, 400MW electrical | Cut-off, U	
4.4 Retail	m3-weeks	2,88	kWh	Electricity, low voltage {DK}| electricity, low voltage, residual mix | Cut-off, U	
4.5 Freight packaging disposal cardboard	kg	1	kg	Waste paperboard {DK}| market for waste paperboard | Cut-off, U	
4.6 Freight packaging disposal LDPE	kg	1	kg	Waste polyethylene {DK}| market for waste polyethylene | Cut-off, U	
4.7 Transport to consumer home	kg product incl. packaging	0,5	km	Transport, passenger car, small size, petrol, EURO 5 {RER}| transport, passenger car, small size, petrol, EURO 5 | Cut-off, U	5 km divided by 10 kg of goods

Table 35 – Amount of unit processes per product in phase 4 – distribution.

Unit process name	Unit	BL1	BL2	ES1	ES2	ES3	BT1	BT2	HT1	HT2	WC1	WC2	BM1	BM2	BR1	BR2	HA1	HA2
4.1 Transport of product to retail - Bedlinen factory	kg product incl. packaging	1,078	1,130	0,635	0,908	1,182	-	-	-	-	-	-	-	-	-	-	-	-
4.2 Transport of product to retail - Towel factory	kg product incl. packaging	-	-	-	-	-	0,603	0,603	0,606	0,606	0,321	0,321	0,525	0,525	1,196	1,196	0,120	0,120
4.3 Warehouse	m3-weeks	0,046	0,046	0,046	0,046	0,046	0,044	0,044	0,045	0,045	0,027	0,027	0,042	0,042	0,197	0,197	0,030	0,030
4.4 Retail	m3-weeks	0,058	0,058	0,058	0,058	0,058	0,055	0,055	0,056	0,056	0,034	0,034	0,052	0,052	0,246	0,246	0,037	0,037
4.5 Freight packaging disposal cardboard	kg	0,125	0,125	0,200	0,200	0,267	0,083	0,083	0,078	0,078	0,075	0,075	0,100	0,100	0,103	0,103	0,050	0,050
4.6 Freight packaging disposal LDPE	kg	0,001	0,001	0,001	0,001	0,001	0,003	0,003	0,003	0,003	0,002	0,002	0,003	0,003	0,003	0,003	0,001	0,001
4.7 Transport to consumer home	kg product incl. packaging	0,953	1,005	0,434	0,707	0,914	0,517	0,517	0,525	0,525	0,244	0,244	0,422	0,422	1,090	1,090	0,069	0,069

5.5 Phase 5: Use of product

Phase 5 "Use of product" is divided into two sections:

1) Washing and drying
2) Disposal of consumer packaging

Relevant information regarding the use phase is summarized in Table 27. The activity data, background data and data quality are described further in the following sections.

Table 36 Relevant information regarding distribution of bedlinen and towel products

Parameter	Information
Product life time and washing/drying frequency	Based on literature values. Bedlinen and towels are estimated to be used for 2 years according to the International Fair Claims Guide for consumer textiles (Dry Cleaning Institute of Australia, 2015). Bedlinen is assumed to be washed two times per month and towels six times per month. Consequently, bedlinen products are washed 24 months x 2 times/month = 48 times in their lifetime, and towel products are washed 24 months x 6 times/month = 144 times in their lifetime.
Washing scenario	Assumed that 100% of the products are machine washed
Drying scenario	Assumed that 50% of the products are dried in a washing/drying machine, and 50% are air dried. Energy consumption for washing/drying machine based on EU Ecodesign benchmark for 7 kg machine as defined in (EU) 2019/2023.

5.5.1 Washing and drying

5.5.1.1 Activity data

The number of wash cycles in the lifetime of the products is based on literature values for life time (24 months) and assumptions regarding the number of wash cycles per month (two cycles for bedlinen products and six cycles for towel products). See Table 37.

Based on DST (2019) it was assumed that 50% of the cycles were in a washing machine combined with air drying and 50% of the cycles were in a washer-dryer. According to this statistic approximately 50% of the Danish households had a dryer in 2019.

The electricity and water consumption per cycle was taken from (EU) 2019/2023 laying down ecodesign requirements for household washing machines and household washer-dryers. The benchmark established for washing machines with a load capacity of 7 kg and washer-dryers with a load capacity of 7 kg were used. The washing in a washing machine requires 0,8 kWh/cycle and 72 L water/cycle with 7 kg textiles, while washing-drying in a washer-dryer requires 4,76 kWh/cycle and 72 L water/cycle with 7 kg textiles. These benchmarks are based on a "cotton 60 degrees" program. The energy and water consumption in the lifetime is shown in Table 37.

The amount of detergent per kg laundry was estimated based on the ecoinvent 3.10 dataset "Washing, drying and finishing laundry {GLO}| washing, drying and finishing laundry | Cut-off, U". The detergent consumption in the lifetime is shown in Table 37.

Table 37 – Number of washing cycles and consumption of electricity, water and detergent in the lifetime of each product.

LCA ID	Product name	# of cycles	Consumption in lifetime		
			kWh electricity	L water	kg detergent
BL1	Bedlinen 200 cm	48	15,6	404	0,45
BL2	Bedlinen 220 cm	48	16,5	429	0,48
ES1	Envelope sheet 90 cm	48	6,1	159	0,18
ES2	Envelope sheet 140 cm	48	11,3	293	0,33
ES3	Envelope sheet 180 cm	48	15,2	394	0,44
BT1	Bath towel, bleached and dyed	144	28,8	746	0,83
BT2	Bath towel, unbleached	144	28,8	746	0,83
HT1	Hand towel, bleached and dyed*	144	29,3	760	0,84
HT2	Hand towel, unbleached*	144	29,3	760	0,84
WC1	Washcloth, bleached and dyed**	144	13,5	350	0,39
WC2	Washcloth, unbleached**	144	13,5	350	0,39
BM1	Bath mat, bleached and dyed	144	23,6	612	0,68
BM2	Bath mat, unbleached	144	23,6	612	0,68
BR1	Bathrobe, bleached and dyed	144	61,3	1588	1,76
BR2	Bathrobe, unbleached	144	61,3	1588	1,76
HA1	Hair turban, bleached and dyed	144	3,6	93	0,10
HA2	Hair turban, unbleached	144	3,6	93	0,10

5.5.1.2 Background data

The water consumption was modelled with the following ecoinvent 3.10 dataset: Tap water {Europe without Switzerland}| tap water production, direct filtration treatment | Cut-off, U.

The detergent consumption was modelled with the following ecoinvent 3.10 dataset: Non-ionic surfactant {GLO}| market for non-ionic surfactant | Cut-off, U.

The electricity consumption was modelled with the following ecoinvent 3.10 dataset: Electricity, low voltage {DK}| market for electricity, low voltage | Cut-off, U.

See overview of LCI data for phase 5 (use of product) in Table 40 and Table 41.

5.5.1.3 Data quality

The activity data is of fair quality because this phase is based on a standard scenario, but the ecodesign benchmark is considered a good approximation. The geographical representativeness of the secondary datasets vary (very good for electricity, good for water use and very low for detergent use). See

Table 38 for data quality rating (DQR).

Table 38 – Data quality rating (DQR) for product washing and drying. Accuracy is rated for the activity data. Geographical, temporal and technological representativeness is rated for the secondary data used to represent the activity data. DQR based on UN Environment Global Guidance on LCA database development with the following scale: 'very good', 'good', 'fair', 'poor', and 'very poor'.

Activity	Accuracy	Geography	Time	Technology
Electricity use	Fair	Very good	Good	Very good
Water use	Fair	Good	Poor	Good
Detergent use	Fair	Very low	Fair	Fair

5.5.2 Disposal of consumer packaging

5.5.2.1 Activity data

The consumer packaging is disposed of by the consumer. The amount of consumer packaging (cardboard belly band) per product can be seen in Table 23. Fabric bags and ribbons are assumed to be disposed of together with the products at their end-of-life.

5.5.2.2 Background data

The disposal of cardboard was modelled with an ecoinvent 3.10 dataset for waste paperboard disposal in Denmark (Waste paperboard {DK}| market for waste paperboard | Cut-off, U). See overview of LCI data for phase 5 (use of product) in Table 40 and Table 41.

5.5.2.3 Data quality

The activity data is of very good quality because the packaging weight is based on the actual packaging designs. The secondary dataset is geographically representative of Denmark and the waste fraction is very similar to the packaging material. See Table 39 for data quality rating (DQR).

Table 39 – Data quality rating (DQR) for disposal of consumer packaging. Accuracy is rated for the activity data. Geographical, temporal and technological representativeness is rated for the secondary data used to represent the activity data. DQR based on UN Environment Global Guidance on LCA database development with the following scale: 'very good', 'good', 'fair', 'poor', and 'very poor'.

Activity	Accuracy	Geography	Time	Technology
Cardboard disposal	Very good	Very good	Good	Good

5.5.3 Phase 5 – unit process overview

Table 40 – Unit processes in phase 5 – use of product.

Unit process name	Unit process unit	Input	Input unit	ecoinvent dataset	Comment
5.1 Washing and drying	kg-cycle	10,3	kg	Tap water {Europe without Switzerland}| tap water production, direct filtration treatment | Cut-off, U	72 liter water per 7 kg cycle
		0,011	kg	Non-ionic surfactant {GLO}| market for non-ionic surfactant | Cut-off, U	
		0,40	kWh	Electricity, low voltage {DK}| market for electricity, low voltage | Cut-off, U	50% of the cycles with washing-drying machine: 4,76 kWh/7 kg cycle 50% of the cycles with washing machine and air drying: 0,8 kWh/7 kg cycle
5.2 Consumer packaging disposal	kg cardboard packaging	1,00	kg	Waste paperboard {DK}| market for waste paperboard | Cut-off, U	

Table 41 – Amount of unit processes per product in phase 5 – use of product.

Unit process name	Unit	BL1	BL2	ES1	ES2	ES3	BT1	BT2	HT1	HT2	WC1	WC2	BM1	BM2	BR1	BR2	HA1	HA2
5.1 Washing and drying	kg-cycle	39,3	41,7	15,5	28,4	38,3	72,6	72,6	73,9	73,9	34,0	34,0	59,5	59,5	154,4	154,4	9,1	9,1
5.2 Consumer packaging disposal	kg cardboard packaging	0,130	0,131	0,108	0,110	0,111	0,013	0,013	0,012	0,012	0,008	0,008	0,009	0,009	0,008	0,008	0,006	0,006

5.6 Phase 6: End-of-life of product

5.6.1 Activity data

In a Danish context, it is assumed that the textile products are either disposed of in the mixed waste or source-segregated for recycling. According to the final draft of the PEF Representative Product Study Report for Apparel and Footwear (PEF-RP A&FW, 2024) 19,5% of apparel is collected for recycling, while 80,5% of apparel is collected with mixed municipal waste. These figures will be used for a representative base case.

For incineration, the process flow is simple: it includes collection and transport to incineration facility, and the incineration process. The distance is estimated to be 41,5 km (0,0415 tkm/kg waste sent to incineration) based on data from Eurostat included in the ecoinvent dataset for mixed municipal waste in Denmark.

For recycling, the process flow was adapted from information from Københavns Kommune (2025). According to this source the textile collected in Copenhagen is first presorted locally, then transported to Poland where it is sorted and sold to recycling companies. For simplicity it is assumed that the recycling process (incl. shredding and baling) also takes place in Poland. The presorting process in Copenhagen and sorting process in Poland is assumed to consume 16,9 kWh/ton textile waste each based on a report evaluating textile recycling in a Swedish context (IVL, 2022). For shredding and baling of the sorted textiles an energy consumption of 552 kWh/ton waste is assumed based on a more recent study in the mechanical recycling of textiles in a Swedish context (IVL, 2024). The distance to presorting in Denmark is estimated to be 41,5 km (0,0415 tkm/kg waste) based on data from Eurostat included in the ecoinvent dataset for mixed municipal waste in Denmark.

The sorting and recycling location in Poland is unknown. A city located centrally in Poland (Lodz) is used for calculating the transport distance using EcoTransit. The distance by truck is 903 km from Copenhagen to Lodz (0,903 tkm/kg waste). The trip includes ferry transport, but for simplicity this ferry trip is assumed to be road transport by truck.

For the bedlinen products (BL1, BL2, ES1, ES2 and ES3) the products are packed in a self-fabric bag which is assumed to be disposed of together with the product itself.

5.6.2 Background data

For waste transport in the incineration and recycling process flows, an ecoinvent 3.10 dataset for truck transport in Europe is applied (Transport, freight, lorry, unspecified {RER}| market for transport, freight, lorry, unspecified | Cut-off, U).

For incineration, an ecoinvent 3.10 dataset for waste textile incineration in Switzerland is applied (Waste textile, soiled {CH}| treatment of waste textile, soiled, municipal incineration FAE | Cut-off, U). Switzerland is considered to have a technology level in waste incineration similar to that of Denmark.

For recycling, the presorting energy consumption in Copenhagen is represented by an ecoinvent 3.10 dataset for the residual electricity mix in Denmark (Electricity, low voltage {DK}| electricity, low voltage, residual mix | Cut-off, U). The energy consumption for sorting, shredding a baling in Poland is represented by an ecoinvent 3.10 dataset for the residual electricity mix in Poland (Electricity, low voltage {PL}| electricity, low voltage, residual mix | Cut-off, U

See overview of LCI data for phase 6 (end-of-life) in Table 43 and Table 44.

5.6.3 Data quality

The activity data is of fair quality because the distribution between incineration and recycling is based on a standard scenario from the draft PEF-RP for footwear and apparel (PEF-RP A&FW, 2024). See Table 39 for data quality rating (DQR).

Table 42 – Data quality rating (DQR) for EOL of textile products. Accuracy is rated for the activity data. Geographical, temporal and technological representativeness is rated for the secondary data used to represent the activity data. DQR based on UN Environment Global Guidance on LCA database development with the following scale: 'very good', 'good', 'fair', 'poor', and 'very poor'.

Activity	Accuracy	Geography	Time	Technology
Textile to incineration	Fair	Fair	Good	Very good
Textile to recycling	Fair	Good	Good	Fair

5.6.4 Phase 6 – unit process overview

Table 43 – Unit processes in phase 6 – end of life of product.

Unit process name	Unit process unit	Input	Input unit	ecoinvent dataset	Comment
6.1 Product EOL - incineration	kg textile to incineration	1	kg	Waste textile, soiled {CH}| treatment of waste textile, soiled, municipal incineration FAE | Cut-off, U	
		0,0415	tkm	Transport, freight, lorry, unspecified {RER}| market for transport, freight, lorry, unspecified | Cut-off, U	41,5 km to waste incinerator
6.2 Product EOL - recycling	kg textile to recycling	0,017	kWh	Electricity, low voltage {DK}| electricity, low voltage, residual mix | Cut-off, U	Electricity for first sorting
		0,017	kWh	Electricity, low voltage {PL}| electricity, low voltage, residual mix | Cut-off, U	Electricity for second sorting
		0,552	kWh	Electricity, low voltage {PL}| electricity, low voltage, residual mix | Cut-off, U	Electricity for shredding/baling
		0,945	tkm	Transport, freight, lorry, unspecified {RER}| market for transport, freight, lorry, unspecified | Cut-off, U	41,5 km to first sorting point, 903 km to second sorting/recycling point in Poland

Table 44 – Amount of unit processes per product in phase 6 – end of life of product.

Unit process name	Unit	BL1	BL2	ES1	ES2	ES3	BT1	BT2	HT1	HT2	WC1	WC2	BM1	BM2	BR1	BR2	HA1	HA2
6.1 Product EOL - incineration	kg textile to incineration	0,662	0,704	0,263	0,481	0,647	0,406	0,406	0,413	0,413	0,190	0,190	0,332	0,332	0,871	0,871	0,051	0,051
6.2 Product EOL - recycling	kg textile to recycling	0,160	0,170	0,064	0,117	0,157	0,098	0,098	0,100	0,100	0,046	0,046	0,081	0,081	0,211	0,211	0,012	0,012

6 Life cycle impact assessment (LCIA)

6.1 LCIA procedures and calculations

The LCIA method Environmental Footprint (EF) 3.1 was selected for this project, since it covers a broad range of environmental impact categories as listed below:

1. Climate change
2. Climate change - Biogenic
3. Climate change - Fossil
4. Climate change – Land use and land use change
5. Acidification
6. Ecotoxicity, freshwater
7. Particulate matter
8. Eutrophication, marine
9. Eutrophication, freshwater
10. Eutrophication, terrestrial
11. Human toxicity, cancer
12. Human toxicity, non-cancer
13. Ionising radiation
14. Land use
15. Ozone depletion
16. Photochemical ozone formation
17. Resource use, fossils
18. Resource use, minerals and metals
19. Water use

The impact category "climate change" is the sum of "climate change – biogenic", "climate change – fossil" and "climate change – land use and land use change". SimaPro v. 9.6 was used to conduct the calculations.

The LCA has been conducted according to this LCIA method to have a broad overview of environmental impacts, and to avoid burden shifting, when the results are used for minimizing the environmental impact of the products. Climate change is a particularly relevant impact category for Mørkegaard since this impact category is more well known by the average consumer and the impact category result will be printed on the product packaging. This impact category will also be the main focus of the contribution analysis and sensitivity analysis carried out in this study.

6.2 LCIA results

The LCIA results per product can be seen in Table 45. Please note that the numbers have different units per impact category meaning that the impact categories cannot be compared to each other. The numbers are shown using scientific notation due to some very small numbers in certain impact categories (i.e., human toxicity). An example of how to read scientific notation is as follows: "1,2E+01" means 12, while "1,2E-01" means 0,12.

In Figure 5 the climate change impact (kg CO2e) per product is presented visually.

