Life Cycle Assessment of Kitchen Textiles of 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: 2026-05-18 (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 & Marie Astrid Steenberg Holm
Independent critical reviewer	Bureau Veritas Solutions Denmark A/S Julie M. V. Larsen, LCA & EPD Consultant.
LCA standard	DS/EN ISO 14040:2008 DS/EN ISO 14044:2008
Products	Kitchen textiles
Life cycle scope	Cradle-to-grave
Temporal scope	Production data collected covers 2025
Geographical scope	Raw materials: Pakistan Production: Pakistan Use and end-of-life: Denmark
Background database	ecoinvent v3.11 (cut-off)
Software	SimaPro 10.2.0.3
Modeling/allocation approach	Attributional LCA and physical allocation in phase 3 (production)
LCIA method	Environmental Footprint 3.1
Impact categories	Climate 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:	2026-05-18 (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 kitchen textiles from the fall 2026 line of Nord Harmony. The life cycle phases included in the LCA are:

1) Raw materials: Production of organic cotton yarn, conventional cotton yarn and polyester thread
2) Raw material transport: Transport of raw materials to the factory
3) Production: Transformation of yarn into final products incl. packaging.
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 lifetime 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.

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

Results and conclusions: The environmental impact of the products was evaluated across 16 impact categories according to the EF3.1 LCIA method. The climate change impact of the products is shown in Table 1.

Table 1 – Climate change impact of the products evaluated in the life cycle assessment (LCA)

ID	Product type	Pattern	Color	Climate change impact (kg CO_2e/product)	
				Cradle-to-consumer	Cradle-to-grave
TT1	Tea Towel	All-over stripes	Lemon pepper/unbleached	0,9	1,7
TT2		All-over stripes	Anthracite/unbleached	0,9	1,7
TT3		Checks	Lemon pepper/unbleached	1,0	1,9
TT4		Checks	Slate grey/unbleached	0,8	1,7
TT5		Panel stripes	Anthracite/unbleached	0,8	1,7
TT6		Panel stripes	Slate grey/unbleached	1,0	1,9
AP1	Apron	All-over stripes	Anthracite/unbleached	1,9	3,7
AP2		All-over stripes	Lemon pepper/unbleached	1,9	3,8
DC1	Dishcloth (2-pack)	Checks	Anthracite/unbleached	0,6	1,1
DC2		Checks	Lemon pepper/unbleached	0,6	1,1
PH1	Potholder	All-over stripes	Anthracite/unbleached	2,1	3,8
PH2		All-over stripes	Lemon pepper/unbleached	2,1	3,8
NK1	Napkin (2-pack)	Solid	Unbleached	0,4	0,9
NK2		All-over stripes	Slate grey/unbleached	0,5	0,9
TC1	Tablecloth	Solid	Unbleached	8,2	17,6
TC2		All-over stripes	Slate grey/unbleached	9,1	18,4

For all products the most contributing life cycle phase to the climate change impact is 'Phase 5 - Use of product' (41-50% contribution) – see Figure 1. This is mainly due to the washing and drying of the products in their lifetime.

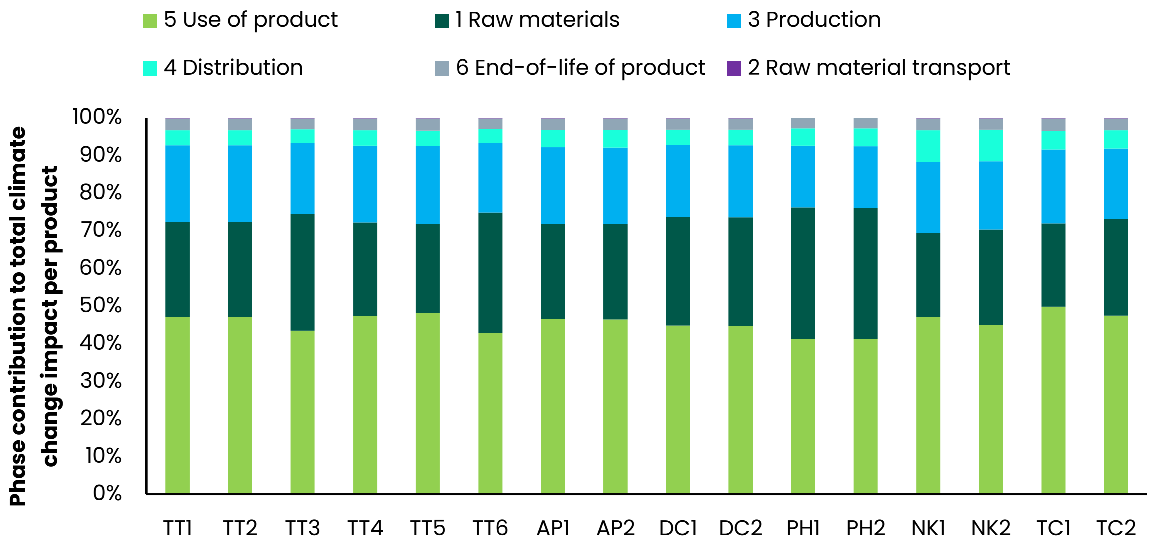

Figure 1 – Contribution analysis for the climate change impact for each product

Critical review: The LCA study was carried out by Better Green ApS and critically reviewed by Julie M. V. Larsen, LCA & EPD Consultant, 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 in April-May 2026.

Contents

Product IDs

ID	Product type	Raw material	Percentage of main fabric bleached and dyed (the rest is unbleached)
TT1	Tea Towel	95,9% organic cotton 1,7% conventional cotton 2,4% polyester	25%
TT2			25%
TT3			80%
TT4			20%
TT5			10%
TT6			90%
AP1	Apron	97,5% organic cotton 0,8% conventional cotton 1,7% polyester	30%
AP2			30%
DC1	Dishcloth (2-pack)	86,4% organic cotton 5,7% conventional cotton 7,9% polyester	50%
DC2			50%
PH1	Potholder	55,7% organic cotton 41,2% conventional cotton 3,1% polyester	30%
PH2			30%
NK1	Napkin (2-pack)	92,1% organic cotton 3,3% conventional cotton 4,6% polyester	0%
NK2			30%
TC1	Tablecloth	99,3% organic cotton 0,2% conventional cotton 0,6% polyester	0%
TC2			30%

List of abbreviations

Abbreviation	Full expression
A&FW	Apparel and Footwear
DK	Denmark
DPP	Digital product passport
DQR	Data quality rating
DST	Statistics Denmark
EF	Environmental Footprint
ESPR	Ecodesign for Sustainable Products Regulation
EU	European Union
GLO	Global
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

2 Goal of the study

2.1 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 aiming at providing transparent product information to the consumer. The DPP pilot project focuses on the product line, *Nord Harmony*, which is being continuously developed with the aim of improving the environmental footprint and circularity of the products.

The aim of this LCA study is to evaluate the environmental footprint of kitchen textiles from the fall 2026 line of Nord Harmony.

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 further minimize the environmental impact of their products and business.

2.2 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 kitchen textile products by:

1) labelling the products with their climate change impact (kg CO_2e 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.

2.3 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 LCA report will be shared with relevant business partners of Mørkegaard A/S as well as the end consumer.

2.4 Comparative claims

This LCA study includes an environmental impact assessment of several different products. The products are not intended to be compared. The purpose of including several products in one LCA is to efficiently calculate and report on the environmental impacts of the products.

3 Scope of the study

3.1 Description of the products

This study assesses kitchen textiles from the Nord Harmony fall 2026 line. See Figure 2 for illustrations of the products.