Table 45 LCIA results for the 19 impact categories assessed per product. **

Impact category	Unit	BL1	BL2	ES1	ES2	ES3	BT1	BT2	HT1	HT2	WC1	WC2	BM1	BM2	BR1	BR2	HA1	HA2
Climate change	kg CO2 eq	1,3E+01	1,4E+01	5,5E+00	9,5E+00	1,3E+01	1,5E+01	1,3E+01	1,5E+01	1,3E+01	7,0E+00	6,0E+00	1,2E+01	1,0E+01	3,2E+01	2,7E+01	2,0E+00	1,7E+00
Climate change - Biogenic	kg CO2 eq	3,1E-01	3,3E-01	1,5E-01	2,4E-01	3,2E-01	1,8E-01	1,8E-01	1,8E-01	1,8E-01	8,8E-02	8,7E-02	1,5E-01	1,5E-01	3,7E-01	3,6E-01	2,8E-02	2,8E-02
Climate change - Fossil	kg CO2 eq	1,2E+01	1,2E+01	4,8E+00	8,4E+00	1,1E+01	1,3E+01	1,1E+01	1,4E+01	1,1E+01	6,3E+00	5,4E+00	1,1E+01	9,3E+00	2,9E+01	2,4E+01	1,8E+00	1,5E+00
Climate change – LULUC*	kg CO2 eq	1,2E+00	1,3E+00	4,7E-01	8,6E-01	1,2E+00	1,2E+00	1,2E+00	1,2E+00	1,2E+00	5,7E-01	5,7E-01	1,0E+00	1,0E+00	2,6E+00	2,6E+00	1,5E-01	1,5E-01
Acidification	mol H+ eq	9,7E-02	1,0E-01	4,0E-02	7,1E-02	9,5E-02	8,7E-02	8,2E-02	8,8E-02	8,3E-02	4,1E-02	3,9E-02	7,2E-02	6,7E-02	1,9E-01	1,7E-01	1,2E-02	1,1E-02
Ecotoxicity, freshwater	CTUe	1,4E+02	1,5E+02	5,6E+01	9,9E+01	1,3E+02	1,9E+02	1,8E+02	1,9E+02	1,9E+02	9,0E+01	8,6E+01	1,6E+02	1,5E+02	4,0E+02	3,9E+02	2,4E+01	2,3E+01
Particulate matter	disease inc.	7,2E-07	7,6E-07	3,1E-07	5,3E-07	7,0E-07	6,5E-07	6,0E-07	6,6E-07	6,1E-07	3,1E-07	2,9E-07	5,4E-07	5,0E-07	1,4E-06	1,3E-06	8,8E-08	8,2E-08
Eutrophication, marine	kg N eq	1,1E-01	1,2E-01	4,4E-02	8,0E-02	1,1E-01	8,6E-02	8,4E-02	8,7E-02	8,6E-02	4,0E-02	4,0E-02	7,0E-02	6,9E-02	1,8E-01	1,8E-01	1,1E-02	1,1E-02
Eutrophication, freshwater	kg P eq	1,7E-02	1,8E-02	6,7E-03	1,2E-02	1,6E-02	1,4E-02	1,3E-02	1,4E-02	1,4E-02	6,4E-03	6,3E-03	1,1E-02	1,1E-02	2,9E-02	2,8E-02	1,7E-03	1,7E-03
Eutrophication, terrestrial	mol N eq	3,1E-01	3,2E-01	1,3E-01	2,2E-01	3,0E-01	2,5E-01	2,4E-01	2,5E-01	2,4E-01	1,2E-01	1,1E-01	2,0E-01	2,0E-01	5,3E-01	5,0E-01	3,3E-02	3,1E-02
Human toxicity, cancer	CTUh	5,3E-08	5,7E-08	2,1E-08	3,6E-08	4,9E-08	5,9E-08	5,0E-08	6,0E-08	5,1E-08	2,8E-08	2,4E-08	4,8E-08	4,1E-08	1,2E-07	1,1E-07	7,6E-09	6,6E-09
Human toxicity, non-cancer	CTUh	-3,1E-08	-3,3E-08	-6,4E-09	-2,1E-08	-2,9E-08	1,3E-07	1,1E-07	1,3E-07	1,2E-07	6,0E-08	5,5E-08	1,1E-07	9,5E-08	2,7E-07	2,4E-07	1,8E-08	1,6E-08
Ionising radiation	kBq U-235 eq	1,5E+00	1,6E+00	6,2E-01	1,1E+00	1,5E+00	2,2E+00	2,1E+00	2,2E+00	2,2E+00	1,0E+00	1,0E+00	1,8E+00	1,8E+00	4,7E+00	4,6E+00	2,9E-01	2,8E-01
Land use	Pt	8,9E+02	9,4E+02	3,7E+02	6,5E+02	8,8E+02	6,8E+02	6,7E+02	6,9E+02	6,8E+02	3,2E+02	3,2E+02	5,6E+02	5,5E+02	1,4E+03	1,4E+03	8,7E+01	8,7E+01
Ozone depletion	kg CFC11 eq	3,8E-07	4,0E-07	1,8E-07	2,8E-07	3,6E-07	3,9E-07	3,1E-07	3,8E-07	3,0E-07	1,7E-07	1,3E-07	3,2E-07	2,5E-07	8,9E-07	7,2E-07	6,1E-08	5,1E-08
Photochemical ozone formation	kg NMVOC eq	5,2E-02	5,5E-02	2,2E-02	3,8E-02	5,0E-02	5,4E-02	4,9E-02	5,5E-02	4,9E-02	2,6E-02	2,3E-02	4,5E-02	4,0E-02	1,2E-01	1,0E-01	7,3E-03	6,6E-03
Resource use, fossils	MJ	1,6E+02	1,7E+02	6,5E+01	1,1E+02	1,5E+02	2,0E+02	1,7E+02	2,0E+02	1,7E+02	9,5E+01	8,0E+01	1,7E+02	1,4E+02	4,3E+02	3,6E+02	2,7E+01	2,3E+01
Resource use, minerals and metals	kg Sb eq	1,3E-04	1,4E-04	5,3E-05	9,4E-05	1,3E-04	1,9E-04	1,8E-04	1,9E-04	1,9E-04	9,0E-05	8,6E-05	1,6E-04	1,5E-04	4,1E-04	3,9E-04	2,5E-05	2,3E-05
Water use	m3 depriv.	5,1E+00	5,4E+00	2,1E+00	3,6E+00	4,9E+00	5,7E+00	5,3E+00	5,8E+00	5,4E+00	2,7E+00	2,5E+00	4,7E+00	4,3E+00	1,2E+01	1,1E+01	7,4E-01	6,9E-01

* LULUC = Land use and land use change

** Numbers are shown in scientific notation due to some very small numbers in certain impact categories. Example: "1,2E+01" means 12, while "1,2E-01" means 0,12.

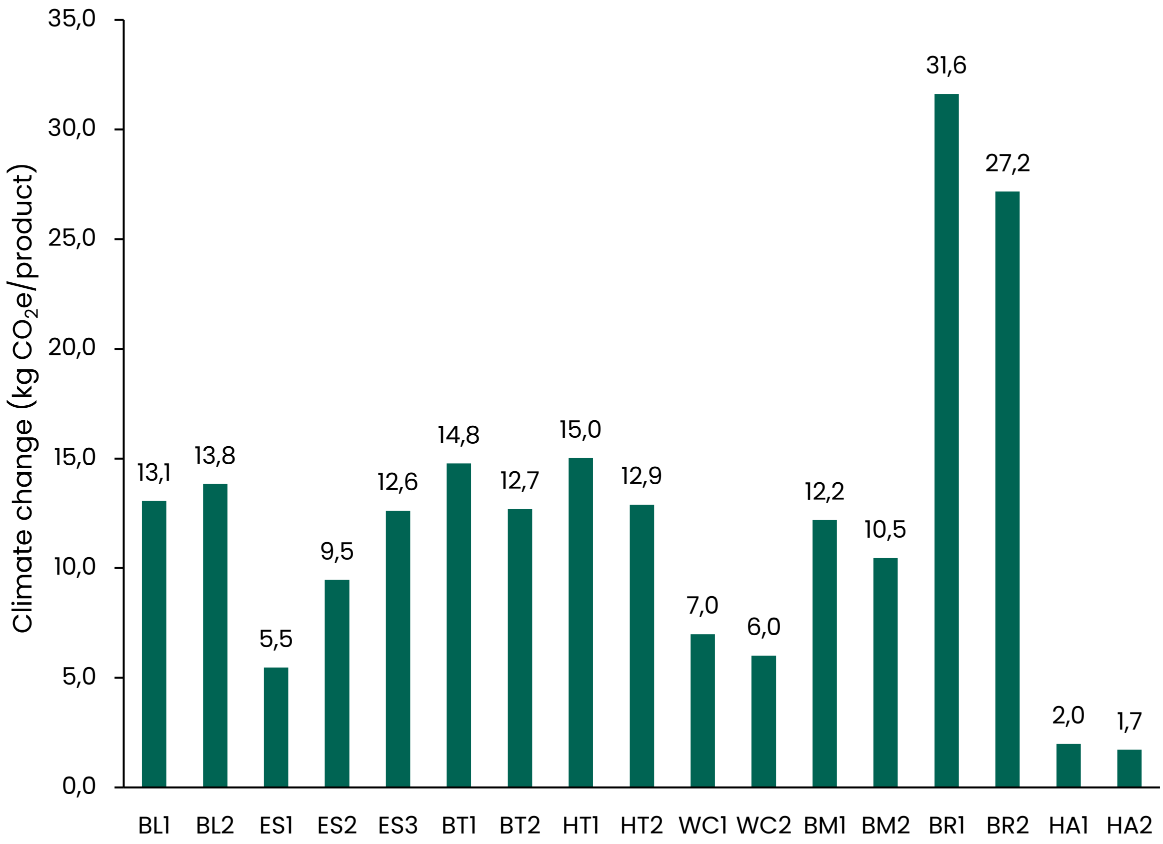

Figure 5 Climate change impact of each product in the LCA across the whole life cycle. Please note that the results for HT1 and HT2 are for a two-pack, and the results for WC1 and WC2 are for a 5-pack.

6.3 Contribution analysis

The % contribution of each life cycle phase to the climate change impact can be seen in Figure 6 for each product. 'Phase 4 - use of product' is the most contributing life cycle phase to the climate change impact, contributing with 34-37% of the impact for bedlinen products (BL1, BL2, ES1, ES2, and ES3) and contributing with 55-69% of the impact for towel products (BT1, BT2, HT1, HT2, WC1, WC2, BM1, BM2, BR1, BR2, HA1, and HA2).

The second most contributing life cycle phase is 'Phase 3 – production' for all products except for the unbleached towel products (BT2, HT2, WC2, BM2, BR2, HA2). For the unbleached towel products, the second most contributing life cycle stage is "Phase 1 – Raw materials".

Overall, 'Phase 1 – raw materials', 'Phase 3 – production', and 'Phase 4 - use of product' together account for 87-95% of the total climate change impact, meaning that the life cycle phases 'Phase 2 – raw material transport', 'Phase 4 - distribution', and 'Phase 6 – end-of-life of product' contribute with 5-13% of the total climate change impact per product. The most contributing life cycle phases will be examined further.

For the other impact categories, the contribution analyses can be found in Section 10.5 (appendix).

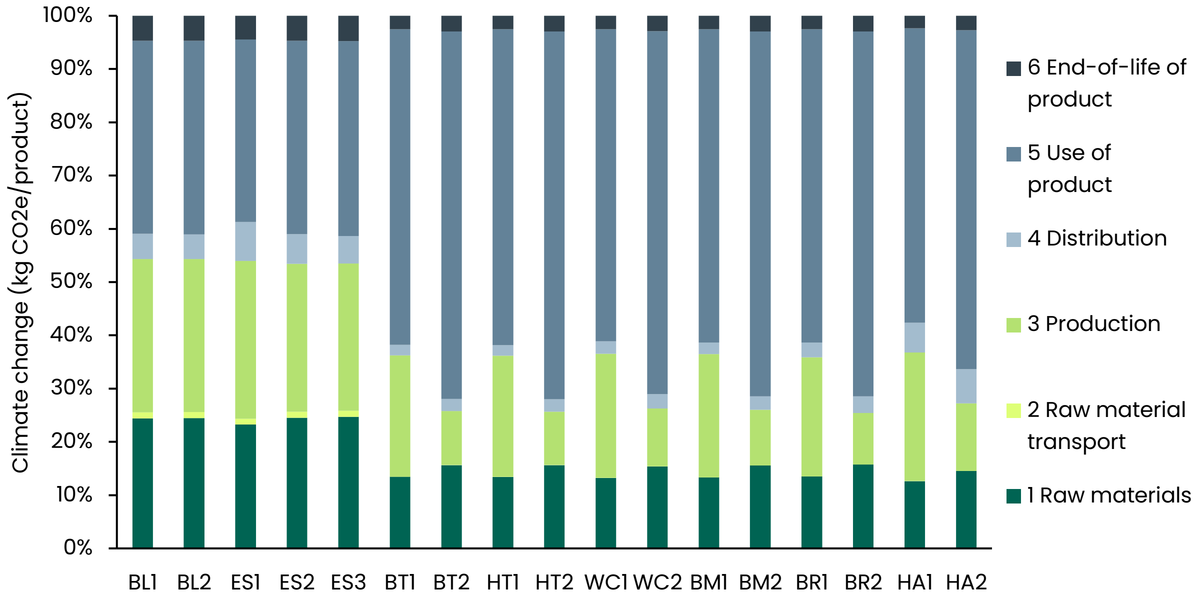

Figure 6 Contribution of each life cycle phase to the 'climate change' impact category per product in the LCA.

6.3.1 Process contribution – phase 1

In Figure 7 the contribution of processes in 'phase 1 – raw materials' to the total climate change impact in phase 1 can be seen. It shows that cotton cultivation and yarn spinning are the most contributing processes in this phase.

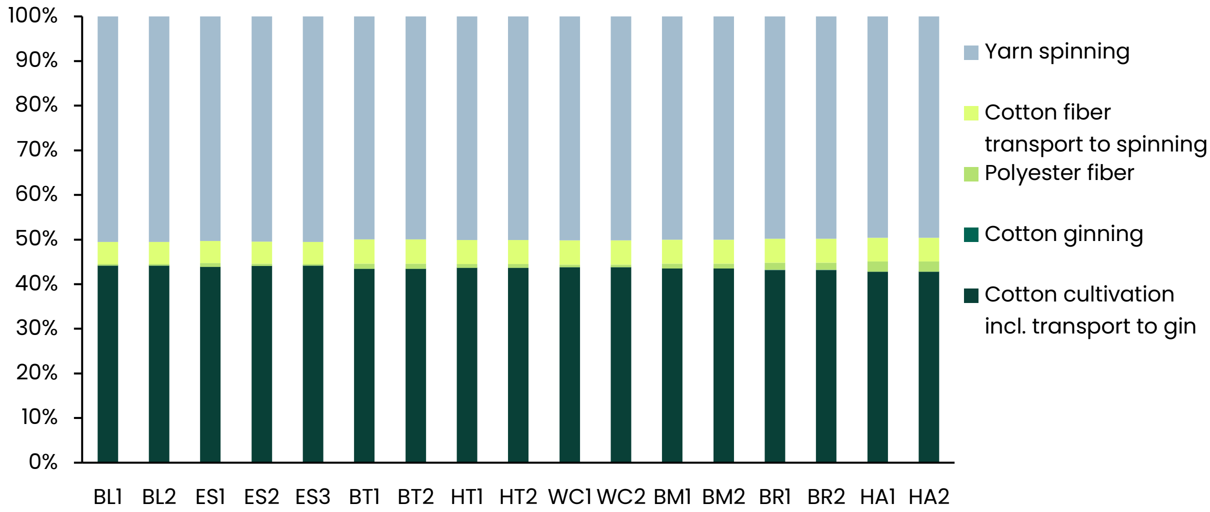

Figure 7 Contribution of processes in 'phase 1 – raw materials' to the total 'climate change' impact category for 'phase 1 – raw materials'.

6.3.2 Process contribution – phase 3

In Figure 8 the contribution of processes in 'phase 3 – production' to the total climate change impact in phase 3 can be seen. It shows that for bedlinen products, chemicals are the most contributing process, which is also the case for unbleached towel products. For bleached and dyed towel products, heat from natural gas is the most contributing process in this phase. Electricity and packaging make a visible contribution to all products, while waste and wastewater, water input and inputs of other materials contribute very little. Here it should be noted that these processes may have a higher contribution in other environmental impact categories.

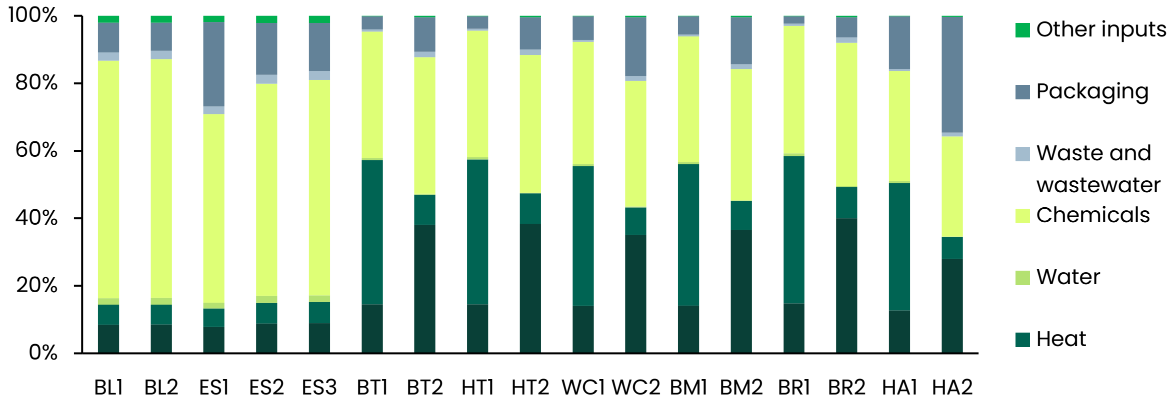

Figure 8 Contribution of processes in 'phase 3 – production' to the total 'climate change' impact category for 'phase 3 – production'.

6.3.3 Process contribution – phase 5

In Figure 9 the contribution of processes in 'phase 5 – use of product' to the total climate change impact in phase 5 can be seen. It shows that electricity and detergent are the most contributing processes in this phase.

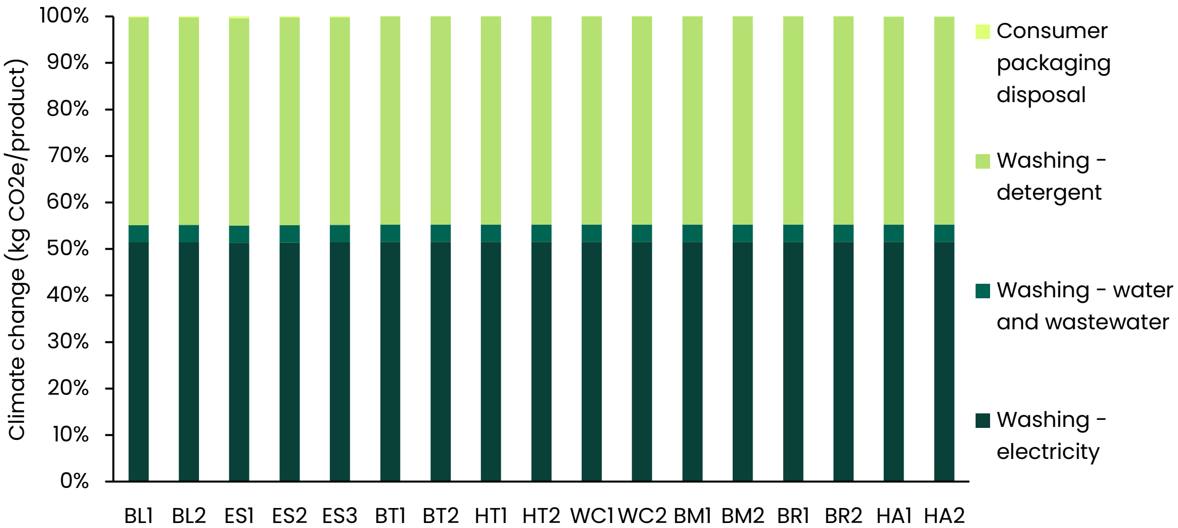

Figure 9 Contribution of processes in 'phase 5 – use of product' to the total 'climate change' impact category for 'phase 5 – use of product'.

7 Life cycle interpretation

7.1 Significant findings

The use phase contributes highly to climate change impact

'Phase 4 - use of product' is the most contributing life cycle phase to the climate change impact across all products, contributing with 34-37% of the impact for bedlinen products (BL1, BL2, ES1, ES2, and ES3) and contribution with 55-69% of the impact for towel products (BT1, BT2, HT1, HT2, WC1, WC2, BM1, BM2, BR1, BR2, HA1, and HA2). 'Phase 3 – production' is the second most contributing life cycle phase for all products except for the unbleached towel products, and for these products 'Phase 1 – Raw materials' is the third most contributing phase. For the unbleached towel products (BT2, HT2, WC2, BM2, BR2, HA2) it is the other way around.

Raw material transport and distribution has little climate change contribution

The life cycle phases 'Phase 2 – raw material transport' and 'Phase 4 - distribution' contribute with 2-8% of the total climate change impact per product.

Production and use have the highest contribution to water use

Production and use of product (washing) have the highest contribution to water use. Raw materials do not contribute significantly to the water use impact, due to the background dataset assuming no irrigation of cotton fields.

Raw materials contribute the most to land use and eutrophication

The raw materials phase contributes the most to the land use impact due to cotton growing activities taking up land. The amount of land used for cotton growing and the land use change (i.e., deforestation) is not specifically accounted for in this LCA, although the effect is included in the generic background dataset for cotton farming.

Raw materials also contribute highly to the eutrophication impact categories (addition of nutrients to land, sea and freshwater), which is mainly due to the use of manure in the cotton farm.

Unbleached towel products have a lower climate change impact

Unbleached towel products have a 13-14% lower climate change impact across the whole life cycle compared to bleached and dyed towel products. For phase 3 – production the reduction in climate change impact is between 54-63% for unbleached towels compared to bleached and dyed towels. For bedlinen the collected data for the production phase was not detailed enough to properly distinguish between bleached and printed products and bleached products.

7.2 Sensitivity analysis

7.2.1 Scenario: Bedlinen with zipper

The bedlinen products, BL1 and BL2, are designed without a zipper, using instead cotton laces to tie together the opening in the bedsheet. It was investigated what the difference in environmental impact is for the designed solution compared to a solution with zipper. The cotton laces weigh 5,5 g, while a 140 cm zipper weights 12,3 g (11,9 g polyester tape and teeth + 0,42 g hard plastic slider). It is assumed that the hard plastic slider is made of glass fiber reinforced polyamide. In Table 46 the background dataset used for the zipper analysis is shown.

Table 46 – Unit process data for 1 zipper production and disposal

Component	Input	Ecoinvent 3.10 dataset	Comment
Tape and teeth production	12,1 g	Fibre, polyester {GLO}| market for fibre, polyester | Cut-off, U	Accounting for 1,5% loss in weaving.
	11,9 g	Weaving, synthetic fibre {GLO}| market for weaving, synthetic fibre | Cut-off, U	
Slider production	0,42 g	Glass fibre reinforced plastic, polyamide, injection moulded {GLO}| market for glass fibre reinforced plastic, polyamide, injection moulded | Cut-off, U	
Zipper disposal	12,3 g	Waste textile, soiled {RoW}| market for waste textile, soiled | Cut-off, U	

In Figure 10 the two solutions are compared across the raw materials phase and the end-of-life phase. The change from cotton laces to zipper makes barely any difference when looking at the whole life cycle impact of the bedlinen. Therefore, the impact of the solutions is shown separately from the whole life cycle impact of the bedlinen. The zipper solution has more than three times higher climate change impact in the raw materials phase, while the climate change impact in the end-of-life phase is more than two times higher.

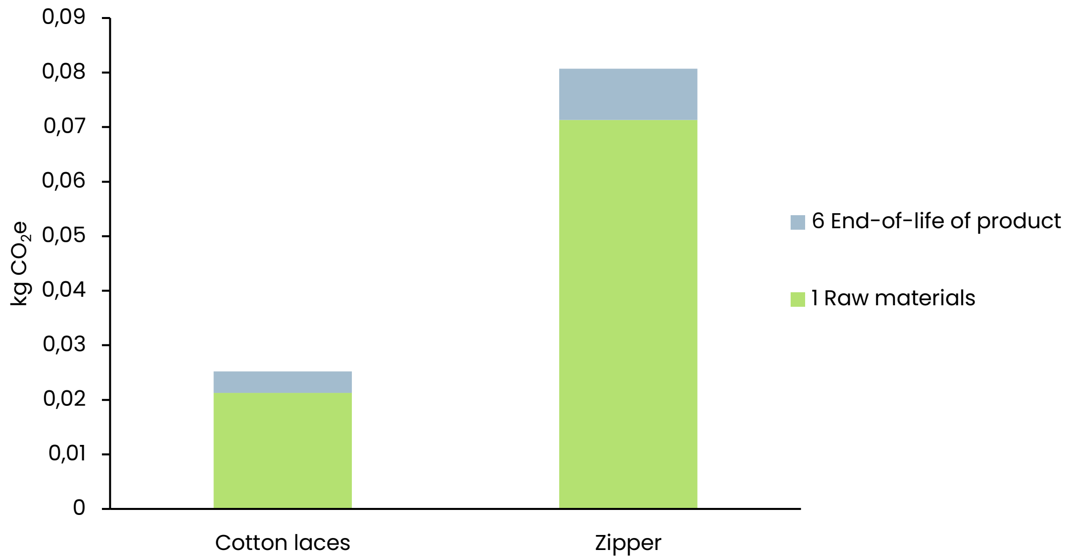

Figure 10 – Climate change impact of cotton laces (5,5 g) and zipper (12,3 g) divided into 'phase 1 – raw materials' and 'phase 6 – end-of-life of product'.

It should be noted that the cotton lace solution was selected to enhance the recyclability of the bedlinen at its end-of-life. If the bedlinen becomes more recyclable at the end-of-life, more recovered material will emerge after recycling, meaning that more virgin material will be displaced, and less material will be incinerated with energy recovery. The effects of this shift are very uncertain and have therefore not been quantified.

7.2.2 Machine drying vs. airdrying of textiles

The effect of using 100% machine drying and 100% air drying instead of 50% of each (as assumed in this LCA) was analyzed. The washing-drying process of 1 kg textiles in this LCA in the three scenarios can be seen in Figure 11. It was found that changing from 100% machine drying to 100% air drying decreased the total climate change impact of the washing-drying process with 54%. With this process contributing 34-69% of the total life cycle climate change impacts, the effect of using air-drying instead of machine drying can be quite significant.

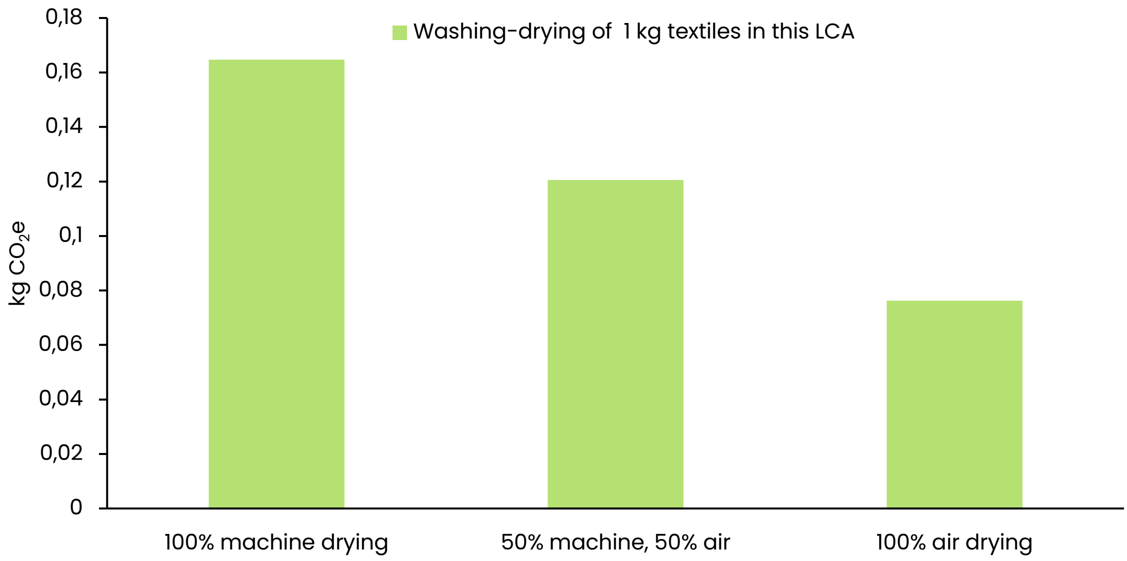

Figure 11 – Scenario evaluating the climate change impact on the washing-drying process of 1 kg textiles in this LCA when using machine drying vs. air drying.

7.3 Assumptions and limitations

Assumptions and limitations of this LCA can be seen in Table 47.

Table 47 Assumptions and limitations per life cycle phase in the LCA

Phase	Assumptions and limitations
1 Raw materials and 2 Raw material transport	• Care labels made of cotton have different supply chains than the cotton for the main fabric, however, in the LCA it is assumed that the care label cotton has the same supply chain as the main fabric cotton. Care labels only account for a small percentage of the composition of the final products (in the range 0,2-4,2% for all products except for HA1 and HA2, where care label accounts for 9,5% of the product weight). • Cotton used for bedlinen is cultivated in Türkiye, but the specific region in Türkiye is unknown. As a major cotton hub in Türkiye, Sanliurfa in Southwest Anatolia is assumed. • For some processes in the supply chain only the region in Pakistan is known. For the region Sindh, Pakistan, the city of Karachi is generally assumed, and for the region of Punjab, Pakistan, the city of Faisalabad is generally assumed. • For transport within the same city a distance of 50 km is assumed. • It is assumed that ginning takes place near the cotton farms • A major limitation in the raw materials phase is the lack of regionalized datasets for organic cotton. Therefore, a secondary dataset from ecoinvent for organic cotton cultivation in India was used. • It is assumed that polyester fiber production and polyester spinning are carried out in the same factory

Phase	Assumptions and limitations

3 Production	• Bedlinen factory:
	  ○ It is assumed that the steam used in the factory is low pressure saturated steam (the consumption of steam was only given in tons)
	  ○ It is assumed that the biomass used for steam production is "wood chips".
	  ○ It is assumed that the amount of plastic, metal and paper waste leaving the factory is plastic, metal and paper that enters the factory as i.e., packaging.
	  ○ The types and amount of chemicals listed by the factory for wet processing were supplemented with data from literature (i.e. sodium hydroxide, sodium silicate, etc.)
	• Towel factory:
	  ○ It is assumed that the amount of wastewater is equal to 110% of the water input to the factory.
	  ○ It is assumed that the amount of plastic, metal and paper waste leaving the factory is plastic, metal and paper that enters the factory as i.e., packaging.
	  ○ The types and amount of chemicals listed by the factory for wet processing were supplemented with data from literature (i.e. sodium hydroxide, sodium silicate, etc.)

4 Distribution	• The distribution scenario is based on distribution to a retail store in Odense, Denmark (selected for its central location within Denmark). • Energy consumption for warehouse and retail is estimated based on standard scenarios defined in PEF. • Transport to consumer home is assumed to be 5 km and in a small passenger car. It is assumed as a conservative estimate that the consumer comes to the store only to buy one product, meaning that 5 km of transport is added for each product.
5 Use of product	• It is assumed that for 50% of the use cycles the products are air dried and for 50% of the use cycles the products are machine dried. • Consumption of electricity and water are based on European ecodesign benchmarks for 7 kg washer-dryers operating on a 60 degrees cotton program. • Consumption of detergent per kg laundry is based on an ecoinvent 3.10 dataset for commercial laundry operation
6 End-of-life of product	• Based on the draft PEFCR for Apparel and Footwear it is assumed that 80,5% of the products are sent to incineration and 19,5% of the products are sent to recycling. • Energy consumption for sorting, shredding, and baling is based on literature values from a Swedish textile recycling scenario • It is assumed that consumer packaging made of cotton fabric (self-fabric bag and cotton ribbon) is disposed of together with the product itself in phase 6. Other consumer packaging (cardboard) is disposed of in phase 5. • The sorting and recycling location in Poland is unknown. A city located centrally in Poland (Lodz) is assumed. • The truck transport from Denmark to recycling in Poland includes a ferry trip. For simplicity, the distance of the ferry trip is added to the distance of the road transport by truck.

8 Conclusions and recommendations

A life cycle assessment (LCA) was carried out to investigate the environmental impacts arising in the full life cycle of five *Nord Harmony* bedlinen products and 12 *Nord Harmony* towel products. The assessed life cycle phases were (1) Raw materials, (2) Raw material transport, (3) Production, (4) Distribution, (5) Use of product, and (6) End-of-life of product.

The goal of the assessment was to get a deeper understanding of the environmental impacts of the products, and to label the product packaging with the climate change impact (greenhouse gas emissions) of the products.

The environmental impact of the products was evaluated across 19 impact categories according to the EF3.1 LCIA method. The climate change impact of all 17 products is shown in Table 1.

Table 48 – Climate change impact of the 17 products evaluated in the life cycle assessment (LCA) – total across the six life cycle phases.

LCA ID	Product name	Climate change impact (kg CO2e)
BL1	Bedlinen 200 cm (one set)	13,1
BL2	Bedlinen 220 cm (one set)	13,8
ES1	Envelope sheet 90 cm (one piece)	5,5
ES2	Envelope sheet 140 cm (one piece)	9,5
ES3	Envelope sheet 180 cm (one piece)	12,6
BT1	Bath towel, bleached and dyed (one piece)	14,8
BT2	Bath towel, unbleached (one piece)	12,7
HT1	Hand towel, bleached and dyed (two-pack)	15,0
HT2	Hand towel, unbleached (two-pack)	12,9
WC1	Washcloth, bleached and dyed (five-pack)	7,0
WC2	Washcloth, unbleached (five-pack)	6,0
BM1	Bath mat, bleached and dyed (one piece)	12,2
BM2	Bath mat, unbleached (one piece)	10,5
BR1	Bathrobe, bleached and dyed (one piece)	31,6
BR2	Bathrobe, unbleached (one piece)	27,2
HA1	Hair turban, bleached and dyed (one piece)	2,0
HA2	Hair turban, unbleached (one piece)	1,7

It was found that 'Phase 4 - use of product' is the most contributing life cycle phase to the climate change impact across all products, contributing with 34-37% of the impact for bedlinen products (BL1, BL2, ES1, ES2, and ES3) and contributing with 55-69% of the impact for towel products (BT1, BT2, HT1, HT2, WC1, WC2, BM1, BM2, BR1, BR2, HA1, and HA2). This is due to the many wash cycles in the life cycle of the products (48 for bedlinen and 144 for towel products). The number of wash cycles and the consumption of water, electricity and detergent for washing was based on literature data, which could be improved for higher accuracy.

'Phase 1 – raw materials' also contributed significantly to the climate change impacts of all products, especially the cotton cultivation process and yarn spinning process. Since it was not possible to obtain data for organic cotton cultivation in Türkiye and Pakistan, a dataset for India was used. This is considered an important limitation of this LCA study. In the future, it is recommended that the LCA is updated with country- or region-specific data for organic cotton cultivation.