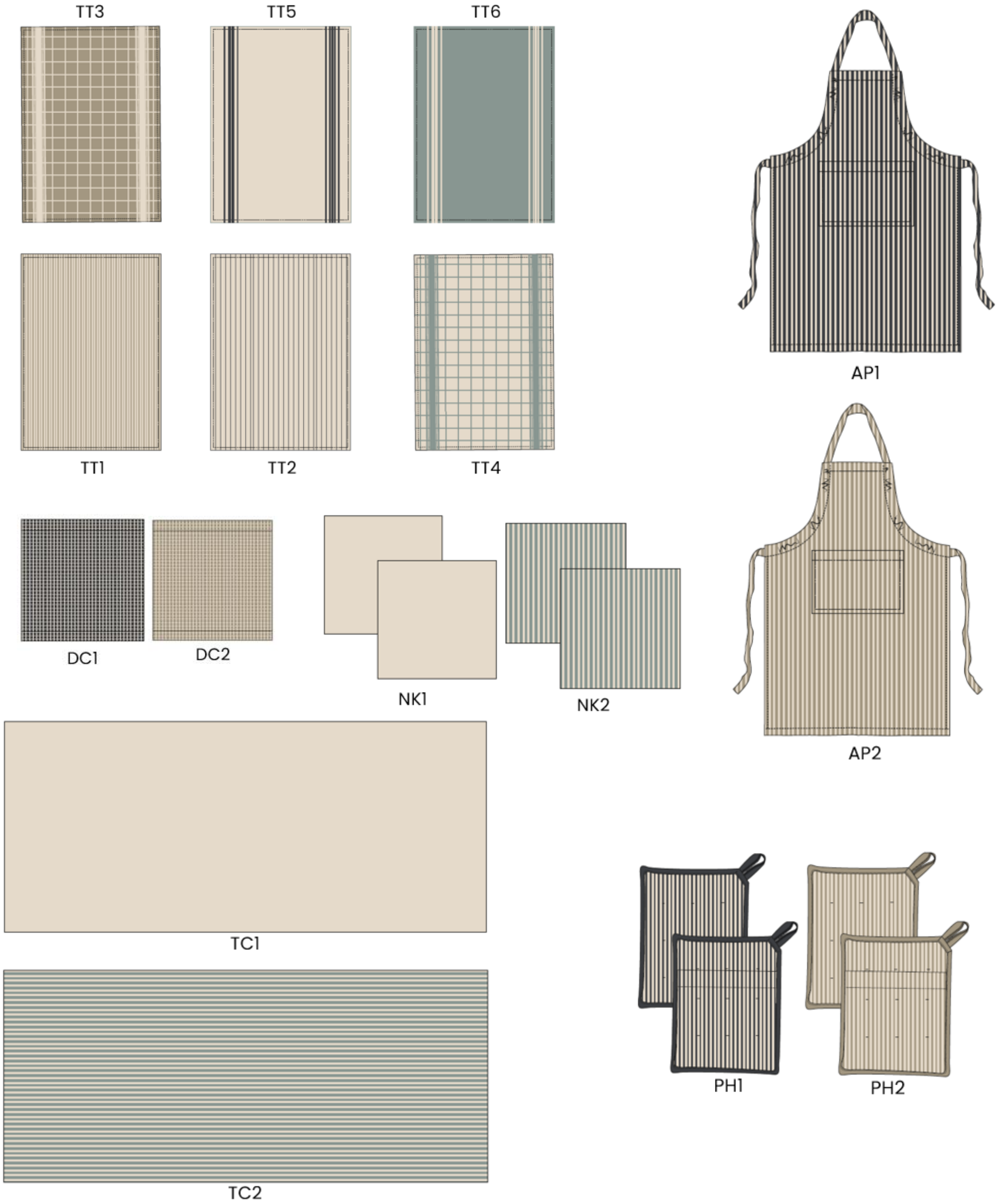

Figure 2 - Illustrations of kitchen textile products in the Nord Harmony fall 2026 line. The pictures are only for illustrative purposes in this LCA and may vary from the actual products. TT = tea towel, AP = apron, DC = dish cloth, PH = potholder, NK = napkin, TC = tablecloth

The products are produced at a factory in Pakistan. Due to confidentiality the factory is not named in this LCA.

The number of LCA results is 16.

Table 2 – Products assessed in the LCA study and LCA ID.

ID	Product type	Organic cotton (main fabric)	Conventional cotton (care label and filling*)	Polyester (thread)	Design	Color of main fabric
TT1	Tea Towel	95,9%	1,7%	2,4%	All-over stripes	25% Lemon pepper/ 75% unbleached
TT2		95,9%	1,7%	2,4%	All-over stripes	25% Anthracite/ 75% unbleached
TT3		95,9%	1,7%	2,4%	Checks	80% Lemon pepper/ 20% unbleached
TT4		95,9%	1,7%	2,4%	Checks	20% Slate grey/ 80% unbleached
TT5		95,9%	1,7%	2,4%	Panel stripes	10% Anthracite/ 90% unbleached
TT6		95,9%	1,7%	2,4%	Panel stripes	90% Slate grey/ 10% unbleached
AP1	Apron	97,5%	0,8%	1,7%	All-over stripes	30% Anthracite/ 70% unbleached
AP2		97,5%	0,8%	1,7%	All-over stripes	30% Lemon pepper/ 70% unbleached
DC1	Dishcloth (2-pack)	86,4%	5,7%	7,9%	Checks	50% Anthracite/ 50% unbleached
DC2		86,4%	5,7%	7,9%	Checks	50% Lemon pepper/ 50% unbleached
PH1	Potholder	55,7%	41,2%	3,1%	All-over stripes	30% Anthracite/ 70% unbleached
PH2		55,7%	41,2%	3,1%	All-over stripes	30% Lemon pepper/ 70% unbleached
NK1	Napkin (2-pack)	92,1%	3,3%	4,6%	Solid	100% Unbleached
NK2		92,1%	3,3%	4,6%	All-over stripes	30% Slate grey/ 70% unbleached
TC1	Tablecloth	99,3%	0,2%	0,6%	Solid	100% Unbleached
TC2		99,3%	0,2%	0,6%	All-over stripes	30% Slate grey/ 70%unbleached

* Filling is only relevant for PH1 and PH2.

3.2 Functional 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. The reference flow and functional unit are listed in Table 3.

Table 3 – Reference flow and functional unit per product in the LCA*

Product	Reference flow	Functional unit
TT1	One tea towel	Drying dishes after daily dishwashing over a period of 0,5 years and a washing frequency of 2,6 times per week.
TT2		
TT3		
TT4		
TT5		
TT6		
AP1	One apron	Protection of clothing during cooking activities once per day over a period of 1,3 years and a washing frequency of 1 time per month.
AP2		
DC1	Two dishcloths (one 2-pack)	Cleaning of kitchen surfaces over a period of 0,6 years and a washing frequency of 2,3 times per week**
DC2		
PH1	One potholder	Thermal protection of hands during cooking activities over a period of 2,9 years and a washing frequency of 2 times per month
PH2		
NK1	Two napkins (one 2-pack)	Wiping of hands and mouth during meals over a period of 0,5 years and a washing frequency of 2,6 times per week**
NK2		
TC1	One tablecloth	Covering and protection of a dining table during meals over a period of 2,9 years and a washing frequency of 1 time per month.
TC2		

**The lifetimes and washing frequencies are calculated based on the washing frequency applied in this LCA. A total of 70 wash cycles is applied to all the products in accordance with Vision Linens (2019). See section 4.5.1 for more information.*

*** This functional unit describes one product, and not the two pack.*

3.3 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 4 the activities included in each life cycle phase are presented.

Table 4 – 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 of cotton from gin to spinning mill or processing for cotton filling • Cotton yarn spinning • Processing of cotton filling • Polyester thread production
2) Transport of raw materials	• Transport of cotton yarn and polyester thread to textile factory

Life cycle phase	Activities included:
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 3.

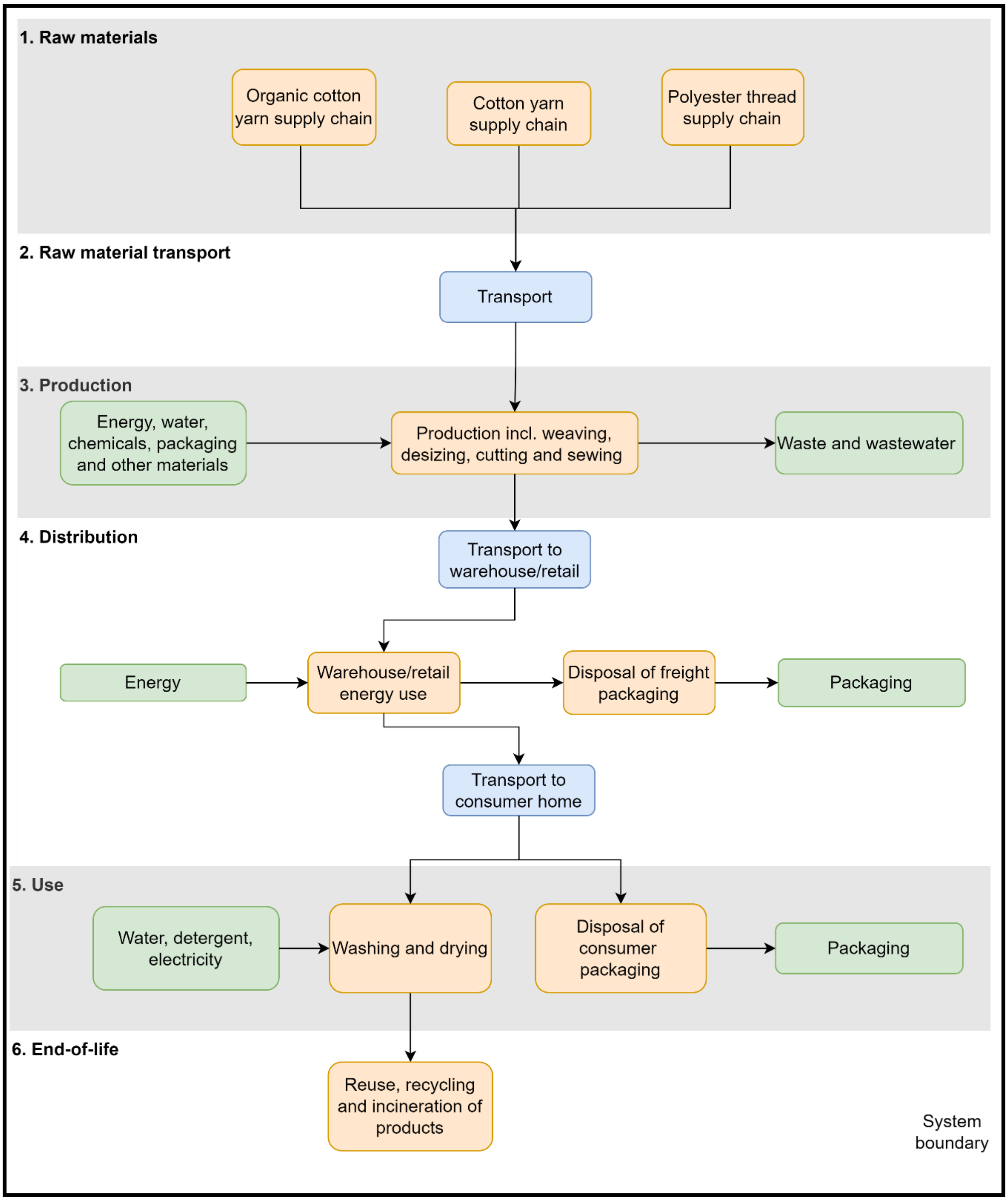

Figure 3 – Flow diagram for life cycle phases in this LCA.