'Phase 3 – production' also contributed significantly to the climate change impacts of all products, mainly due to chemicals, heat and electricity. For bedlinen the use of chemicals was more contributing than energy, while energy was more contributing for the towel products. For towel products it was also found unbleached products had 54-63% lower climate change impact in the production phase than bleached and dyed products. Looking at the total climate change impact, unbleached towel products had 13-14% lower impact than bleached and dyed towel products.

In a sensitivity scenario the effect of using a polyester zipper instead of cotton laces to close the bed sheets (BL1 and BL2) was analyzed. It was found that in the whole life cycle of the product the effect on climate change was negligible. However, when looking only at the cotton lace solution and the zipper solution, it was found that the zipper had 3 times higher climate change impact in the raw material phase than the cotton laces, and 2 times higher climate change impact in the end-of-life of product phase. The potential benefits of increased recyclability of the bed sheets when using cotton laces were not included in the analysis. It is recommended to collect actual data for recyclability of the products, and more accurate data for the recycling value chain when sending cotton waste to recycling in Denmark.

Furthermore, large differences were observed in the energy consumption and waste amounts per kg of product across the two factories. In the future it is recommended that even more effort is made to properly allocate the inputs and outputs from the factories to each processing step.

9 References

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10 Appendix

10.1 Product pictures

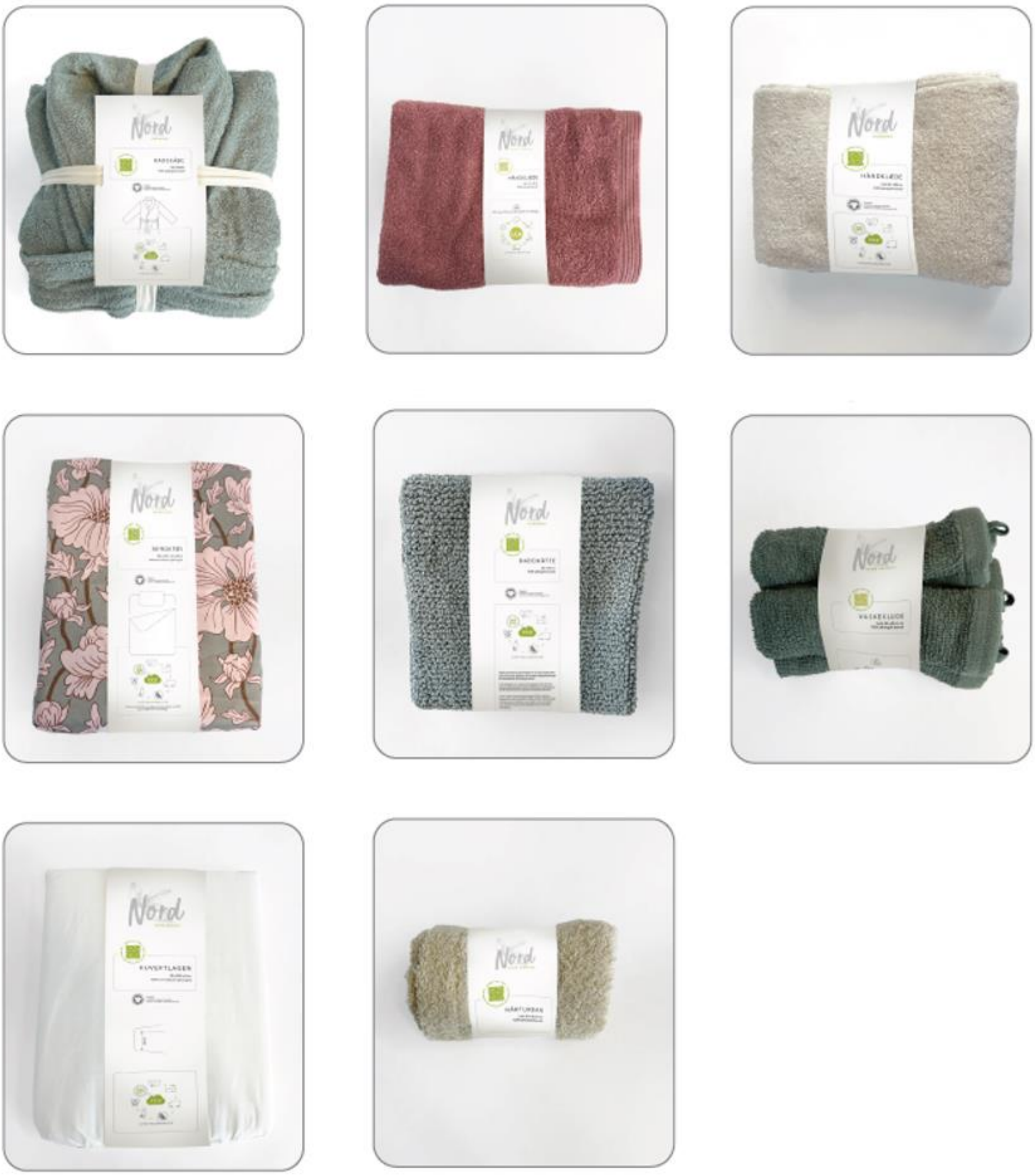

Figure 12: Product pictures (same product types and packaging as the products assessed in this LCA, but not the actual products). The pictures represent (from left to right, from top to bottom): Bathrobe, towel (1-pack), towel (2-pack), bed sheets, bath mat, wash cloths (5-pack), envelope sheet, hair turban.

10.2 Bedlinen factory – determination of inputs and outputs

Table 49 – Determining energy and consumables per kg of final bedlinen product

Input	Procedure for determining input per kg final product
Electricity for weaving (sub-meter)	Electricity for weaving (1.956.299 kWh) was divided by the amount of fabric woven in the factory (1.517.529 kg) and multiplied by 1,03 to account for losses in the cut and sew step. 6,2% of the electricity comes from solar, the rest comes from the grid.
Electricity for wet processing (sub-meter)	Electricity for wet processing (13.687.418 kWh) was divided by the amount of fabric passing through wet processing in the factory (12.302.165 kg) and multiplied by 1,03 to account for losses in the cut and sew step. 6,2% of the electricity comes from solar, the rest comes from the grid.
Electricity for cut and sew (sub-meter)	Electricity for cut and sew (762.731 kWh) was divided by the amount of fabric passing through cut and sew in the factory (4.866.310 kg) and multiplied by 1,03 to account for losses in the cut and sew step. 6,2% of the electricity comes from solar, the rest comes from the grid.
Electricity for other (sub-meter)	Electricity for other processes (126.693 kWh) was divided by the amount of fabric passing through wet processing in the factory (12.302.165 kg) and multiplied by 1,03 to account for losses in the cut and sew step. 6,2% of the electricity comes from solar, the rest comes from the grid.
Steam from biomass	Steam from biomass (163.326 tons) was divided by the amount of fabric passing through wet processing in the factory (12.302.165 kg) and multiplied by 1,03 to account for losses in the cut and sew step.
Natural gas	Natural gas (41.635 mmBTU = 1.176.785 m3) was divided by the amount of fabric passing through wet processing in the factory (12.302.165 kg) and multiplied by 1,03 to account for losses in the cut and sew step.
Clean water	Clean water (823.011 m3) was divided by the amount of fabric passing through wet processing in the factory (12.302.165 kg) and multiplied by 1,03 to account for losses in the cut and sew step.
Lubricants	Lubricant (54.743 kg) was divided by the amount of fabric passing through wet processing in the factory (12.302.165 kg) and multiplied by 1,03 to account for losses in the cut and sew step.
Plastic	Plastic input to the factory was assumed to be the same amount as the plastic waste leaving the factory. See calculation of plastic waste.
Metal	Metal input to the factory was assumed to be the same amount as the metal waste leaving the factory. See calculation of metal waste.
Paper	Paper input to the factory was assumed to be the same amount as the paper waste leaving the factory. See calculation of paper waste.
Starch for sizing	8-10% of yarn weight according to factory (9% assumed). Multiplied by 1,03 to account for losses in the cut and sew step.
Enzyme for desizing	0,2% of enzyme in solution according to factory. Assumed 20 L solution per kg fabric. Multiplied by 1,03 to account for losses in the cut and sew step.
Sodium hydroxide for scouring	3% of sodium hydroxide in solution based on CBSE (2014). Assumed 20 L solution per kg fabric. Multiplied by 1,03 to account for losses in the cut and sew step.
Hydrogen peroxide for bleaching	3% of the fabric weight according to factory. Multiplied by 1,03 to account for losses in the cut and sew step.
Sodium hydroxide for bleaching	2% of sodium hydroxide in solution based on CBSE (2014). Assumed 20 L solution per kg fabric. Multiplied by 1,03 to account for losses in the cut and sew step.

Input	Procedure for determining input per kg final product
Sodium silicate for bleaching	3% of sodium silicate in solution based on CBSE (2014). Assumed 20 L solution per kg fabric. Multiplied by 1,03 to account for losses in the cut and sew step.
Pigment agent	Pigment agent (664.451 kg) was divided by the amount of fabric passing through printing in the factory (4.509.466 kg) and multiplied by 1,03 to account for losses in the cut and sew step.

Table 50 – Determining waste and wastewater per kg of final bedlinen product

Output	Procedure for determining input per kg final product
Plastic waste	Plastic waste (1.429 kg) and 50% of "Empty drums and cans" (87.900 kg) was divided by the amount of fabric passing through wet processing in the factory (12.302.165 kg) and multiplied by 1,03 to account for losses in the cut and sew step.
Metal waste	Metal waste (56.899 kg) and 50% of "Empty drums and cans" (87.900 kg) was divided by the amount of fabric passing through wet processing in the factory (12.302.165 kg) and multiplied by 1,03 to account for losses in the cut and sew step.
Paper waste	Plastic waste (293.345 kg) was divided by the amount of fabric passing through wet processing in the factory (12.302.165 kg) and multiplied by 1,03 to account for losses in the cut and sew step.
Wastewater	Wastewater (985.505 m3) was divided by the amount of fabric passing through wet processing in the factory (12.302.165 kg) and multiplied by 1,03 to account for losses in the cut and sew step.
Textile waste	The amount of textile waste was calculated from the loss rates according to the factory (1% in weaving and 3% in cut and sew).

10.3 Towel factory - determination of inputs and outputs

Table 51 – Determining energy and consumables per kg of final towel product

Input	Procedure for determining input per kg final product
Electricity for weaving (sub-meter)	Electricity for weaving (2.900.000 kWh) was divided by the amount of fabric woven in the factory (1.691.492 kg) and multiplied by 1,01 to account for losses in the cut and sew step.
Electricity for wet processing (sub-meter)	Electricity for wet processing (3.600.000 kWh) was divided by the amount of final product from the factory (1.556.173 kg).
Electricity for cut and sew (sub-meter)	Electricity for cut and sew (1.800.000 kWh) was divided by the amount of final product from the factory (1.556.173 kg).
Electricity for other (sub-meter)	Electricity for other processes (1.600.000 kWh) was divided by the amount of final product from the factory (1.556.173 kg).
Natural gas for sizing	Total natural gas consumption was 32.760 mmBTU = 925.918 m3. 15% of this was estimated by the factory to be used for sizing (138.888 m3), which was divided by the amount of fabric woven in the factory (1.691.492 kg) and multiplied by 1,01 to account for losses in the cut and sew step.
Natural gas for bleaching	Total natural gas consumption was 32.760 mmBTU = 925.918 m3. 40% of this was estimated by the factory to be used for bleaching (370.367 m3), which was divided by the amount of fabric bleached in the factory (676.596 kg) and multiplied by 1,01 to account for losses in the cut and sew step.
Natural gas for dyeing	Total natural gas consumption was 32.760 mmBTU = 925.918 m3. 45% of this was estimated by the factory to be used for dyeing (416.663 m3), which was divided by the amount of fabric dyed in the factory (1.014.895 kg) and multiplied by 1,01 to account for losses in the cut and sew step.
Clean water for bleaching	Total consumption of clean water was 7.831.000 m3. The factory estimated that the same amount of water is used for bleaching and dyeing (meaning double the amount of water is used for fabrics that are both bleached and dyed compared to only bleached products). The total water consumption was divided by the sum of fabric going through bleaching (676.596 kg) and fabric going through dyeing (1.014.895 kg) and multiplied by 1,01 to account for losses in the cut and sew step.
Clean water for dyeing	Total consumption of clean water was 7.831.000 m3. The factory estimated that the same amount of water is used for bleaching and dyeing (meaning double the amount of water is used for fabrics that are both bleached and dyed compared to only bleached products). The total water consumption was divided by the sum of fabric going through bleaching (676.596 kg) and fabric going through dyeing (1.014.895 kg) and multiplied by 1,01 to account for losses in the cut and sew step.
Clean water for unbleached products	Unbleached and undyed products still go through some wet processing steps. The factory estimates that they consume 25% of the water of products that are only bleached or only dyed, or 12,5% of products that are bleached and dyed.
Lubricants	Lubricant (1.500 liter, assumed 1.500 kg) was divided by the amount of final product from the factory (1.556.173 kg).
Plastic	Plastic input to the factory was assumed to be the same amount as the plastic waste leaving the factory. See calculation of plastic waste.
Metal	Metal input to the factory was assumed to be the same amount as the metal waste leaving the factory. See calculation of metal waste.
Paper	Paper input to the factory was assumed to be the same amount as the paper waste leaving the factory. See calculation of paper waste.

Input	Procedure for determining input per kg final product
Starch for sizing	8,5% of yarn weight according to factory. Multiplied by 1,01 to account for losses in the cut and sew step.
Acid for desizing	0,5% of fabric weight according to factory. Multiplied by 1,01 to account for losses in the cut and sew step.
Sodium hydroxide for scouring	3% of sodium hydroxide in solution based on CBSE (2014). Assumed 20 L solution per kg fabric. Multiplied by 1,01 to account for losses in the cut and sew step.
Hydrogen peroxide for bleaching	3% of the fabric weight according to factory. Multiplied by 1,01 to account for losses in the cut and sew step.
Sodium hydroxide for bleaching	2% of sodium hydroxide in solution based on CBSE (2014). Assumed 20 L solution per kg fabric. Multiplied by 1,01 to account for losses in the cut and sew step.
Sodium silicate for bleaching	3% of sodium silicate in solution based on CBSE (2014). Assumed 20 L solution per kg fabric. Multiplied by 1,01 to account for losses in the cut and sew step.
Dye agent	According to factory: 0,065 kg dye per kg 350 gsm fabric; 0,075 kg dye per kg 500 gsm fabric, and 0,090 kg dye per kg 1000 gsm fabric. Multiplied by 1,01 to account for losses in the cut and sew step.

Table 52 – Determining waste and wastewater per kg of final towel product

Output	Procedure for determining input per kg final product
Plastic waste	Plastic waste (2.300 kg) was divided by the amount of final product from the factory (1.556.173 kg).
Metal waste	Metal waste (1.900 kg) was divided by the amount of final product from the factory (1.556.173 kg).
Paper waste	Plastic waste (1.100 kg) was divided by the amount of final product from the factory (1.556.173 kg).
Wastewater	Wastewater to treatment was estimated as 110% of the clean water input to the factory. See calculation of water input.
Textile waste	The amount of textile waste was calculated from the loss rates according to the factory (3,5% in weaving and 1% in cut and sew).

10.5 Contribution analysis for all environmental impacts

10.5.1 BL1: Bedlinen 200 cm (one set)

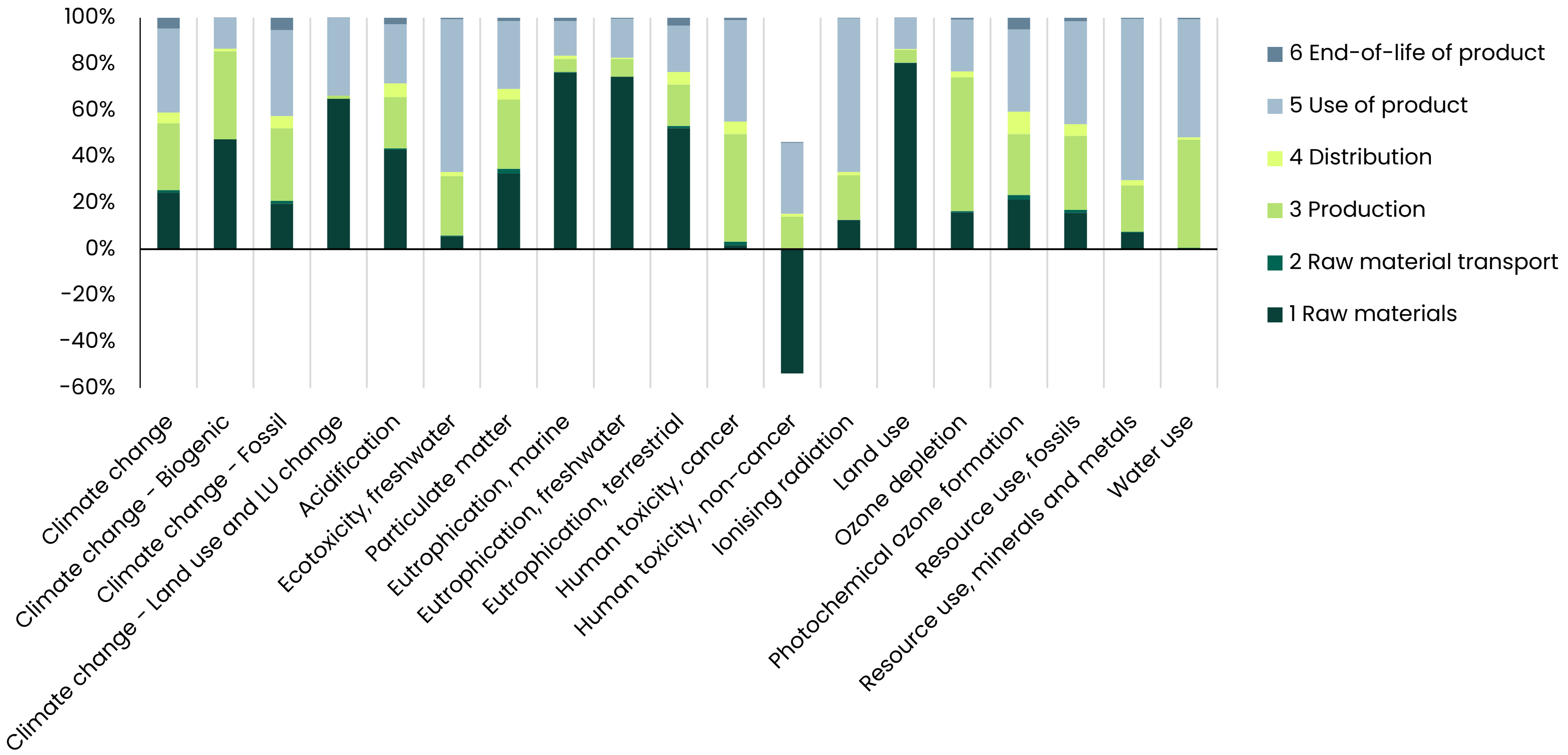

Figure 13 – BL1: Contribution of each life cycle phase to each of the environmental impact categories in %.