3.4 Modelling approach

3.4.1 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 category rules for apparel and footwear (PEFCR Apparel and Footwear, 2025).

3.4.2 Database and software

The ecoinvent 3.11 database ("cut-off by classification") has been used for background LCI datasets. The software SimaPro 10.2.0.3 and Microsoft Excel have been used for LCA modelling.

3.4.3 LCA method

This is an attributional LCA, meaning the LCA models the environmental impacts of the activities included 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.

3.4.4 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, the data for the foreground system (Phase 3: Production) 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). Mass allocation was selected for this LCA because data for the total mass of processed material was available at the factories across different processing steps allowing for a consistent application of allocation methods. Although there is not a direct relationship between the mass of a textile product and the consumption of energy and auxiliaries in the manufacturing process, - there are many factors affecting this - it is assessed to be the best available data and a fair approximation. Data was not available for other physical units such as total processing time or surface area processed per processing step.

For the background system, the ecoinvent 3.11 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.

3.4.5 Cut-off criteria

In this LCA, a cut-off threshold is set at a maximum of 5%, meaning that the cumulative exclusion of mass inputs (kg) and energy inputs (MJ) must not exceed this limit across the whole life cycle. This approach ensures that all significant inputs are considered while allowing minor contributions to be omitted to streamline the analysis. Furthermore, any processes which are known to have a high environmental impact intensity per kg or MJ shall not be excluded.

3.5 Temporal and geographical scope

The temporal and geographical scope of this LCA is presented in Table 5.

The temporal scope of the production is 2026, which is the year where the products studied in this LCA will be manufactured. Data for the production is, however, collected for 2025, which is considered representative for the production of similar products in 2026.

Table 5 – 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	2025/2026	2026	2026	2026	2026-2029	2027-2029
Geographical	Pakistan	International	Pakistan	Denmark	Denmark	Denmark

3.6 Data quality requirements

3.6.1 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. 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 in approximately 0,5-3 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.

3.6.2 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.

3.6.3 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.

3.6.4 Other data quality requirements

The data quality requirements are applied uniformly to ensure consistency throughout the study. Furthermore, the methodology and assumptions are reported as transparently as possible regarding sources of the data, modelling choices and uncertainty.

3.7 Critical review

This LCA has undergone a critical review by an independent expert from Bureau Veritas Solutions Denmark A/S, Julie M. V. Larsen, LCA & EPD Consultant. The critical review took place in April-May 2026 and included written feedback and a review meeting. The study was adapted based on the comments from the reviewer. See dialogue between the reviewer and the LCA practitioner during the review process in section 9.5 (appendix).

4 Life cycle inventory analysis (LCI)

4.1 Phase 1: Raw materials

Relevant supply chain information regarding the products is summarized in Table 6. The activity data, background data and data quality are described further in the following sections.

Table 6 – Supply chain information for cotton for the factory.

Parameter	Supply chain information		
	Main fabric	Care label	Filling
Cotton origin	Faisalabad, Punjab, Pakistan	Faisalabad, Punjab, Pakistan	Multan, Punjab, Pakistan
Cotton cultivation method	Organic	Conventional	Conventional
Ginning location	Assumed nearby the cotton cultivation (15 km)	Assumed nearby the cotton cultivation (15 km)	Assumed nearby the cotton cultivation (15 km)
Yarn spinning method	Ring spinning	Open end	-
Yarn spinning mill location	Faisalabad, Punjab, Pakistan	Faisalabad, Punjab, Pakistan	-
Bleach, dye, and sizing location	Assumed at spinning mill	-	-
Processing of filling	-	-	Opening, cleaning, carding
Processing of filling location	-	-	Multan, Punjab, Pakistan

In Table 7 the composition of the products can be seen. These figures do not include the material losses occurring in the life cycle. For modelling of phase 1 and 2 the amount of raw material used per product considers the losses in each processing step including the textile factory.

The products assessed in this LCA consist of a main fabric of cotton, a care label of cotton and thread of polyester. The products consist of 56-99% organic cotton (main fabric), 0,8-41,2% conventional cotton (care label and filling) and 0,6-7,9% polyester (thread).

There are two different origins of the cotton used in the products – organic cotton from Pakistan used for the main fabric and conventional cotton from Pakistan used for the care label and the cotton filling.

Table 7 – Product composition (grams)

Product	Product name	Main fabric (organic cotton)	Care label (cotton)	Thread (polyester)	Filling (cotton)	Total
TT1	Tea Towel	80	1,5	2		83,5
TT2		80	1,5	2		83,5
TT3		80	1,5	2		83,5
TT4		80	1,5	2		83,5
TT5		80	1,5	2		83,5
TT6		80	1,5	2		83,5
AP1	Apron	175	1,5	3		179,5
AP2		175	1,5	3		179,5
DC1	Dishcloth (2-pack)	44	2,9	4		50,9
DC2		44	2,9	4		50,9
PH1	Potholder	90	1,5	5	65	161,5
PH2		90	1,5	5	65	161,5
NK1	Napkin (2-pack)	40	1,5	2		43,5
NK2		40	1,5	2		43,5
TC1	Tablecloth	900	1,5	5		906,5
TC2		900	1,5	5		906,5

4.1.1 Cotton cultivation and ginning

4.1.1.1 Activity data

The cotton for the main fabric is grown using organic farming methods in Faisalabad, Punjab, Pakistan.

The cotton for the care label is grown using conventional farming methods in Faisalabad, Punjab, Pakistan.

The cotton for the filling is grown using conventional farming methods in Multan, Punjab, 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 for the main fabric and the care label, and in Multan, Punjab for the filling. 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.

4.1.1.2 Background data

The organic and conventional cultivation of cotton is modelled with secondary data, since the factory does not have primary data for their supply chains. A literature search for LCI datasets for organic and conventional cotton cultivation was carried out, but it was not possible to find a suitable LCI dataset representing organic or conventional cotton growing in Pakistan. Therefore, an Indian dataset from ecoinvent 3.11 for cultivation of organic cotton was used (Seed-cotton, organic {IN-OR}| seed-cotton production, organic | Cut-off, U). 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. An Indian dataset from ecoinvent 3.11 was also used for cultivation of conventional cotton (Seed-cotton {IN-GJ}| seed-cotton production, conventional | Cut-off, U).

The ginning process was modelled with an ecoinvent 3.11 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.

4.1.1.3 Data quality

Information about the cotton cultivation regions was collected from the product factory and has a good accuracy. Nonetheless, secondary LCI data for the cotton cultivation and ginning steps are not available for Pakistan. 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 fair. The ginning process is not location specific, and it was possible to adapt the available dataset from India (IN) to Pakistan (PK) to increase the geographical representativeness. See Table 8 for data quality rating (DQR).

Table 8 – Data quality rating (DQR) for cotton cultivation and ginning in Pakistan (PK)*.

Activity	Accuracy	Geography	Time	Technology
Organic cotton growing	Good	Fair	Very good	Very good
Conventional cotton growing	Good	Fair	Very good	Very good
Ginning	Good	Good	Very good	Very good

*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'. Temporal representativeness is rated as follows: Very good = data is no more than 3 years old, Good = data is no more than 6 years old, Fair = data is no more than 10 years old, Poor = data is no more than 15 years old, Very poor = data is older than 15 years old or unknown.

4.1.2 Transport to yarn further processing

4.1.2.1 Activity data

After the ginning process, the next step for the main fabric and the care label is yarn spinning. The cotton filling is not spun but still undergoes further processing before it is transported to the factory (see section 4.1.5).

The yarn spinning mill is located in Faisalabad, Punjab, Pakistan, the same region as the cotton ginning for the main fabric and care label. Therefore, the transport distance from gin to spinning mill is estimated to be 30 km, based on the size of Faisalabad.

The processing facility for cotton filling is located in Multan, Punjab, Pakistan, the same region as the cotton ginning for the filling. Therefore, the transport distance is estimated to be 40 km, based on the size of Multan.

4.1.2.2 Background data

The truck transport was modelled with an ecoinvent 3.11 dataset for unspecified truck in the 'Rest of World' (RoW) geography (Transport, freight, lorry, diesel, unspecified {RoW}| market for transport, freight, lorry, unspecified | Cut-off, U).

4.1.2.3 Data quality

Information about the cotton supply chain for the products was collected from the factory and has a good accuracy, since the country and regions for the supply chain steps are known and thus giving a good estimate of the transport distances. The secondary LCI data for this transport is considered as fair geographical representativeness and good technological representativeness. See Table 9 for data quality rating (DQR). The actual transport distances for recycled cotton are unknown, and the accuracy and geographical representativeness are therefore very poor.

Table 9 – Data quality rating (DQR) for transport of cotton fiber to yarn spinning mill*.

Activity	Accuracy	Geography	Time	Technology
Transport to final processing	Good	Poor	Very good	Good

*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'. Temporal representativeness is rated as follows: Very good = data is no more than 3 years old, Good = data is no more than 6 years old, Fair = data is no more than 10 years old, Poor = data is no more than 15 years old, Very poor = data is older than 15 years old or unknown.

4.1.3 Yarn spinning

4.1.3.1 Activity data

The yarn used in main fabric is ring spun and the yarn used in care label is open spun.

4.1.3.2 Background data

The yarn ring spinning process was modelled with an ecoinvent 3.11 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 input and ginning are modelled separately.