10.5.2 BL2: Bedlinen 220 cm (one set)

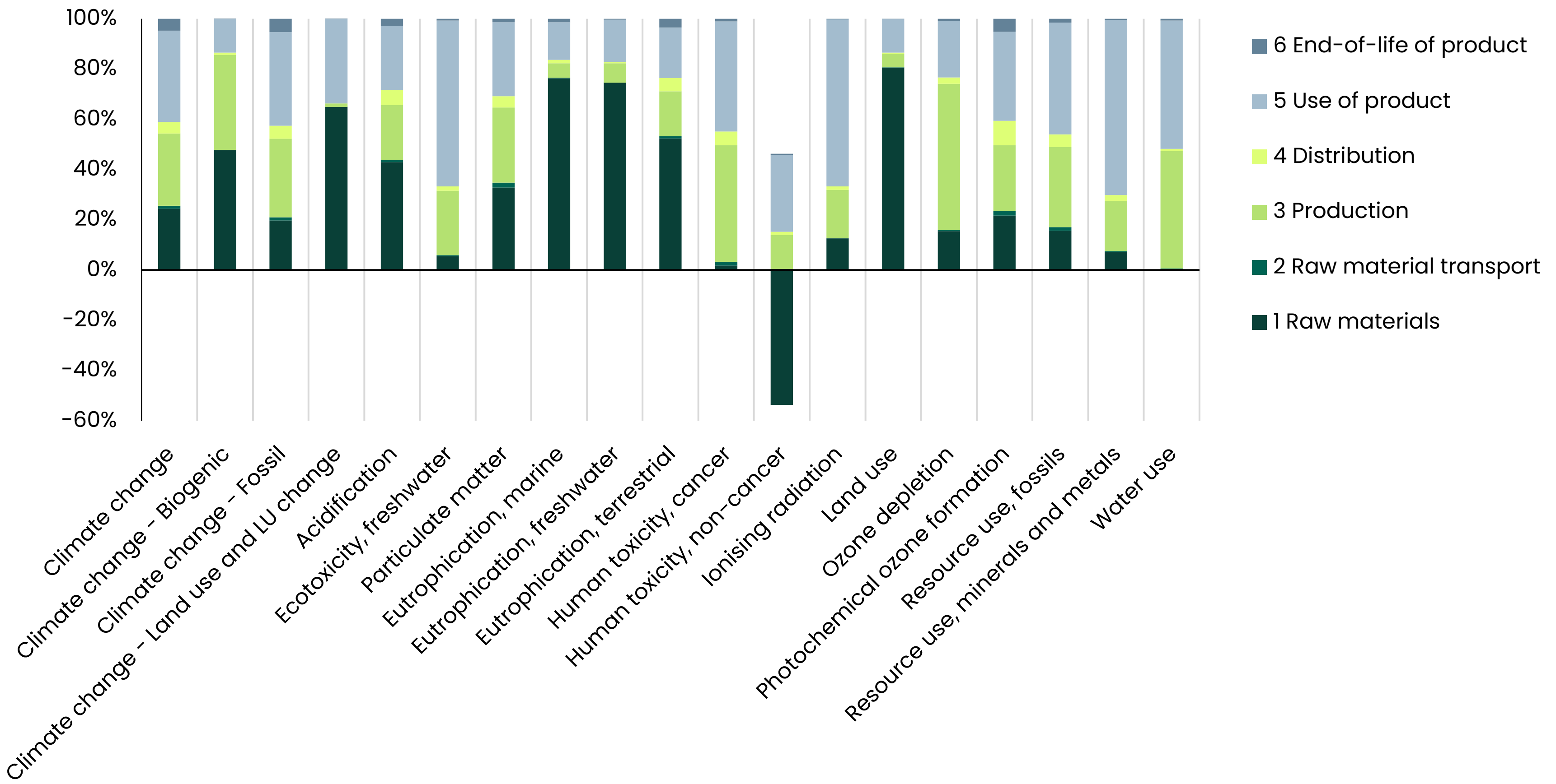

Figure 14 – BL2: Contribution of each life cycle phase to each of the environmental impact categories in %.

10.5.3 ES1: Envelope sheet 90 cm (one sheet)

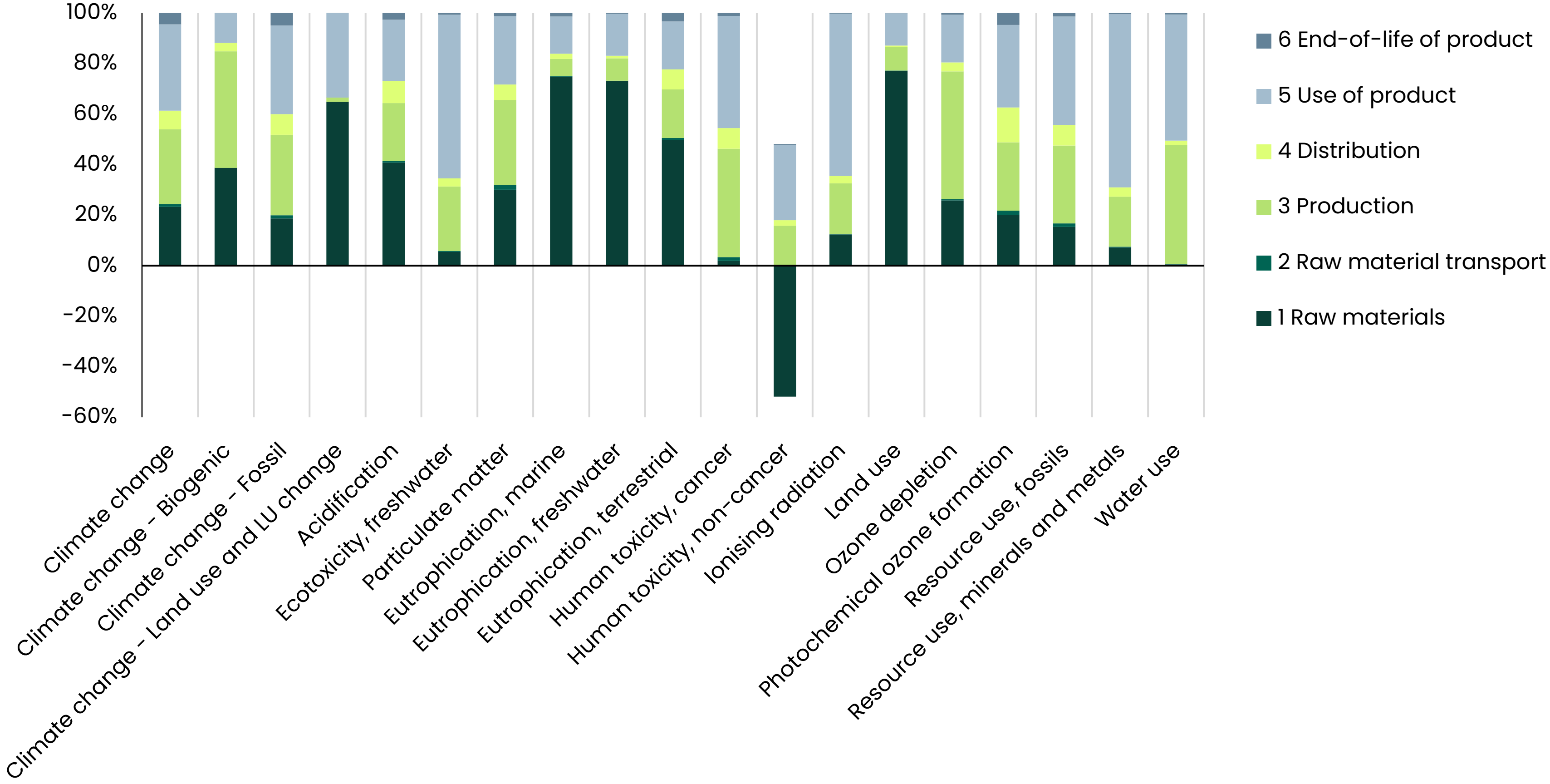

Figure 15 – ES1: Contribution of each life cycle phase to each of the environmental impact categories in %.

10.5.4 ES2: Envelope sheet 140 cm (one sheet)

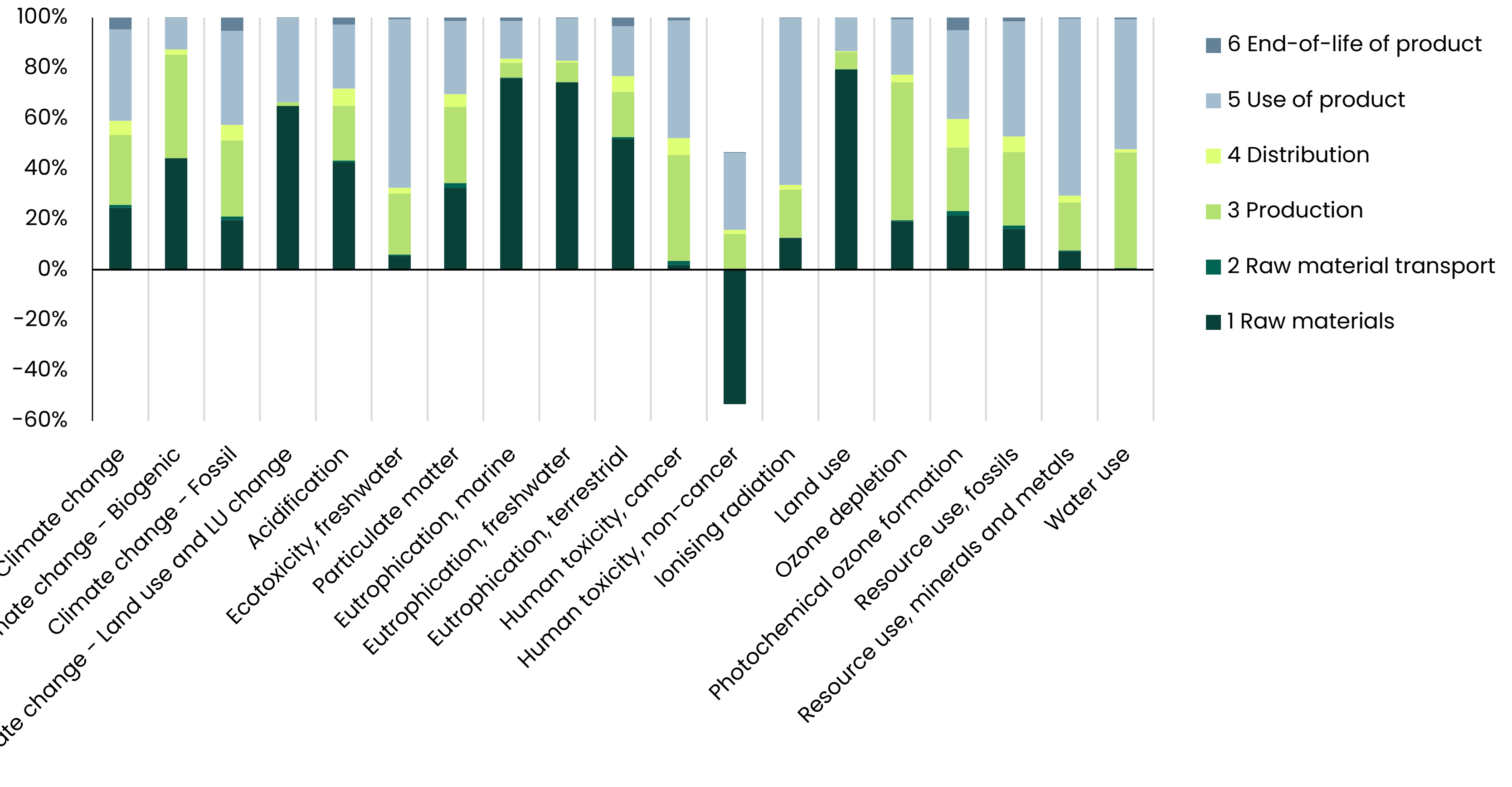

Figure 16 – ES2: Contribution of each life cycle phase to each of the environmental impact categories in %.

10.5.5 ES3: Envelope sheet 180 cm (one sheet)

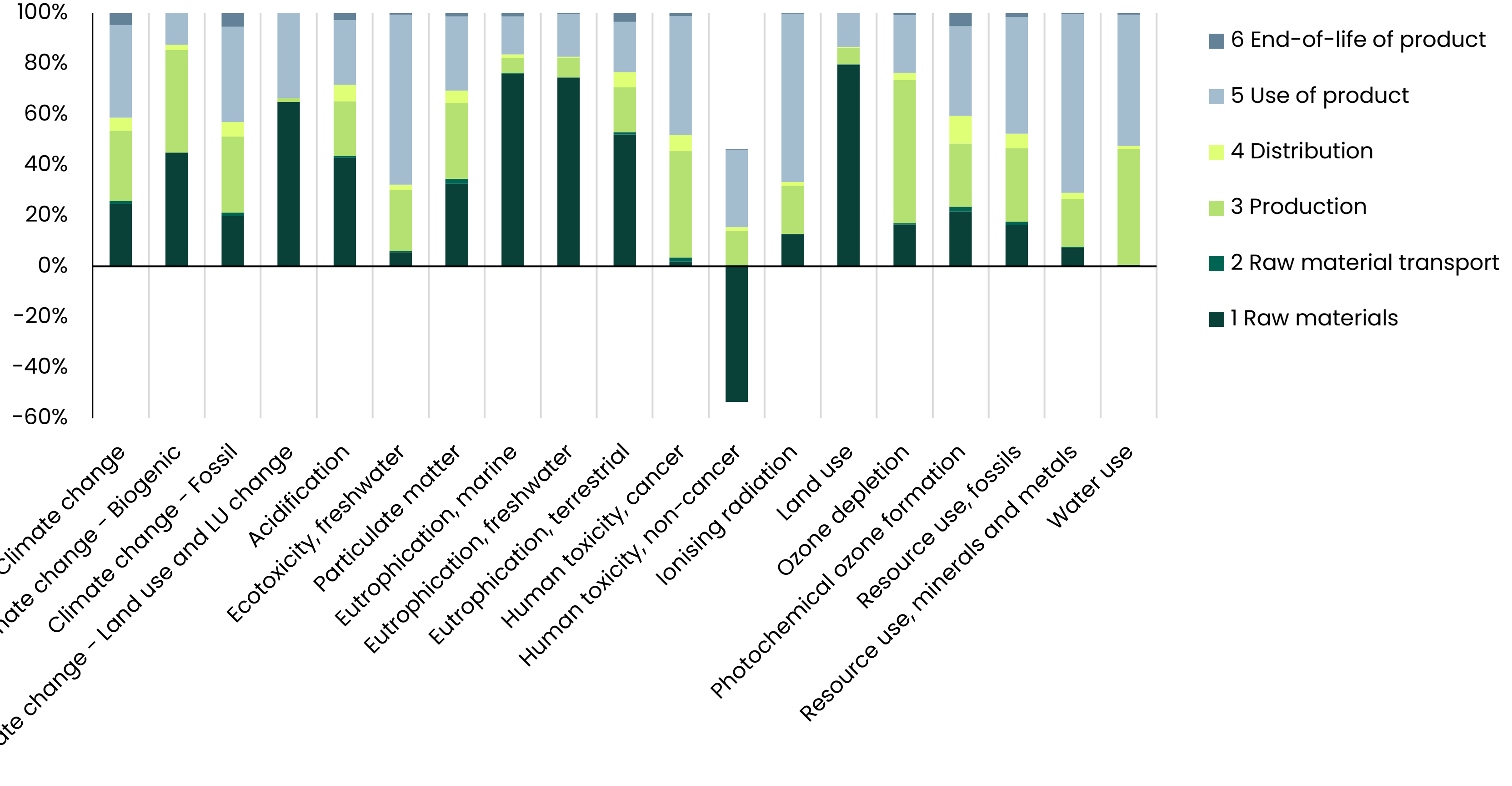

Figure 17 – ES3: Contribution of each life cycle phase to each of the environmental impact categories in %.