The yarn open spinning process was modelled with an ecoinvent 3.11 dataset for cotton yarn spinning globally, where the electricity mix was changed from India (IN) to Pakistan (PK) (Yarn, cotton {IN}| yarn production, cotton, open end spinning | Cut-off, U - adapted to PK). Furthermore, the cotton fiber input was removed from the dataset, since the cotton input and ginning are modelled separately.

4.1.3.3 Data quality

Information about the yarn spinning location and method was collected from the factory and has a good accuracy. Secondary LCI data was not available for the yarn spinning process in Pakistan. Nonetheless, it was possible to adapt the available global dataset to Pakistan to increase the geographical representativeness. See Table 10 for data quality rating (DQR).

Table 10 – Data quality rating (DQR) for yarn spinning process*.

Activity	Accuracy	Geography	Time	Technology
Ring spinning	Good	Poor	Very good	Very good
Open spinning	Good	Fair	Very good	Very good

*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'. Temporal representativeness is rated as follows: Very good = data is no more than 3 years old, Good = data is no more than 6 years old, Fair = data is no more than 10 years old, Poor = data is no more than 15 years old, Very poor = data is older than 15 years old or unknown.

4.1.4 Yarn bleaching, dyeing, and sizing

After spinning, the yarn undergoes bleaching, dyeing, and sizing before arriving at the factory. It is assumed that these processes take place in the same location as the yarn spinning.

4.1.4.1 Background data

The yarn bleaching and dyeing was modelled with an ecoinvent 3.11 dataset for yarn bleaching and dyeing, where the electricity mix was changed from India (IN) to Pakistan (PK) (Bleaching and dyeing, yarn {IN}| bleaching and dyeing, yarn | Cut-off, U – adapted to PK). Starch for sizing was modelled with an ecoinvent 3.11 dataset for maize starch in the geography 'Global' (GLO) (Maize starch {GLO} | market for maize starch | Cut-off, U). The amount of starch needed per kg of yarn was determined based on the ecoinvent 3.11 dataset for weaving. (Textile, woven cotton {BD} | textile production, cotton, weaving | Cut-off, U). No energy consumption was included in the sizing process, since sizing requires 0.1%

of the total energy consumption for spinning, sizing, and weaving according to S. Palamutcu (2010).

4.1.4.2 Data quality

Information about the yarn bleaching, dyeing, and sizing is based on secondary LCI data and therefore the accuracy is fair. Secondary LCI data was not available for the yarn bleaching, dyeing, and sizing in Pakistan. Nonetheless, it was possible to adapt the available Indian dataset for yarn bleaching and dyeing to Pakistan to increase the geographical. See Table 11 for data quality rating (DQR).

Table 11 – Data quality rating (DQR) for yarn bleaching, dyeing, and sizing*.

Activity	Accuracy	Geography	Time	Technology
Yarn bleaching and dyeing	Fair	Fair	Very good	Good
Yarn sizing	Fair	Poor	Very good	Fair

*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'. Temporal representativeness is rated as follows: Very good = data is no more than 3 years old, Good = data is no more than 6 years old, Fair = data is no more than 10 years old, Poor = data is no more than 15 years old, Very poor = data is older than 15 years old or unknown.

4.1.5 Processing of cotton filling

4.1.5.1 Activity data

The cotton filling does not require the same processing step as the main fabric and care label, since it is not spun into yarn. After ginning, the cotton undergoes opening, cleaning, mixing and carding (Textile Engineering, 2025 and Barnhardt, 2016).

4.1.5.2 Background data

Since it has not been possible to find a dataset for opening, cleaning, mixing and carding, the processes have been included with the ecoinvent 3.11 dataset for electricity in Pakistan (Electricity, low voltage {PK}| market for electricity, low voltage | Cut-off, U). The electricity consumption is based on a critically reviewed LCA study on cotton fiber and fabric (Cotton Incorporated, 2017), which investigated the energy consumption for each step in cotton processing including opening, cleaning, mixing and carding. The study is nine years old, and it is likely that the energy efficiency has increased in the last nine years. In this LCA it is assumed that this is not the case as a conservative estimate. Furthermore, to be conservative, the electricity consumption found in Cotton Incorporated (2017), has been doubled in this LCA. Hence, it is assumed that it requires 0,4 kWh/kg cotton for opening, cleaning, mixing and carding cotton filling.

4.1.5.3 Data quality

Information about the processing location was collected from the factory and it has a good data quality. Secondary LCI data was not available for the process, and therefore the electricity consumption has been estimated through other sources (Textile Engineering, 2025; Banhardt, 2016 and Cotton Incorporated, 2017) resulting in poor accuracy. See Table 12 for data quality rating (DQR).

Table 12 – Data quality rating (DQR) for processing of cotton filling*.

Activity	Accuracy	Geography	Time	Technology
Processing of filling	Poor	Very good	Very good	Fair

*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'. Temporal representativeness is rated as follows: Very good = data is no more than 3 years old, Good = data is no more than 6 years old, Fair = data is no more than 10 years old, Poor = data is no more than 15 years old, Very poor = data is older than 15 years old or unknown.

4.1.6 Polyester thread

4.1.6.1 Activity data

The products contain 0,6%-7,9% polyester thread.

The polyester thread is produced in Pakistan (fiber production in Karachi, Sindh, Pakistan and thread production in Faisalabad, Punjab, Pakistan). Transport between the processing steps is estimated with the EcoTransit online tool. The distance from the fiber production in Karachi, Pakistan, to the thread production in Faisalabad, Pakistan, is estimated at 1120 km by truck.

4.1.6.2 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 3.11 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). The transport from fiber production to thread production has been modelled with an ecoinvent 3.11 dataset for unspecified truck in the 'Rest of World' (RoW) geography (Transport, freight, lorry, diesel, unspecified {RoW}| market for transport, freight, lorry, unspecified | Cut-off, U).

4.1.6.3 Data quality

Information about the polyester supply chain was collected from the 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. The processing is not location specific, and it was possible to adapt the available dataset to the actual location to increase geographical representativeness. See Table 13 for data quality rating (DQR).

Table 13 – Data quality rating (DQR) for polyester thread.

Activity	Accuracy	Geography	Time	Technology
Fiber production	Good	Fair	Very good	Fair
Transport of thread	Good	Poor	Very good	Good

*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'. Temporal representativeness is rated as follows: Very good = data is no more than 3 years old, Good = data is no more than 6 years old, Fair = data is no more than 10 years old, Poor = data is no more than 15 years old, Very poor = data is older than 15 years old or unknown.

Phase 1 – unit process overview

Table 14 – Unit processes in phase 1 – raw materials.

Unit process name	Unit process unit	Input	Input unit	ecoinvent dataset	Comment
1.01 Organic cotton cultivation incl. transport to gin	kg seed-cotton	1	kg	Seed-cotton, organic {IN-OR}| seed-cotton production, organic | Cut-off, U	
				Transport, freight, lorry, diesel, unspecified {GLO}| market group for transport, freight, lorry, diesel, unspecified | Cut-off, U	
1.02 Conventional cotton cultivation incl. transport to gin	kg seed-cotton	1	kg	Seed-cotton {IN-GJ}| seed-cotton production, conventional | Cut-off, U	
				Transport, freight, lorry, diesel, unspecified {GLO}| market group for transport, freight, lorry, diesel, unspecified | Cut-off, U	
1.03 Cotton ginning	kg cotton	1	kg	Fibre, cotton {IN}| fibre production, cotton, ginning | Cut-off, U – adapted to PK	Background dataset adapted from India to Pakistan.
1.04 Truck transport to final processing	tkm	1	tkm	Transport, freight, lorry, diesel, unspecified {RoW}| market for transport, freight, lorry, unspecified | Cut-off, U	
1.05 Yarn ring spinning	kg cotton yarn	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.
1.06 Yarn open spinning	kg cotton yarn	1	kg	Yarn, cotton {IN}| yarn production, cotton, open end spinning | Cut-off, U - adapted to PK	Background dataset adapted from India to Pakistan.
1.07 Yarn bleaching and dyeing	kg cotton yarn	1	kg	Bleaching and dyeing, yarn {IN}| bleaching and dyeing, yarn | Cut-off, U – adapted to PK	Background dataset adapted from India to Pakistan.
1.08 Yarn sizing	kg cotton yarn	0,1567	kg	Maize starch {GLO} | market for maize starch | Cut-off, U	Amount of starch needed per kg cotton yarn is based on the ecoinvent 3.11 dataset Textile, woven cotton {BD} | textile production, cotton, weaving | Cut-off, U
1.09 Cotton filling processing	kg cotton	1	Kg	Electricity, low voltage {PK}| market for electricity, low voltage | Cut-off, U	
1.10 Polyester fiber	kg polyester	1	kg	Fibre, polyester {IN}| polyester fibre production, finished | Cut-off, U – adapted to PK	Background dataset adapted from India to Pakistan.

Table 15 – Amount of unit processes per product in phase 1 – raw materials.