10.5.6 BT1: Bath towel, bleached and dyed (one towel)

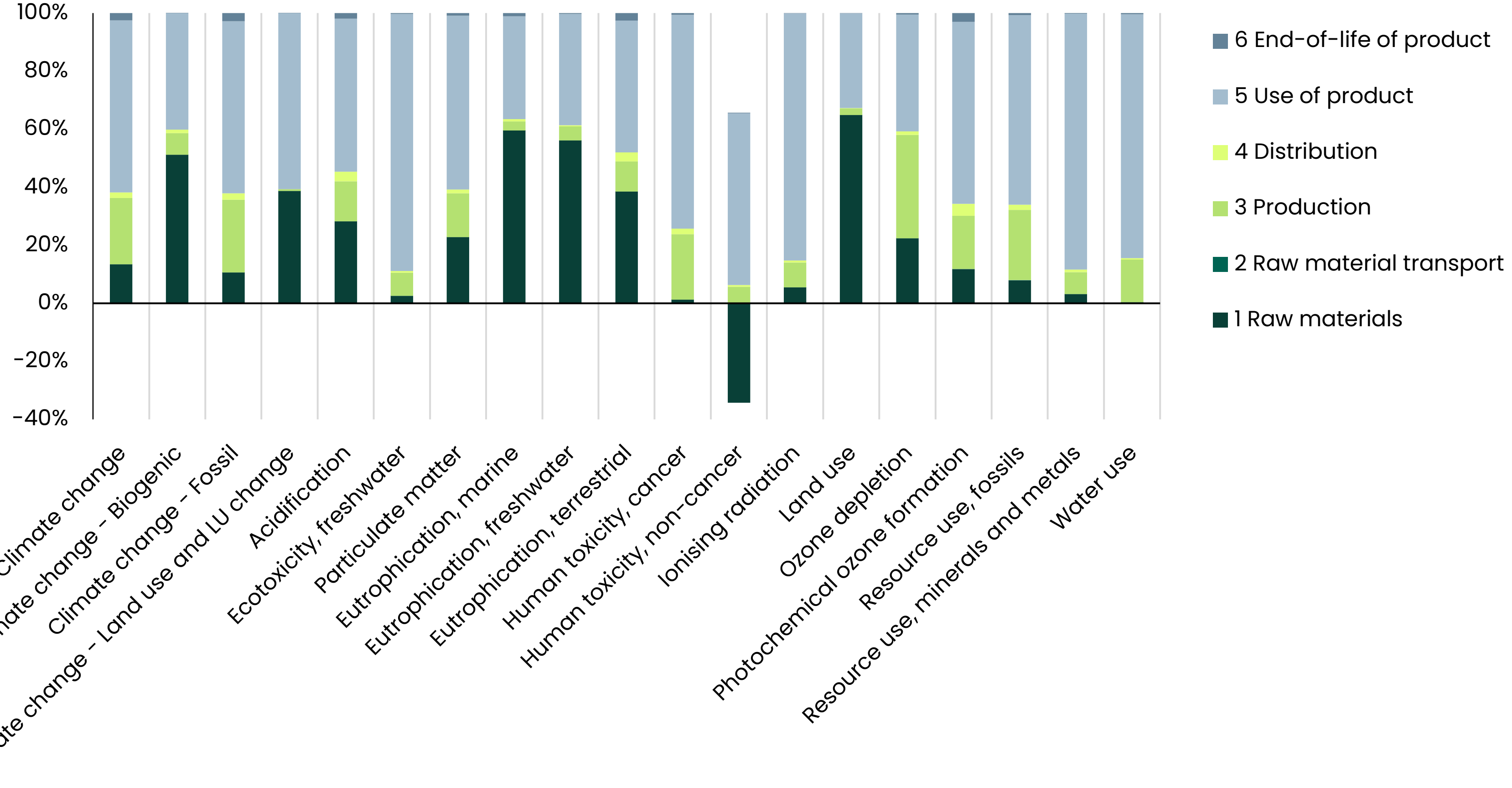

Figure 18 – BT1: Contribution of each life cycle phase to each of the environmental impact categories in %.

10.5.7 BT2: Bath towel, unbleached (one towel)

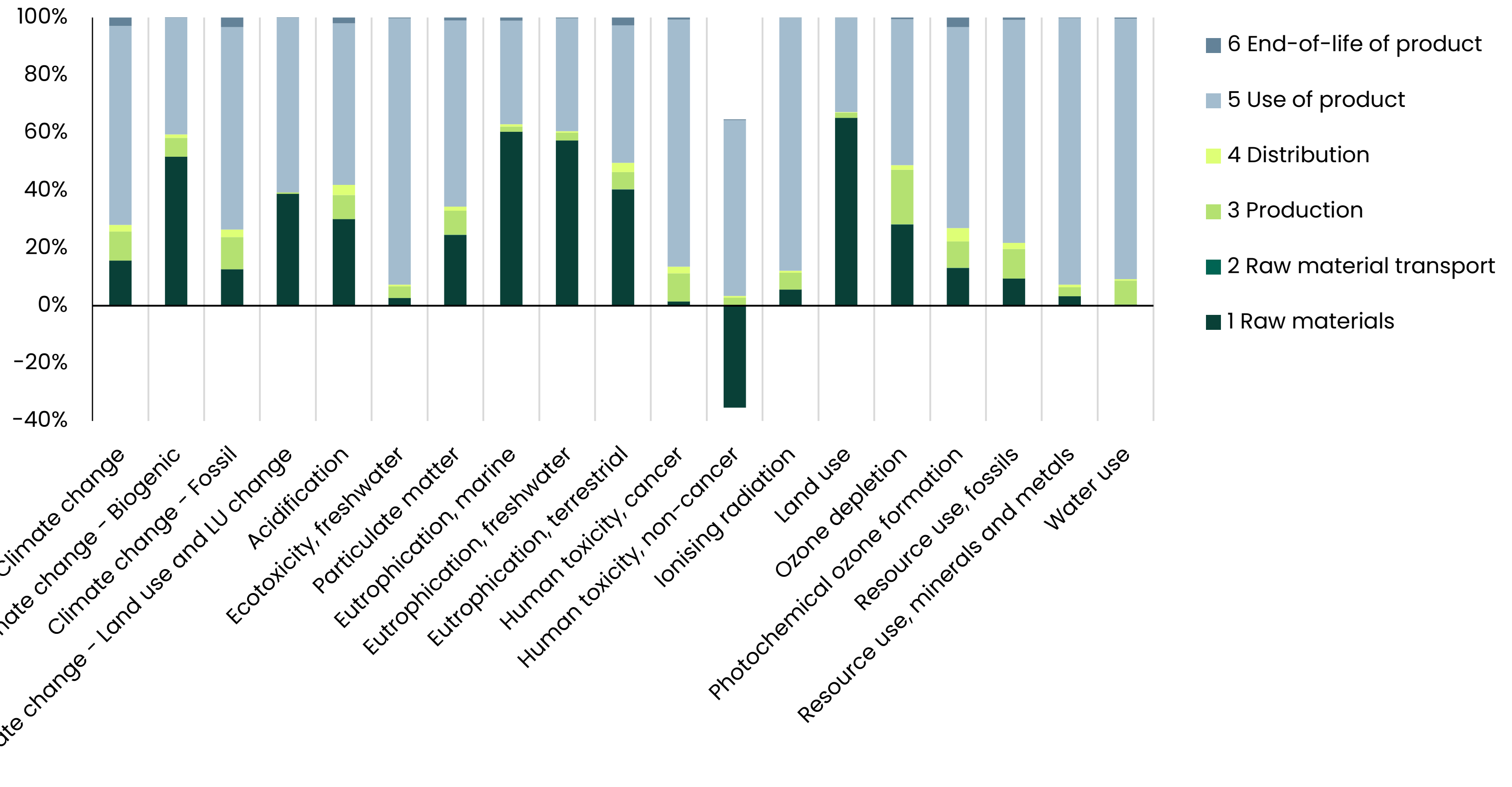

Figure 19 – BT2: Contribution of each life cycle phase to each of the environmental impact categories in %.

10.5.8 HT1: Hand towel, bleached and dyed (2-pack)

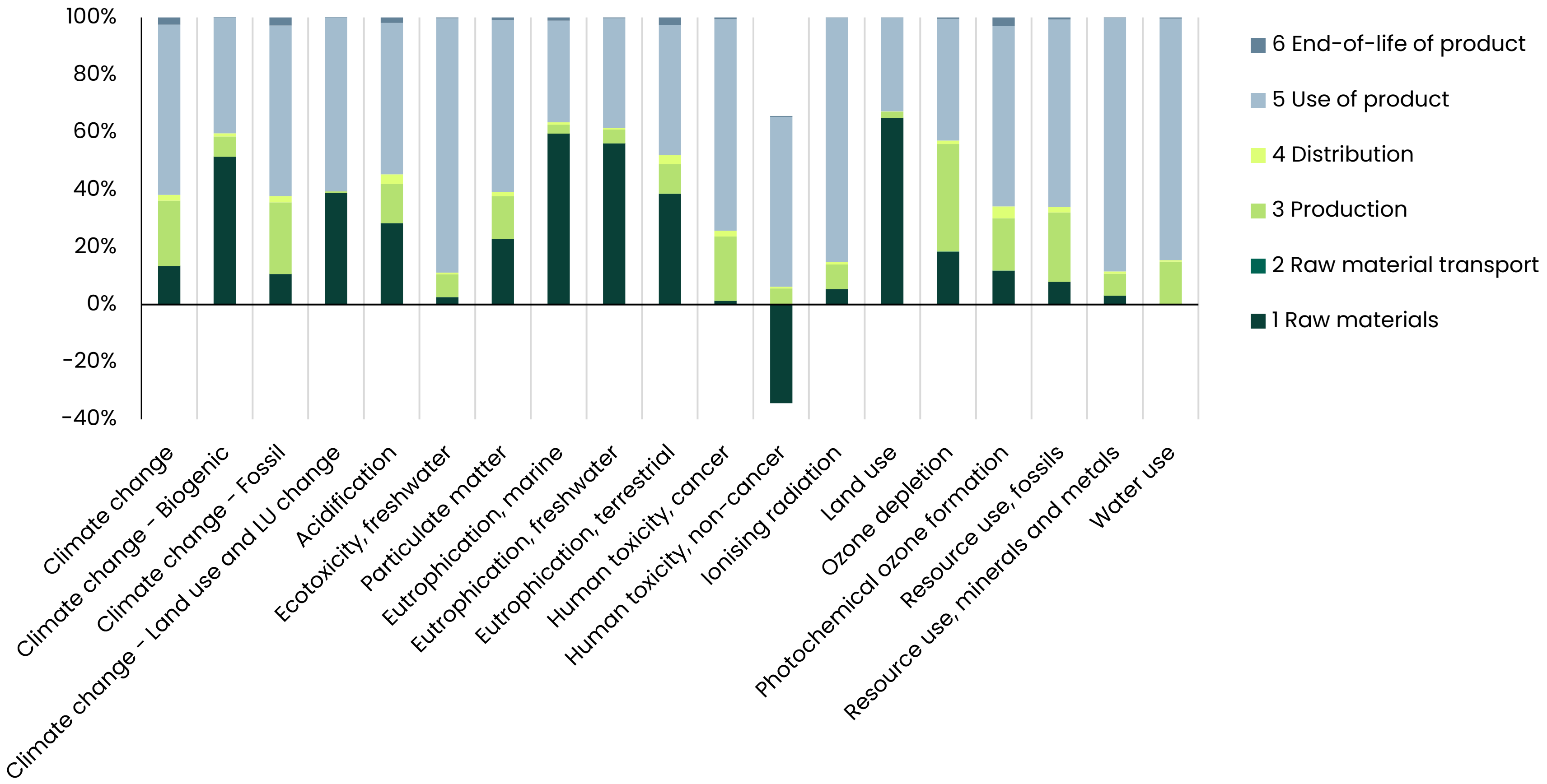

Figure 20 – HT1: Contribution of each life cycle phase to each of the environmental impact categories in %.

10.5.9 HT2: Hand towel, unbleached (2-pack)

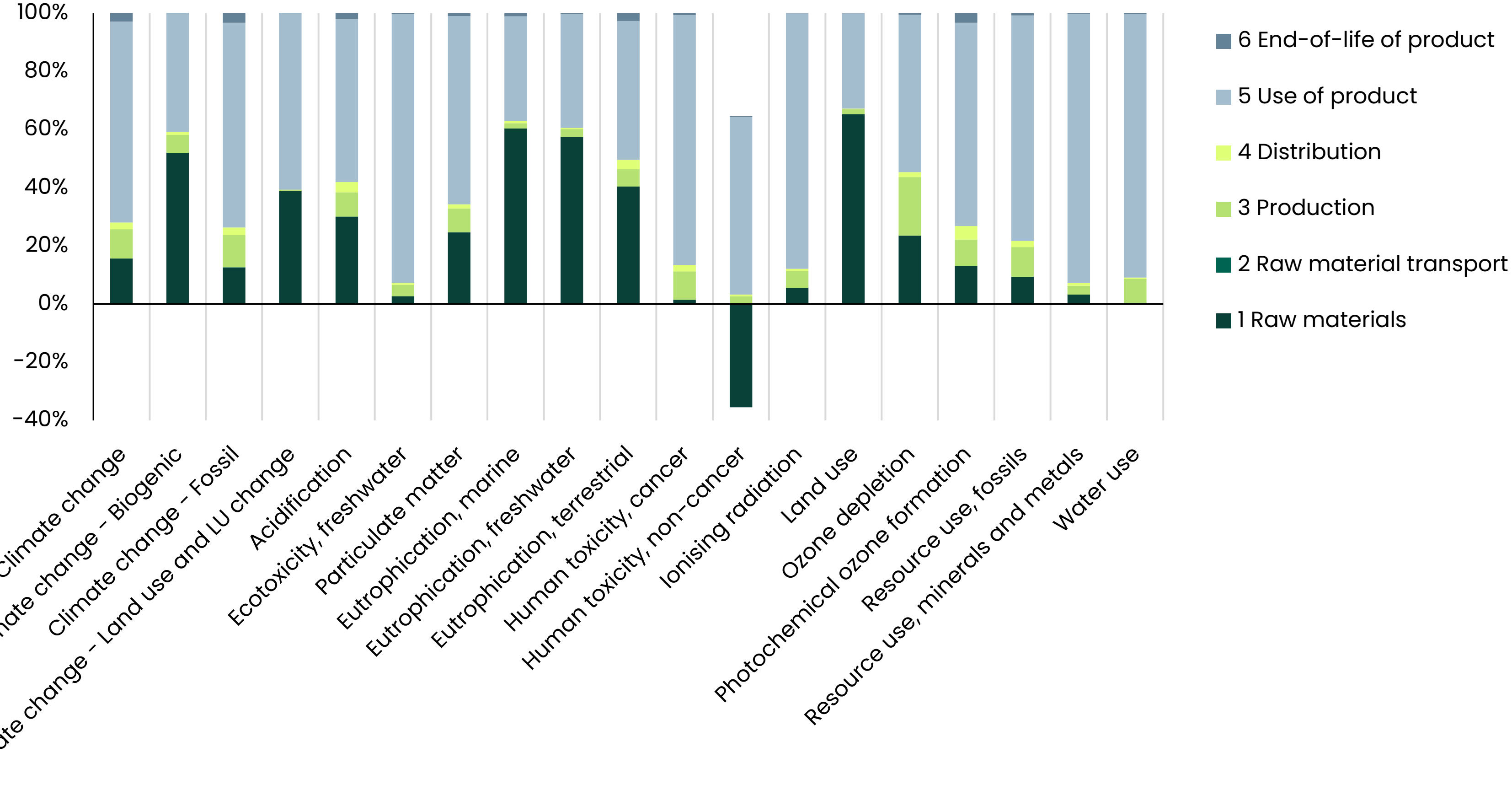

Figure 21 – HT2: Contribution of each life cycle phase to each of the environmental impact categories in %.

10.5.10 WC1: Washcloth, bleached and dyed (5-pack)

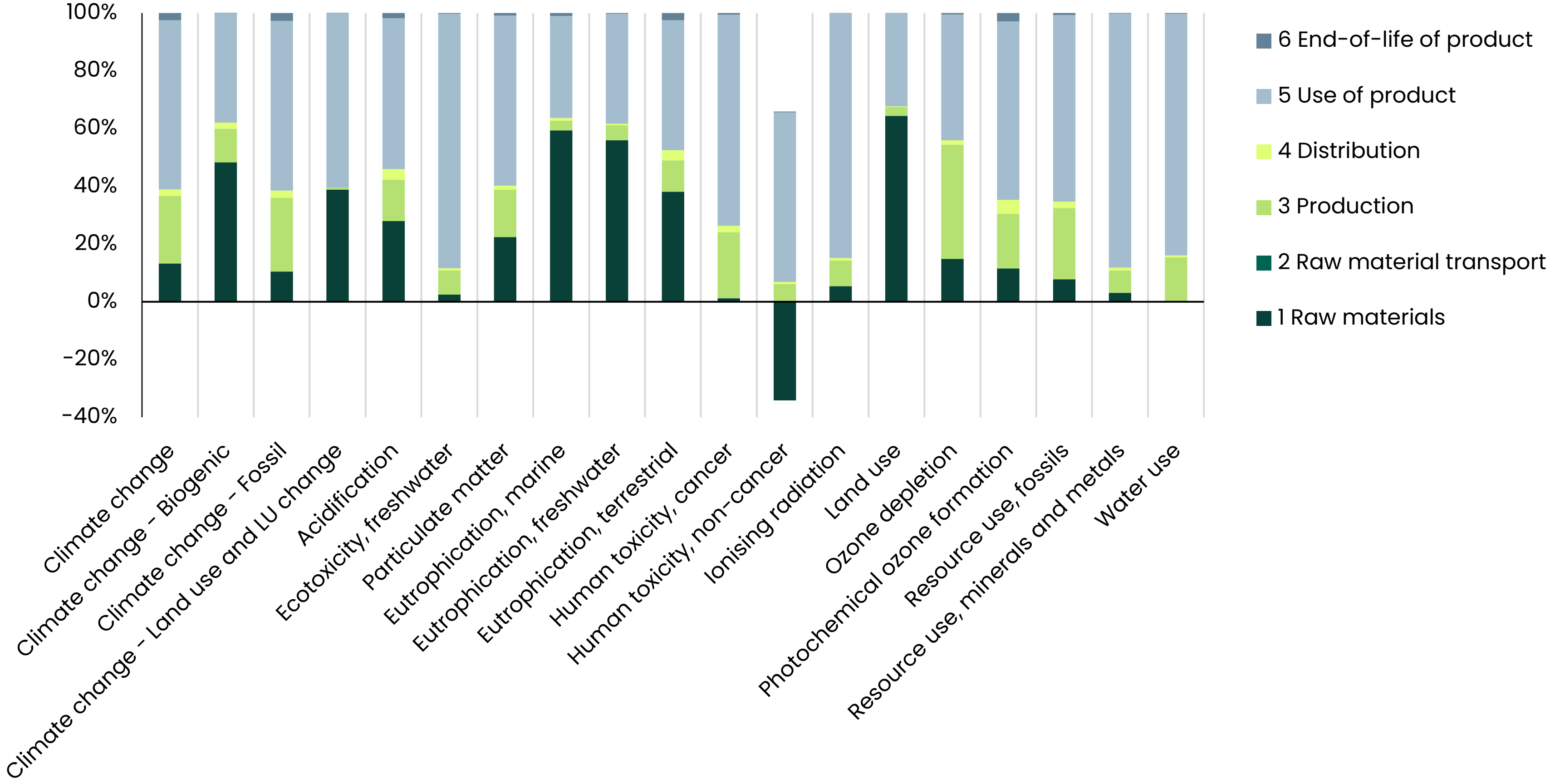

Figure 22 – WC1: Contribution of each life cycle phase to each of the environmental impact categories in %.