Unit process name	Unit	TT1	TT2	TT3	TT4	TT5	TT6	AP1	AP2	DC1	DC2	PH1	PH2	NK1	NK2	TC1	TC2
1.01 Organic cotton cultivation incl. transport to gin	kg seed-cotton	0,200	0,200	0,200	0,200	0,200	0,200	0,438	0,438	0,110	0,110	0,225	0,225	0,100	0,100	2,250	2,250
1.2 Conventional cotton cultivation incl. transport to gin	kg cotton fiber	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,007	0,007	0,166	0,166	0,004	0,004	0,004	0,004
1.03 Cotton ginning	kg cotton	0,103	0,103	0,103	0,103	0,103	0,103	0,223	0,223	0,059	0,059	0,197	0,197	0,052	0,052	1,138	1,138
1.04 Truck transport to final processing	tkm	0,005	0,005	0,005	0,005	0,005	0,005	0,009	0,009	0,006	0,006	0,011	0,011	0,004	0,004	0,035	0,035
1.05 Yarn ring spinning	kg cotton yarn	0,086	0,086	0,086	0,086	0,086	0,086	0,188	0,188	0,047	0,047	0,097	0,097	0,043	0,043	0,967	0,967
1.06 Yarn open spinning	kg cotton yarn	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,003	0,003	0,002	0,002	0,002	0,002	0,002	0,002
1.07 Yarn bleaching and dyeing	kg cotton yarn	0,021	0,021	0,067	0,017	0,008	0,076	0,055	0,055	0,023	0,023	0,028	0,028		0,013		0,284
1.08 Yarn sizing	kg cotton yarn	0,084	0,084	0,084	0,084	0,084	0,084	0,184	0,184	0,046	0,046	0,095	0,095	0,042	0,042	0,947	0,947
1.09 Cotton filling processing	kg cotton											0,070	0,070				
1.10 Polyester fiber	kg polyester	0,002	0,002	0,002	0,002	0,002	0,002	0,003	0,003	0,004	0,004	0,005	0,005	0,002	0,002	0,005	0,005

4.2 Phase 2: Transport of raw materials

Phase 2 “Raw materials” includes the transportation of raw material from the last processing step to the factory. See relevant information about phase 2 in Table 16. The activity data, background data and data quality are described further in the following sections.

Table 16 – Information about the transport routes from spinning mill to textile factory

Parameter	Transport information
Cotton spinning location	Faisalabad, Punjab, Pakistan
Polyester thread production location	Faisalabad, Punjab, Pakistan
Filling processing location	Multan, Punjab Pakistan
Factory location	Multan, Punjab, Pakistan
Transport yarn spinning mill to textile factory	Leg 1: Faisalabad-Multan 240 km (estimated distance)
Transport thread to textile factory	Leg 1: Faisalabad- Multan 240 km (estimated distance)
Transport filling to textile factory	Leg 1: Multan-Multan 40 km (estimated distance)
Transport secondary dataset	Transport, freight, lorry, unspecified {RoW}| market for transport, freight, lorry, unspecified | Cut-off, U

4.2.1 Activity data

The factory is located in Multan, Punjab, and cotton yarn and thread comes from Faisalabad, Punjab Pakistan. The transport distance by truck is measured to be 240 km using Google Maps. The filling comes from Multan, Punjab, and a distance of 40 km is assumed based on the size of Multan.

4.2.2 Background data

The truck transport in Pakistan was modelled with an ecoinvent 3.11 dataset for unspecified truck in the ‘Rest of World’ (RoW) geography (Transport, freight, lorry, diesel, 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 18 and Table 19.

4.2.3 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. Table 17 for data quality rating (DQR).

Table 17 – Data quality rating (DQR) for transport of raw materials*.

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

*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'. Temporal representativeness is rated as follows: Very good = data is no more than 3 years old, Good = data is no more than 6 years old, Fair = data is no more than 10 years old, Poor = data is no more than 15 years old, Very poor = data is older than 15 years old or unknown.

4.2.4 Phase 2 – unit process overview

Table 18 – Unit processes in phase 2 – transport of raw materials.

Unit process name	Unit process unit	Input	Input unit	ecoinvent dataset	Comment
2.1 Truck transport to textile factory	tkm	1	tkm	Transport, freight, lorry, diesel, unspecified {RoW}| market for transport, freight, lorry, unspecified | Cut-off, U	

Table 19 – Amount of unit processes per product in phase 2 – transport of raw materials.

Unit process name	Unit	TT1	TT2	TT3	TT4	TT5	TT6	AP1	AP2	DC1	DC2	PH1	PH2	NK1	NK2	TC1	TC2
2.1 Truck transport to textile factory	tkm	0,020	0,020	0,020	0,020	0,020	0,020	0,043	0,043	0,012	0,012	0,026	0,026	0,010	0,010	0,218	0,218

4.3 Phase 3: Production

4.3.1 Production inputs and outputs

4.3.1.1 Activity data

The products included in this LCA undergo the following processes in the factory:

1) Weaving
2) Desizing
3) Cut and sew

According to the factory, the weaving process has a loss of 2% of the yarn, while the cut and sew process has a loss of 5% of the fabric. Overall, this means that (1,02 kg x 1,05 kg =) 1,07 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 factory in 2025:

- 239.616 kg fabric was woven
- 1.560.000 kg fabric underwent desizing
- 123.382 kg fabric underwent cut and sew (final products)

The processed amounts vary per processing step in the factory due to processing of fabric that has been woven in other factories.

Inputs of energy, water, materials and chemicals per kg of product are listed in Table 20 and Table 21. Outputs of waste and wastewater per kg of product are listed in Table 22. For a more detailed description of how each input or output flow was determined and allocated to 1 kg of each product see Section 9.1 (Appendix).

Table 20 – Energy and consumables per kg of final product

Input	Unit	per kg of product	Source
Electricity from grid	kWh	1,25	Primary data (allocated)
Natural gas	m^3	0,43	Primary data (allocated)
Diesel	L	0,07	Primary data (allocated)
Gasoline	L	0,07	Primary data (allocated)
Biomass for heat	kg	3,18	Primary data (allocated)
Clean water	m^3	0,11	Primary data (allocated)
Lubricants	kg	0,01	Primary data (allocated)
Plastic	kg	0,003	Calculated from mass balance*
Paper	kg	0,02	Calculated from mass balance*
* The amount of plastic and paper waste is assumed to enter the factory i.e., misc. packaging etc.			

Table 21 - Chemicals per kg of final product

Input	Unit	pr. kg TT1	pr. kg TT2	pr. kg TT3	pr. kg TT4	pr. kg TT5	pr. kg TT6	pr. kg AP1	pr. kg AP2	pr. kg DC1	pr. Kg DC2	pr. kg PH1	pr. kg PH2	pr. kg NK1	pr. kg NK2	pr. kg TC1	pr. kg TC2	Source
Acid for desizing	kg	0,0062	0,0062	0,0062	0,0062	0,0062	0,0062	0,0064	0,0064	0,0056	0,0056	0,0009	0,0009	0,0054	0,0054	0,0058	0,0058	Primary data
Enzymes for desizing	kg	0,0008	0,0008	0,0008	0,0008	0,0008	0,0008	0,0017	0,0017	0,0002	0,0002	0,0003	0,0003	0,0004	0,0004	0,0087	0,0087	Primary data
Sodium hydroxide for scouring	kg	0,008	0,008	0,008	0,008	0,008	0,008	0,017	0,017	0,002	0,002	0,003	0,003	0,004	0,004	0,087	0,087	Primary data

Table 22 – Waste and wastewater per kg of final product

Input	Unit	Per kg of product	Source
Plastic waste	kg	0,003	Primary data (allocated)
Paper waste	kg	0,02	Primary data (allocated)
Wastewater	m3	0,13	Calculated (125% of water input)
Textile waste	kg	0,07	Calculated from loss rate

4.3.1.2 Background data

The electricity consumption from the grid was modelled with an ecoinvent 3.11 dataset for electricity in Pakistan (PK) (Electricity, medium voltage {PK}| market for electricity, medium voltage | Cut-off, U).

The natural gas for heating was modelled with an ecoinvent 3.11 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). The unit for this dataset is MJ, while the natural gas consumption in the factory is defined in mmBTU or m^3. Conversion from mmBTU to m^3 natural gas was carried out (28,26 m^3 natural gas per mmBTU according to Index Mundi, (n.d.)). Then the amount of m^3 natural gas needed to produce 1 MJ heat was taken from within the dataset (0,029 m^3 natural gas/MJ) to define the amount of MJ of the dataset required to represent the consumption of 1 m^3 natural gas in the factory (34,6 MJ/kg).

The diesel for generators was modelled with an ecoinvent 3.11 dataset for diesel burned in a building machine in the geography 'Global' (GLO) (Diesel, burned in building machine {GLO}| diesel, burned in building machine | Cut-off, U). The unit for the dataset is MJ, while the diesel consumption in the factory is defined in liter. Conversion from MJ is based on the ecoinvent dataset (42,7 MJ/kg diesel), and The Engineering ToolBox (2003) (0,849 kg diesel/L diesel).

The gasoline for company vehicles was modelled with an ecoinvent 3.11 dataset for petrol in the geography 'Rest of World' (RoW) (Petrol, unleaded {RoW}| market for petrol, unleaded | Cut-off, U). The unit for the dataset is kg, while the gasoline consumption in the factory is defined in liter. Conversion from kg is based on The Engineering ToolBox (2003) (0,746 kg gasoline/L gasoline).

The heat from biomass was modelled with an ecoinvent 3.11 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). The unit for the dataset is MJ. The kg biomass needed to produce 1 MJ heat was taken from within the dataset (0,0756 kg/MJ) to define the amount of MJ of the dataset required to represent the consumption of 1 kg biomass in the factory (13,2 MJ/kg).

The water consumption was modelled with an ecoinvent 3.11 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 3.11 dataset for lubricating oil the geography 'Rest of World' (RoW) (Lubricating oil {RoW}| market for lubricating oil | Cut-off, U).

The disposal of plastic waste was modelled with an ecoinvent 3.11 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 paper waste was modelled with an ecoinvent 3.11 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 3.11 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 wastewater was modelled with an ecoinvent 3.11 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 3.11 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 paper to the factory was modelled with an ecoinvent 3.11 dataset for woodfree paper in the geography 'Rest of World' (RoW) (Paper, woodfree, uncoated {RoW}| market for paper, woodfree, uncoated | Cut-off, U).

Acid for desizing was modelled with an ecoinvent 3.11 dataset for Hydrogen peroxide in the geography 'Rest of World' (RoW) (Hydrogen peroxide, without water, in 50% solution state {RoW}| market for hydrogen peroxide, without water, in 50% solution state | Cut-off, U).

Enzymes for desizing modelled with an ecoinvent 3.11 dataset for enzymes in the geography 'Global' (GLO) (Enzymes {GLO}| market for enzymes | Cut-off, U).

Sodium hydroxide for scouring and for bleaching was modelled with an ecoinvent 3.11 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).

See overview of LCI data for phase 3 (production) in Table 26 and Table 27.

4.3.1.3 Data quality

The data quality rating for the production phase can be seen in Table 23. Overall, the data accuracy and technological representativeness of background data is good, while the geographical and temporal representativeness is poor.

Table 23 – Data quality rating (DQR) for production*.

Activity	Accuracy	Geography	Time	Technology
Electricity from grid	Good	Very good	Very good	Very good
Natural gas	Good	Poor	Very good	Good
Diesel	Good	Poor	Very good	Good
Gasoline	Good	Poor	Very good	Good
Heat from biomass	Good	Poor	Very good	Good
Clean water	Good	Poor	Very good	Good
Lubricant	Good	Poor	Very good	Good
Acid for desizing	Good	Poor	Very good	Good
Enzymes for desizing	Good	Poor	Very good	Fair
Sodium hydroxide for scouring	Good	Poor	Very good	Very good
Plastic waste	Good	Poor	Very good	Good
Paper waste	Good	Poor	Very good	Good
Textile waste	Good	Poor	Very good	Good
Wastewater treatment	Good	Poor	Very good	Good
Plastic input	Fair	Poor	Very good	Good
Paper input	Fair	Poor	Very good	Good

*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'. Temporal representativeness is rated as follows: Very good = data is no more than 3 years old, Good = data is no more than 6 years old, Fair = data is no more than 10 years old, Poor = data is no more than 15 years old, Very poor = data is older than 15 years old or unknown.

4.3.2 Product packaging

4.3.2.1 Activity data

The amount of packaging per product can be seen in Table 24.

Table 24 Product packaging composition (grams)

LCA ID	Consumer packaging			Freight packaging		
	Belly band (printed cardboard)	Hang tag (cardboard)	Jute rope (jute)	Box (cardboard)	Polybag (LDPE)	Packaging tape (LDPE)
TT1		4	1	45	0,6	0,4
TT2		4	1	45	0,6	0,4
TT3		4	1	45	0,6	0,4
TT4		4	1	45	0,6	0,4
TT5		4	1	45	0,6	0,4
TT6		4	1	45	0,6	0,4
AP1	34			98	1,3	0,9
AP2	34			98	1,3	0,9

LCA ID	Consumer packaging			Freight packaging		
	Belly band (printed cardboard)	Hang tag (cardboard)	Jute rope (jute)	Box (cardboard)	Polybag (LDPE)	Packaging tape (LDPE)
DC1		4	1	12	0,2	0,1
DC2		4	1	12	0,2	0,1
PH1		4	1	50	0,7	0,4
PH2		4	1	50	0,7	0,4
NK1		4	1	10	0,2	0,1
NK2		4	1	10	0,2	0,1
TC1	34			230	4,6	3,2
TC2	34			230	4,6	3,2

4.3.2.2 Background data

The bellyband and hang tag, which is printed, was modelled with an ecoinvent 3.11 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 jute rope was modelled with an ecoinvent 3.11 dataset for jute in the 'India' (IN) geography (Yarn, jute {IN}| yarn production, jute | Cut-off, U).

The polybag and packaging tape was modelled with an ecoinvent 3.11 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).

The freight box was modelled with an ecoinvent 3.11 dataset for cardboard box in the 'Rest of World' (RoW) geography (Corrugated board box {RoW}| market for corrugated board box | Cut-off, U).

See overview of LCI data for phase 3 (production) in Table 26 and Table 27.

4.3.2.3 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 fair-good. See Table 25 for data quality rating (DQR).

Table 25 – Data quality rating (DQR) for product packaging*.

Activity	Accuracy	Geography	Time	Technology
Unprinted cardboard	Very good	Poor	Very good	Good
Printed cardboard	Very good	Poor	Very good	Good
Jute rope	Very good	Fair	Very good	Very good
LDPE bag	Very good	Poor	Very good	Good
Packaging tape	Very good	Poor	Very good	Fair

*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'. Temporal representativeness is rated as follows: Very good = data is no more than 3 years old, Good = data is no more than 6 years old, Fair = data is no more than 10 years old, Poor = data is no more than 15 years old, Very poor = data is older than 15 years old or unknown.

4.3.3 Phase 3 – unit process overview

Table 26 – 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 Natural gas	m^3	34,6	MJ	Heat, central or small-scale, natural gas {RoW}| heat production, natural gas, at boiler modulating <100kW | Cut-off, U – adapted to PK	0,0289 m^3 natural gas/MJ according to dataset. 1/(0,0289 m^3/MJ) = 34,6 MJ/m^3. Electricity mix was changed from various geographies to Pakistan (PK)
3.03 Diesel	1,2 L	42,7	MJ	Diesel, burned in building machine {GLO}| diesel, burned in building machine | Cut-off, U	0,0234 kg diesel/MJ according to dataset. 1/(0,0234 kg/MJ) = 42,7 MJ. 0,849 kg/L diesel according to The Engineering ToolBox (2003). 1/(0,849 kg/L) = 1,2 L.
3.04 Gasoline	1,3 L	1	kg	Petrol, unleaded {RoW}| market for petrol, unleaded | Cut-off, U	0,747 kg/L gasoline according to The Engineering ToolBox (2003). 1/(0,747 kg/L) = 1,3 L
3.05 Heat from biomass	kg biomass	13,2	MJ	Heat, central or small-scale, other than natural gas {RoW}| heat production, wood chips from industry, at furnace 50kW | Cut-off, U	According to the dataset it requires 0,0756 kg biomass to produce 1 MJ of heat. 1/0,0756 kg/MJ = 13,2 MJ/kg
3.06 Water consumption	m^3	1000	kg	Tap water {RoW}| market for tap water | Cut-off, U	
3.07 Lubricant	kg	1	kg	Lubricating oil {RoW}| market for lubricating oil | Cut-off, U	
3.08 Plastic waste	kg	1	kg	Waste polyethylene {RoW}| market for waste polyethylene | Cut-off, U	
3.09 Paper waste	kg	1	kg	Waste paperboard {RoW}| market for waste paperboard | Cut-off, U	
3.10 Textile waste	kg	1	kg	Waste textile, soiled {RoW}| market for waste textile, soiled | Cut-off, U	
3.11 Wastewater	kg	1	kg	Wastewater from textile production {RoW}| market for wastewater from textile production | Cut-off, U	

Unit process name	Unit process unit	Input	Input unit	ecoinvent dataset	Comment
3.12 Other material inputs – plastic	kg	1	kg	Packaging film, low density polyethylene {GLO}| market for packaging film, low density polyethylene | Cut-off, U	
3.13 Other material inputs – paper	kg	1	kg	Paper, woodfree, uncoated {RoW}| market for paper, woodfree, uncoated | Cut-off, U	
3.14.1 Acid for desizing	kg	1	kg	Hydrogen peroxide, without water, in 50% solution state {RoW}| market for hydrogen peroxide, without water, in 50% solution state | Cut-off, U	
3.14.2 Enzymes for desizing	Kg	1	kg	Enzymes {GLO}| market for enzymes | Cut-off, U	
3.14.3 NaOH for scouring	kg	1	kg	Sodium hydroxide, without water, in 50% solution state {RoW}| market for sodium hydroxide, without water, in 50% solution state | Cut-off, U	
3.15 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	
3.16 Packaging - unprinted cardboard	kg	1	kg	Corrugated board box {RoW}| market for corrugated board box | Cut-off, U	
3.17 Packaging - LDPE	kg	1	kg	Packaging film, low density polyethylene {GLO}| market for packaging film, low density polyethylene | Cut-off, U	
3.18 Packaging – jute	kg	1	kg	Yarn, jute {IN}| yarn production, jute | Cut-off, U	

Table 27 – Amount of unit processes per product in phase 3 – production.