10.5.11 WC2: Washcloth, unbleached (5-pack)

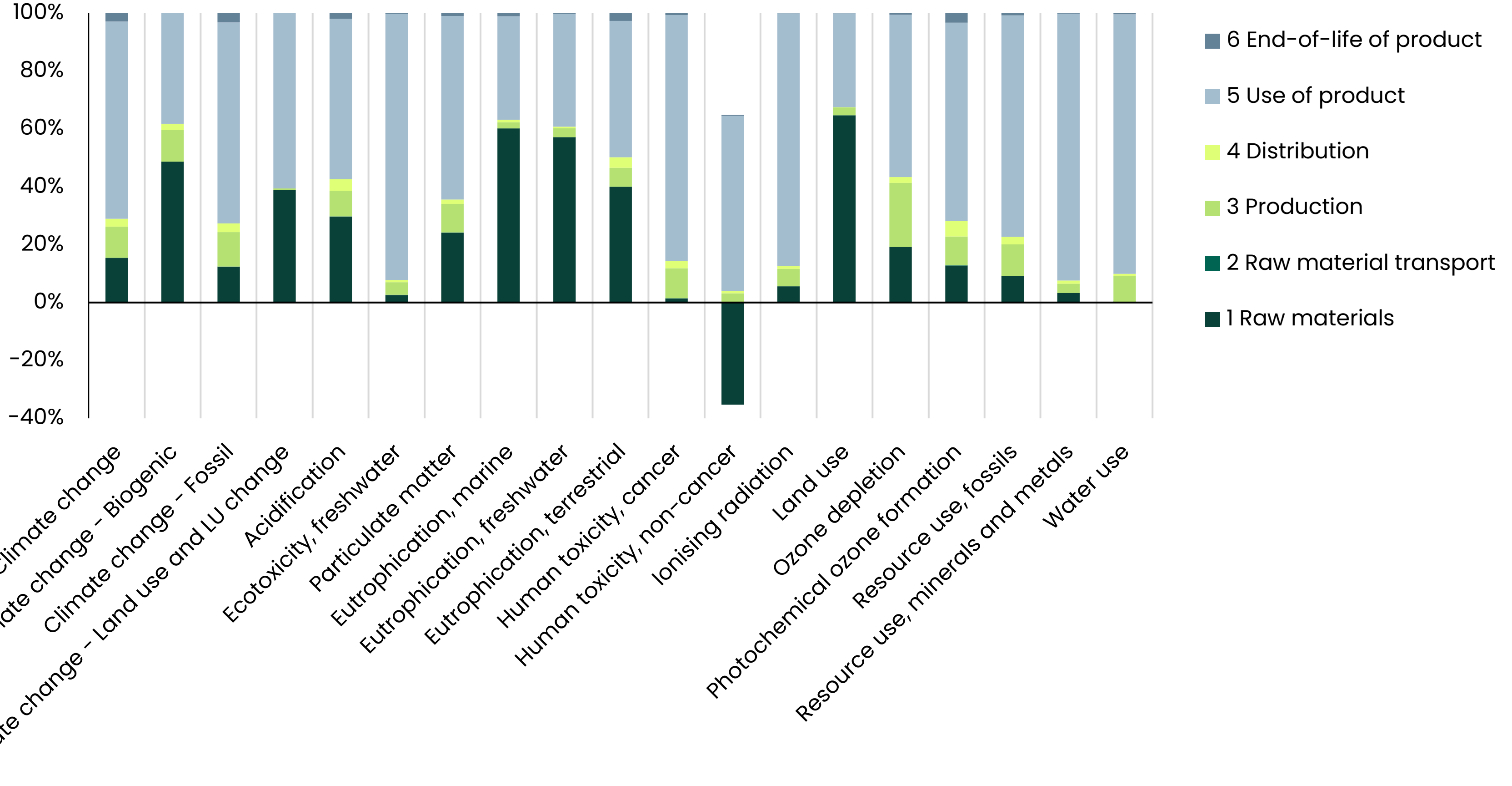

Figure 23 – WC2: Contribution of each life cycle phase to each of the environmental impact categories in %.

10.5.12 BM1: Bath mat, bleached and dyed (one bath mat)

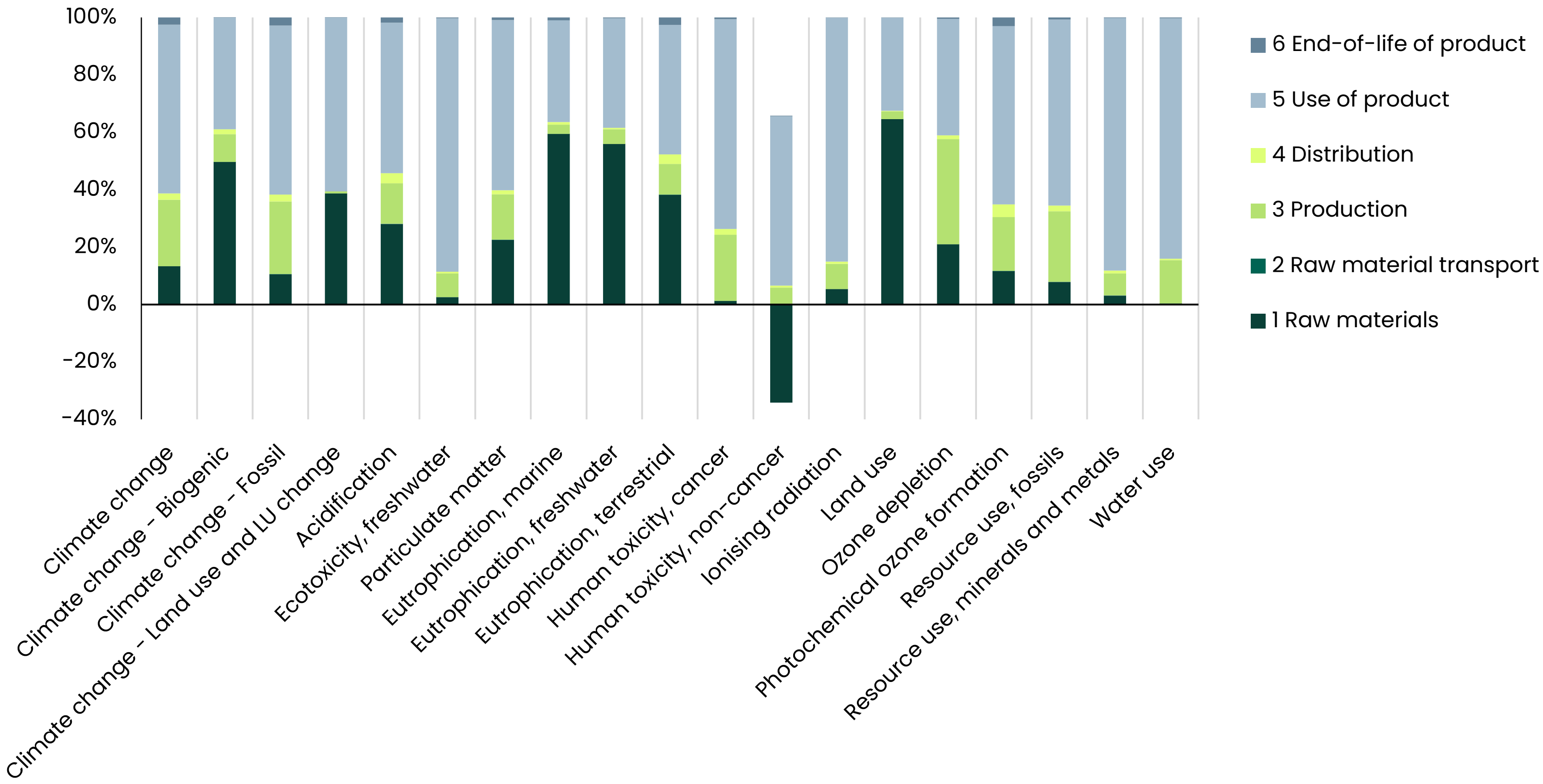

Figure 24 – BM1: Contribution of each life cycle phase to each of the environmental impact categories in %.

10.5.13 BM2: Bath mat, unbleached (one bath mat)

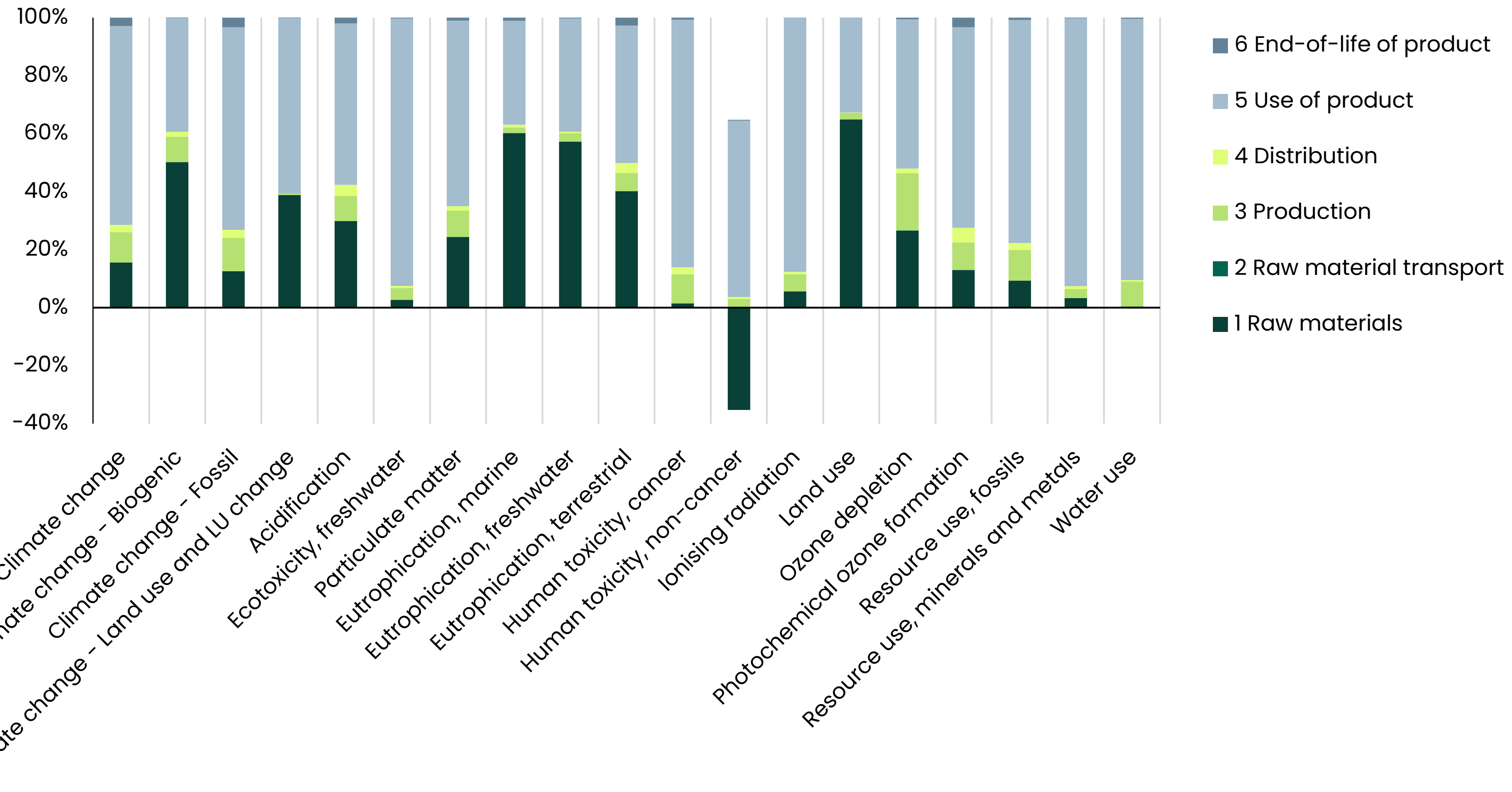

Figure 25 – BM2: Contribution of each life cycle phase to each of the environmental impact categories in %.

10.5.14 BR1: Bathrobe, bleached and dyed (one bathrobe)

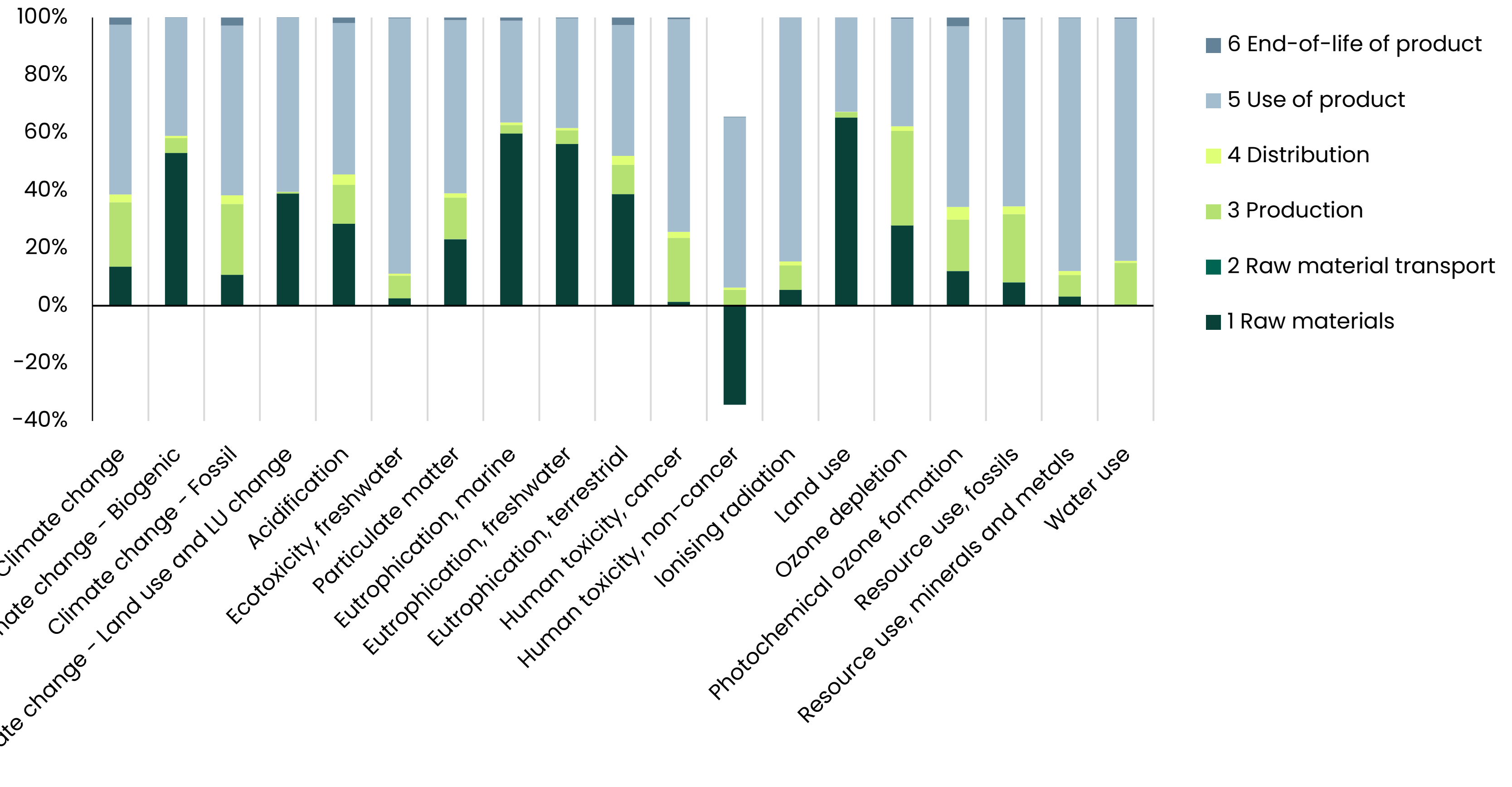

Figure 26 – BR1: Contribution of each life cycle phase to each of the environmental impact categories in %.