Unit process name	Unit	TT1	TT2	TT3	TT4	TT5	TT6	AP1	AP2	DC1	DC2	PH1	PH2	NK1	NK2	TC1	TC2
3.01 Electricity from grid	kWh	0,105	0,105	0,105	0,105	0,105	0,105	0,225	0,225	0,064	0,064	0,203	0,203	0,055	0,055	1,137	1,137
3.02 Natural gas	m^3	0,036	0,036	0,036	0,036	0,036	0,036	0,077	0,077	0,022	0,022	0,069	0,069	0,019	0,019	0,389	0,389
3.03 Diesel	L	0,006	0,006	0,006	0,006	0,006	0,006	0,012	0,012	0,003	0,003	0,011	0,011	0,003	0,003	0,061	0,061
3.04 Gasoline	L	0,006	0,006	0,006	0,006	0,006	0,006	0,013	0,013	0,004	0,004	0,012	0,012	0,003	0,003	0,066	0,066

Unit process name	Unit	TT1	TT2	TT3	TT4	TT5	TT6	AP1	AP2	DC1	DC2	PH1	PH2	NK1	NK2	TC1	TC2
3.05 Heat from biomass	kg	0,265	0,265	0,265	0,265	0,265	0,265	0,570	0,570	0,162	0,162	0,513	0,513	0,138	0,138	2,880	2,880
3.06 Water consumption	m^3	0,009	0,009	0,009	0,009	0,009	0,009	0,019	0,019	0,005	0,005	0,017	0,017	0,005	0,005	0,095	0,095
3.07 Lubricant	kg	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,0003	0,0003	0,001	0,001	0,0003	0,0003	0,006	0,006
3.08 Plastic waste	kg	0,000	0,000	0,000	0,000	0,000	0,000	0,001	0,001	0,0002	0,0002	0,001	0,001	0,0001	0,0001	0,003	0,003
3.09 Paper waste	kg	0,002	0,002	0,002	0,002	0,002	0,002	0,004	0,004	0,001	0,001	0,004	0,004	0,0010	0,0010	0,020	0,020
3.10 Textile waste	kg	0,006	0,006	0,006	0,006	0,006	0,006	0,013	0,013	0,004	0,004	0,012	0,012	0,003	0,003	0,067	0,067
3.11 Wastewater	kg	0,009	0,009	0,009	0,009	0,009	0,009	0,020	0,020	0,007	0,007	0,018	0,018	0,005	0,005	0,099	0,099
3.12 Other material inputs - plastic	kg	0,000	0,000	0,000	0,000	0,000	0,000	0,001	0,001	0,0002	0,0002	0,001	0,001	0,0001	0,0001	0,003	0,003
3.13 Other material inputs - paper	kg	0,002	0,002	0,002	0,002	0,002	0,002	0,004	0,004	0,001	0,001	0,004	0,004	0,0010	0,0010	0,020	0,020
3.14.1 Acid for desizing	kg	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,0001	0,0001	0,0002	0,0002	0,0002	0,0002	0,005	0,005
3.14.2 Enzymes for desizing	kg	0,00006	0,00006	0,00006	0,00006	0,00006	0,00006	0,00014	0,00014	0,00002	0,00002	0,00002	0,00002	0,000032	0,000032	0,0007	0,0007
3.14.3 NaOH for scouring	kg	0,0006	0,0006	0,0006	0,0006	0,0006	0,0006	0,0014	0,0014	0,0002	0,0002	0,0002	0,0002	0,000322	0,000322	0,0073	0,0073
3.15 Packaging - printed cardboard	kg	0,004	0,004	0,004	0,004	0,004	0,004	0,034	0,034	0,004	0,004	0,004	0,004	0,004	0,004	0,034	0,034
3.16 Packaging - unprinted cardboard	kg	0,045	0,045	0,045	0,045	0,045	0,045	0,098	0,098	0,022	0,022	0,050	0,050	0,010	0,010	0,230	0,230
3.17 Packaging - LDPE	kg	0,001	0,001	0,001	0,001	0,001	0,001	0,002	0,002	0,000	0,000	0,001	0,001	0,000	0,000	0,008	0,008
3.18 Packaging – jute	kg	0,001	0,001	0,001	0,001	0,001	0,001			0,001	0,001	0,001	0,001	0,001	0,001		

4.4 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 it is a larger city located more or less midway between the two retail stores located the furthest away from each other (Skagen and Nexø). The distance from Odense to Skagen and Nexø is 352 km and 358 km, respectively.

Relevant information regarding distribution is summarized in Table 28. The activity data, background data and data quality are described further in the following sections.

Table 28 Relevant information regarding distribution of the products

Parameter	Information
Transport from factory to retail in Denmark	Leg 1: 900 km by truck (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 'm^3-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 'm^3-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

4.4.1 Transport to retail in Denmark

4.4.1.1 Activity data

The products are transported from the factory in Multan to the Karachi port in Pakistan by truck (900 km). From the port in Karachi, the products are transported by container ship to the port in Copenhagen (12.200 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.

4.4.1.2 Background data

The truck transport in Pakistan was modelled with an ecoinvent 3.11 dataset for unspecified truck in the 'Rest of World' (RoW) geography (Transport, freight, lorry, diesel, unspecified {RoW}| market for transport, freight, lorry, unspecified | Cut-off, U).

The ship transport was modelled with an ecoinvent 3.11 dataset for global container shipping (Transport, freight, sea, container ship, heavy fuel oil {GLO}| transport, freight, sea, container ship, heavy fuel oil | Cut-off, U).

The truck transport in Denmark was modelled with an ecoinvent 3.11 dataset for >32 ton, EURO 4 truck in the 'Rest of Europe' (RER) geography (Transport, freight, lorry, >32 metric ton, diesel, EURO 4 {RER}| transport, freight, lorry, >32 metric ton, diesel, EURO 4 | Cut-off, U).

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

4.4.1.3 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 rated as poor, since the applied datasets are either global or representing large regions (i.e. Europe). The temporal representativeness is rated as very good, since ecoinvent extrapolates the data yearly to increase the temporal representativeness. The technological representativeness is rated as good. See Table 29 for data quality rating (DQR).

Table 29 – Data quality rating (DQR) for product transport to Denmark*.

Activity	Accuracy	Geography	Time	Technology
Transport to DK	Very good	Poor	Very good	Good

*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'. Temporal representativeness is rated as follows: Very good = data is no more than 3 years old, Good = data is no more than 6 years old, Fair = data is no more than 10 years old, Poor = data is no more than 15 years old, Very poor = data is older than 15 years old or unknown.

4.4.2 Warehouse and retail

4.4.2.1 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/m^2/yr, while the heating consumption is 360 MJ/m^2/yr. The heating is assumed to come from natural gas. An average distribution center has a size of 30.000 m^2 and a storage volume of 60.000 m^3 (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 m^3-weeks. The specific electricity consumption is calculated as 0,29 kWh/m^3-week, and the specific heating consumption is calculated as 3,46 MJ/m^3-week.

Retail: According to PEF (2021) the electricity consumption for an average retail store is 150 kWh/m^2/yr. An average retail store center has a size of 2.000 m^2 and a storage volume of 2.000 m^3 (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 m^3-weeks. The specific electricity consumption is calculated as 2,88 kWh/m^3-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 m^3-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 30 for warehousing and retail, respectively.

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

LCA ID	Storage occupancy* (m^3)	Storage time warehouse (weeks)	Storage time retail (weeks)	Specific storage occupancy warehouse (m^3-weeks)	Specific storage occupancy retail (m^3-weeks)
TT1	0,0003	4	5	0,001	0,001
TT2	0,0003	4	5	0,001	0,001

LCA ID	Storage occupancy* (m^3)	Storage time warehouse (weeks)	Storage time retail (weeks)	Specific storage occupancy warehouse (m^3-weeks)	Specific storage occupancy retail (m^3-weeks)
TT3	0,0003	4	5	0,001	0,001
TT4	0,0003	4	5	0,001	0,001
TT5	0,0003	4	5	0,001	0,001
TT6	0,0003	4	5	0,001	0,001
AP1	0,0007	4	5	0,003	0,004
AP2	0,0007	4	5	0,003	0,004
DC1	0,0002	4	5	0,001	0,001
DC2	0,0002	4	5	0,001	0,001
PH1	0,0010	4	5	0,004	0,005
PH2	0,0010	4	5	0,004	0,005
NK1	0,0005	4	5	0,002	0,002
NK2	0,0005	4	5	0,002	0,002
TC1	0,0029	4	5	0,012	0,015
TC2	0,0029	4	5	0,012	0,015

* Estimated as four times the actual volume of the products

4.4.2.2 Background data

The electricity consumed at the warehouse and the retail store was modelled with an ecoinvent 3.11 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 3.11 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.

4.4.2.3 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 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*.

Activity	Accuracy	Geography	Time	Technology
Warehouse	Fair	Very good	Very good	Very good
Retail	Fair	Very good	Very good	Very good

*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'. Temporal representativeness is rated as follows: Very good = data is no more than 3 years old, Good = data is no more than 6 years old, Fair = data is no more than 10 years old, Poor = data is no more than 15 years old, Very poor = data is older than 15 years old or unknown.

4.4.3 Disposal of freight packaging

4.4.3.1 Activity data

The freight packaging is disposed of after distribution. The amount of freight packaging (cardboard box, LDPE polybag and packaging tape) per product can be seen in Table 24.

4.4.3.2 Background data

The disposal of cardboard box was modelled with an ecoinvent 3.11 dataset for waste paperboard disposal in Denmark (Waste paperboard {DK}| market for waste paperboard | Cut-off, U).

The disposal of LDPE polybag and packaging tape was modelled with an ecoinvent 3.11 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.

4.4.3.3 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*.

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

*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'. Temporal representativeness is rated as follows: Very good = data is no more than 3 years old, Good = data is no more than 6 years old, Fair = data is no more than 10 years old, Poor = data is no more than 15 years old, Very poor = data is older than 15 years old or unknown.

4.4.4 Transport to consumer

4.4.4.1 Activity data

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.

4.4.4.2 *Background data*

The transport to consumer home was modelled with an ecoinvent 3.11 dataset for a small petrol car in Europe (Transport, passenger, car, petrol, small size, EURO 5 {RER}| transport, passenger, car, petrol, small size, EURO 5 | Cut-off, U). See overview of LCI data for phase 4 (distribution) in Table 34 and Table 35.

4.4.4.3 *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*.

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

*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'. Temporal representativeness is rated as follows: Very good = data is no more than 3 years old, Good = data is no more than 6 years old, Fair = data is no more than 10 years old, Poor = data is no more than 15 years old, Very poor = data is older than 15 years old or unknown.