10.5.15 BR2: Bathrobe, unbleached (one bathrobe)

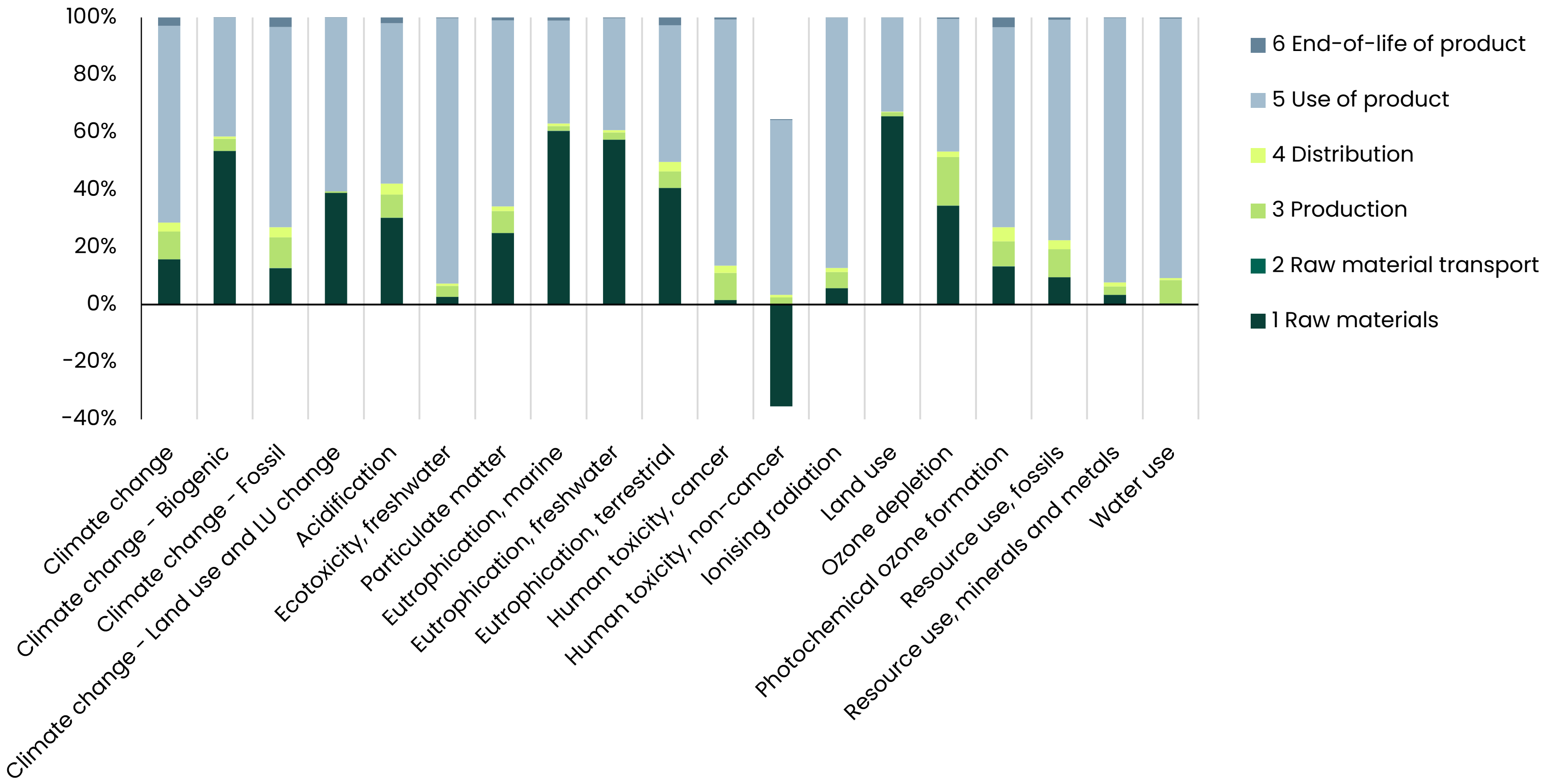

Figure 27 – BR2: Contribution of each life cycle phase to each of the environmental impact categories in %.

10.5.16 HA1: Hair turban, bleached and dyed (one hair turban)

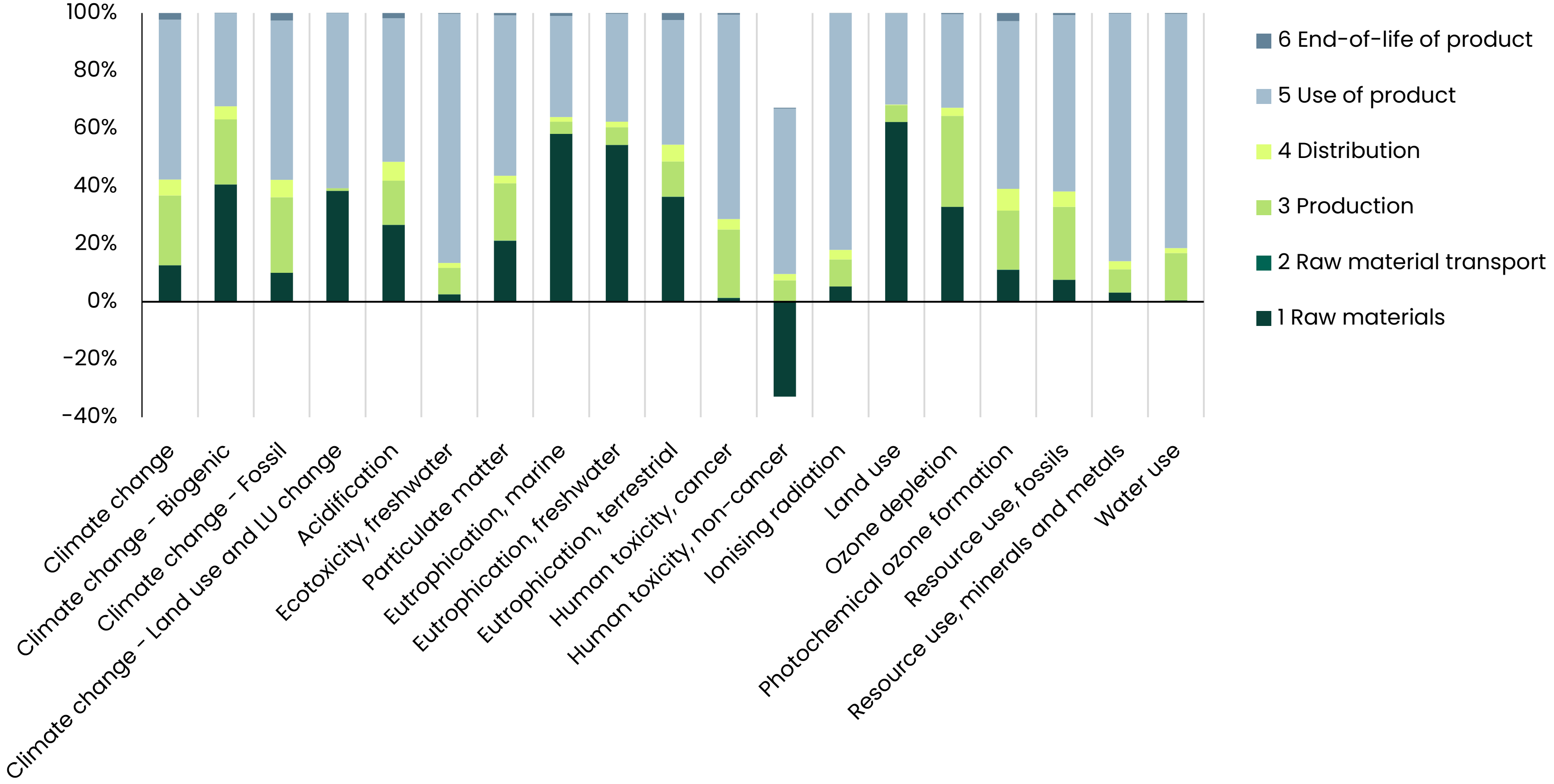

Figure 28 – HA1: Contribution of each life cycle phase to each of the environmental impact categories in %.

10.5.17 HA2: Hair turban, unbleached (one hair turban)

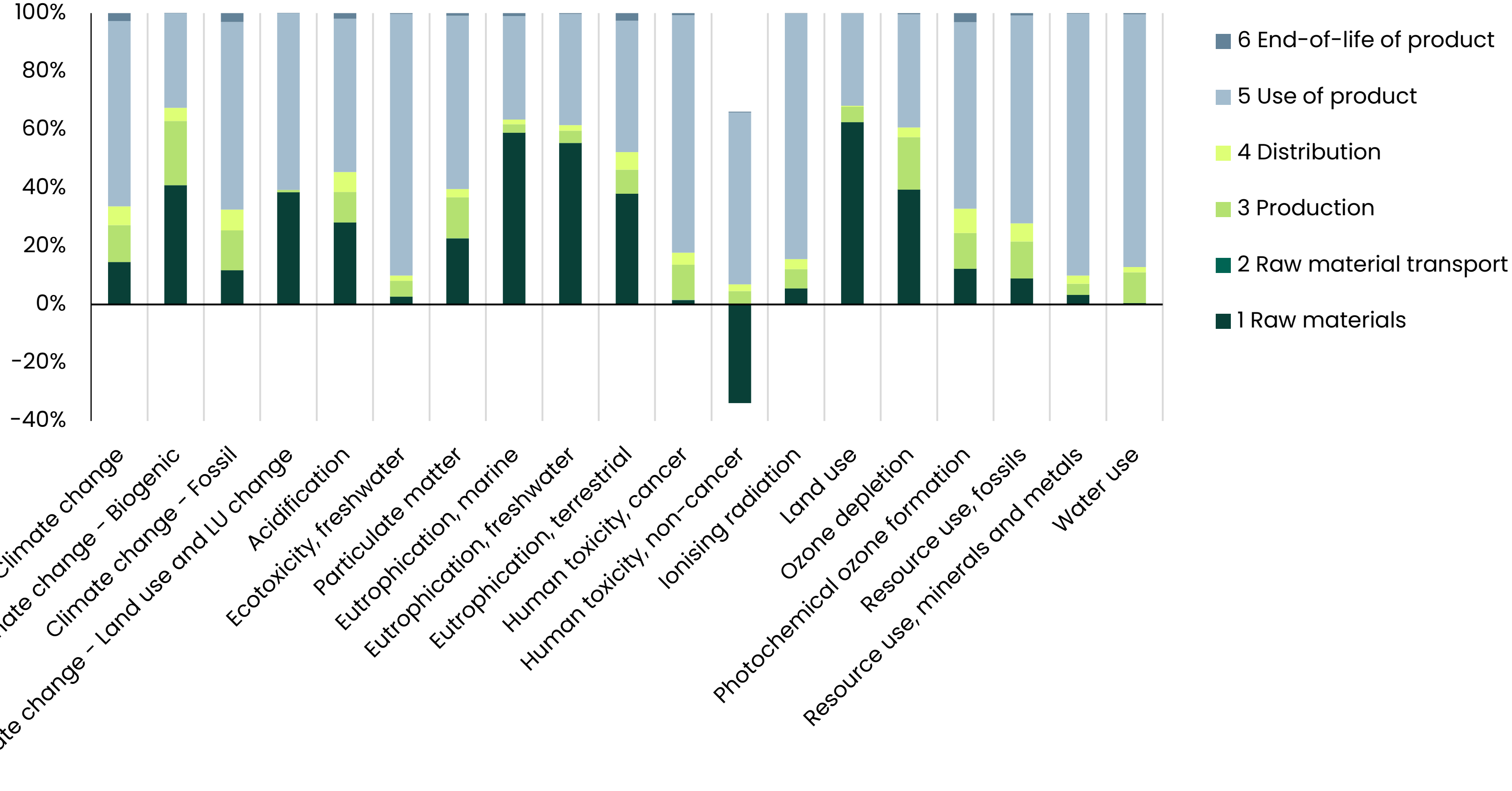

Figure 29 – HA2: Contribution of each life cycle phase to each of the environmental impact categories in %.

10.6 Dialogue between critical reviewer and LCA practitioner

Type of comment: (ED: Editorial, TE: Technical, GE: Generic)

No.	CHAPTER, ARTICLE, PARAGRAPH, TABLE	TYPE OF COMMENT	REFERENCE TO CHECKLIST OR PRANDRAMME INSTRUCTIONS	REVIEWER COMMENT AND RECOMMENDATION	LCA PRACTITIONER ANSWER	FINAL REVIEWER STATEMENT
1	Page 2	Ed		Please include name of practitioner	Added	Ok
2	Page 2	Ed		Please include the name and position of the reviewer. Waldemar C. Hemdrup - Sustainability specialist	Added	Ok
3	1 Summary	Te		Please provide any certification on the cotton being 100% organic **Round 2:** I cannot make the invoices add up to what has been purchased. Please advise. Additionally, the certificates are valid until mid-2025 – please confirm that certificates will be purchased in the future production, as the scenario is 2024 and 2025.		OK – Additional explanation and documentation received
4	1 Summary	Ge		This is comparative	Deleted	OK
5	2 Contents	Ed		Please include a list of abbreviations	Added	OK
6	4.4.1 LCA Standards	Ge		In what way?	Explained during the meeting	OK
7	4.4.4 Handling of multifunctional processes	Ed		Please include the list of allocation rules from ISO 14040/44 in this section	Added	OK
8	Table 6	Ge		Please elaborate on this table - the data is from 2024	Explained	OK

				but the scope is 2025?		
9	4.7 Critical review	Ed		Please include reviewer name - Waldemar C. Hemdrup, Sustainability specialist	Added	OK
10	Table 7	Ge		Please provide documentation on this **Round 2:** I cannot make the invoices add up to what has been purchased. Please advise. Additionally, the certificates are valid until mid-2025 – please confirm that certificates will be purchased in the future production, as the scenario is 2024 and 2025.		OK – Additional explanation and documentation received
11	Table 8	Te		Please provide the documentations that this is build on for ES1, HT1, and BM2 - Bill of material, documentation from the supplier or the like	Checked during meeting	OK
12	5.1.1.1 Activity data	Te		Please show during the meeting how this is done	Done during meeting	OK
13	5.1.1.2 Background data	Ge		Why was an Indian process used instead of a Global or RoW process?	Global is based on India so for transparency India was choosen.	OK
14	5.1.1.2 Background data	Te		Please show the changes made to the process during the meeting	Shown during meeting	OK
15	5.1.1.2 Background data	Te		Please provide source for the electricity mix	Shown during meeting	OK

16	5.1.1.2 Background data	Te		Please show the changes made to the process during the meeting	Shown during meeting	OK
17	5.1.1.2 Background data	Te		Please provide source for the electricity mix	Shown during meeting	OK
18	5.1.2.1 Activity data	Ge		Is the fabric bag for the two product where this is included handled the same as for the bedlinen products?	Yes this is handled the same	OK
19	5.1.2.2 Background data	Ge		Why not Global or RoW?	Global is based on India so for transparency India was choosen.	OK
20	5.1.2.2 Background data	Te		What is the electricity mix based on?	Shown during meeting	OK
21	5.1.3.2 Background data	Te		Please show and elaborate during meeting	Shown during meeting	OK
22	5.1.3.2 Background data	Te		What is this based on?	Shown during meeting	OK
23	5.2.1 Activity data	Ge		What is this assumption based on?	Based on the distance from the actory to the other side of the city	OK
24	Table 17	Ed		Should the unit not be tkm or kgkm to show the input for the products for this specific process?	No the unit process from table 16 is the unit - it is described with the use of kgkm and tkm	OK
25	Table 18	Ge		Please provide certificates for the green electricrity	Provided a statement from the producer that the production site uses solar energy and that they are not connected to the grid	OK
26	Table 18	Ge		Please provide documentation on the amount used on starch, hydrogen peroxide, sodium	LCA Model provided and sample checks has been made	OK

				silicate, and pigment agent		
27	Table 20	Ge		What is the metal, plastic, and paper used for in the production	Part of their waste, so assumed to be included in the production	OK
28	5.3.1.3 Background data	Te		Please show the changes made during the meeting	Showed during meeting	OK
29	Table 22	Ed		Missing rating in Technology	Added	OK
30	Table 25	Ge		Does this represent one product, on kg of textile product, or the total amount?	See comment 24	OK
31	Table 26	Ge		How come there is such a similarity between the electricity but the rest has so big differences - E.g. BR1 and BR2 or HA1 and HA2	Units are different see comment 24	OM
32	Table 26	Ge		Why are these values so much higher compared to the rest of the products?	The weight is higher	OK
33	5.4.2.1 Activity data	Te		Should it not be 900.000 kWh?	Only a mistake In the report – Corrected	OK
34	5.4.2.1 Activity data	Ge		Please explain this.	Shown during the meeting	OK
35	5.4.2.1 Activity data	Ge		Please show the calculations during the meeting	Shown during the meeting	OK
36	5.4.2.1 Activity data	Ed		Incorrect unit - it should be kWh	Corrected	OK
37	5.4.2.2 Background data	Te		Use residual mix	Corrected	OK
38	Table 34	Ge		There is something wrong with the calculations - please provide explanation on the calculation during the meeting	Corrected	OK

39	5.5.1.2 Background data	Te		Use residual mix **Round 2:** This comment is retracted and therefore residual mix should not be used.	Corrected	OK
40	Table 40	Ge		Does the product consist of 1 kg cardboard packaging for the final product?	See comment 24	OK
41	5.6.2 Background data	Te		Please use residual mix	Corrected	OK
42	Table 43	Ge		I don't think i understand the input values in these tables - please elaborate on the meeting for my clarification	See comment 24	OK
43	6.1 LCIA procedures and calculations	Ge		There needs to be a reason for including the other impact categories as well. From what you write here a ISO 14067 would be more fitting. An explanation could be to have a holistic view or avoid burden shifting. Climate change is allowed to be the most important to look at for the company, but the other just needs reasoning as well.	Explanation added	OK
44	Table 48	Te		Please show how the specific electricity consumption for each of the different steps in the production is assessed.	Shown during the meeting	OK