4.4.5 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	kg product incl. all packaging	0,9	tkm	Transport, freight, lorry, diesel, unspecified {RoW}| market for transport, freight, lorry, unspecified | Cut-off, U	Multan - Karachi port (900 km)
		12,2	tkm	Transport, freight, sea, container ship, heavy fuel oil {GLO}| transport, freight, sea, container ship, heavy fuel oil | Cut-off, U	Karachi port - Copenhagen port (12200 km)
		0,19	tkm	Transport, freight, lorry, >32 metric ton, diesel, EURO 4 {RER}| transport, freight, lorry, >32 metric ton, diesel, EURO 4 | Cut-off, U	Copenhagen port - Køge - Odense (50 km + 140 km)
4.2 Warehouse	m^3-weeks	0,29	kWh	Electricity, low voltage {DK}| electricity, low voltage, residual mix | Cut-off, U	The total electricity consumption for a year is calculated as 900.000 kWh. The specific storage volume is calculated to be 3.120.000 m^3-weeks. The specific electricity consumption is calculated as 0,29 kWh/m^3-week,
		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	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 m^3-weeks. The specific heating consumption is calculated as 3,46 MJ/m^3-week.

Unit process name	Unit process unit	Input	Input unit	ecoinvent dataset	Comment
4.3 Retail	m^3-weeks	2,88	kWh	Electricity, low voltage {DK}| electricity, low voltage, residual mix | Cut-off, U	The total electricity consumption for a year is calculated as 300.000 kWh. The specific storage volume is calculated to be 104.000 m^3-weeks. The specific electricity consumption is calculated as 2,88 kWh/m^3-week.
4.4 Freight packaging disposal cardboard	kg	1	kg	Waste paperboard {DK}| market for waste paperboard | Cut-off, U	
4.5 Freight packaging disposal LDPE	kg	1	kg	Waste polyethylene {DK}| market for waste polyethylene | Cut-off, U	
4.6 Transport to consumer home	kg product incl. product 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	TT1	TT2	TT3	TT4	TT5	TT6	AP1	AP2	DC1	DC2	PH1	PH2	NK1	NK2	TC1	TC2
4.1 Transport of product to retail	kg product incl. packaging	0,134	0,134	0,134	0,134	0,134	0,134	0,313	0,313	0,079	0,079	0,218	0,218	0,059	0,059	1,178	1,178
4.2 Warehouse	m^3-weeks	0,005	0,005	0,005	0,005	0,005	0,005	0,012	0,012	0,003	0,003	0,015	0,015	0,008	0,008	0,047	0,047
4.3 Retail	m^3-weeks	0,006	0,006	0,006	0,006	0,006	0,006	0,017	0,020	0,005	0,006	0,038	0,042	0,024	0,025	0,165	0,177
4.4 Freight packaging disposal cardboard	kg	0,045	0,045	0,045	0,045	0,045	0,045	0,098	0,098	0,022	0,022	0,050	0,050	0,010	0,010	0,230	0,230
4.5 Freight packaging disposal LDPE	kg	0,001	0,001	0,001	0,001	0,001	0,001	0,002	0,002	0,000	0,000	0,001	0,001	0,000	0,000	0,008	0,008
4.6 Transport to consumer home	kg product incl. packaging	0,088	0,088	0,088	0,088	0,088	0,088	0,213	0,213	0,056	0,056	0,166	0,166	0,048	0,048	0,940	0,940

4.5 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 36. The environmental impacts from the use phase are modelled using a total of 70 wash cycles in the whole life cycle. This is assumes based on expected number of wash cycles for cotton napkins according to Vision Linens (2019). In Table 36, examples of washing frequencies and lifetimes for 70 wash cycles for the different product are described. Use patterns of household textiles vary greatly from consumer to consumer and have a large impact on the environmental impacts on textile products. The data used for the use phase in this LCA are based on literature values from Vision Linens, 2019. It was not possible to find more representative data. This introduces uncertainty in the environmental impact of the products in their lifetime and should be noted when interpreting the results. The sensitivity of the number of washes in the lifetime has been evaluated in a sensitivity analysis – see section 0.

It is assumed that the products are machine washed, and that 58% of the products are machine dried, and 42% are air dried based on DST (2023). Energy consumption for washing/drying machines based on EU Ecodesign benchmark for 7 kg machine as defined in (EU) 2019/2023.

The activity data, background data and data quality are described further in the following sections.

Table 36 – Examples of use scenarios of 70 wash cycles in the entire lifetime.

Product	Washing frequency	Lifetime
Tea Towels	**2,6 times per week**. Calculated as the average washing frequency across households in the study *'Reusing a tea towel or cloth for multiple purposes'* (Food Standards Agency, 2023). See section 9.2 (Appendix) for calculation.	70 cycles / 2,6 cycles/week / 52 weeks/year = **0,5 years**
Aprons	**1 time per week** according to recommendations from Food Standards Agency (2023)	70 cycles / 1 cycle/week / 52 weeks/year = **1,3 years**
Dishcloths (2-pack)	**2,3 times per week**. Calculated as the average washing frequency across households in the study *'Reusing a tea towel or cloth for multiple purposes'* (Food Standards Agency, 2023). See section 9.2 (Appendix) for calculation.	70 cycles / 2,3 cycles/week / 52 weeks/year **= 0,6 years**
Potholders	**2 times per month**. Assumption based on the best guess of the LCA author due to lack of available data sources.	70 cycles / 2 cycles/month / 12 months/year = **2,9 years**

Product	Washing frequency	Lifetime
Napkins (2-pack)	**2,6 times per week**. Calculated as the average washing frequency of tea towels across households in the study *'Reusing a tea towel or cloth for multiple purposes'* (Food Standards Agency, 2023). See section 9.2 (Appendix) for calculation.	70 cycles / 2,6 cycles/week / 52 weeks/year = **0,5 years**
Tablecloths	**2 times per month**. Assumption based on the best guess of the LCA author due to lack of available data sources.	70 cycles / 2 cycles/month / 12 months/year = **2,9 years**

4.5.1 Washing and drying

4.5.1.1 Activity data

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 amount of detergent per kg laundry was estimated based on the ecoinvent 3.11 dataset "Washing, drying and finishing laundry {GLO}| washing, drying and finishing laundry | Cut-off, U".

4.5.1.2 Background data

The water consumption was modelled with the following ecoinvent 3.11 dataset: Tap water {Europe without Switzerland}| tap water production, direct filtration treatment | Cut-off, U.

The detergent consumption was modelled with the following ecoinvent 3.11 dataset: Non-ionic surfactant {GLO}| market for non-ionic surfactant | Cut-off, U.

The electricity consumption was modelled with the following ecoinvent 3.11 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 39 and Table 40.

4.5.1.3 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 varies (very good for electricity, good for water use and very low for detergent use). See Table 37 for data quality rating (DQR).

Table 37 – Data quality rating (DQR) for product washing and drying*.

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

*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'. Temporal representativeness is rated as follows: Very good = data is no more than 3 years old, Good = data is no more than 6 years old, Fair = data is no more than 10 years old, Poor = data is no more than 15 years old, Very poor = data is older than 15 years old or unknown.

4.5.2 Disposal of consumer packaging

4.5.2.1 Activity data

The consumer packaging is disposed of by the consumer. The amount of consumer packaging per product can be seen in Table 24.

4.5.2.2 Background data

The disposal of cardboard was modelled with an ecoinvent 3.11 dataset for waste paperboard disposal in Denmark (Waste paperboard {DK}| market for waste paperboard | Cut-off, U).

The disposal of jute rope was modelled witn an ecoinvent 3.11 dataset for biowaste disposal in Switzerland (CH) (Biowaste {CH}| treatment of biowaste, municipal incineration FAE | Cut-off, U).

See overview of LCI data for phase 5 (use of product) in Table 39 and Table 40.

4.5.2.3 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 38 for data quality rating (DQR).

Table 38 – Data quality rating (DQR) for disposal of consumer packaging*.

Activity	Accuracy	Geography	Time	Technology
Cardboard disposal	Very good	Very good	Very good	Good
Jute rope disposal	Very good	Fair	Very good	Good

*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'. Temporal representativeness is rated as follows: Very good = data is no more than 3 years old, Good = data is no more than 6 years old, Fair = data is no more than 10 years old, Poor = data is no more than 15 years old, Very poor = data is older than 15 years old or unknown.

4.5.3 Phase 5 – unit process overview

Table 39 – 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	
		0,44	kWh	Electricity, low voltage {DK}| market for electricity, low voltage | Cut-off, U	58% of the cycles with washing-drying machine: 4,76 kWh/7 kg cycle 42% of the cycles with washing machine and air drying: 0,8 kWh/7 kg cycle
5.2 Consumer packaging cardboard disposal	kg cardboard packaging	1	kg	Waste paperboard {DK}| market for waste paperboard | Cut-off, U	
5.3 Consumer packaging jute disposal	kg jute packaging	1	kg	Biowaste {CH}| treatment of biowaste, municipal incineration FAE | Cut-off, U	

Table 40 – Amount of unit processes per product in phase 5 – use of product.

Unit process name	Unit	TT1	TT2	TT3	TT4	TT5	TT6	AP1	AP2	DC1	DC2	PH1	PH2	NK1	NK2	TC1	TC2
5.1 Washing and drying	kg-cycle	5,8	5,8	5,8	5,8	5,8	5,8	12,6	12,6	3,6	3,6	11,3	11,3	3,0	3,0	63,5	63,5
5.2 Consumer packaging cardboard disposal	kg cardboard packaging	0,004	0,004	0,004	0,004	0,004	0,004	0,034	0,034	0,004	0,004	0,004	0,004	0,004	0,004	0,034	0,034
5.3 Consumer packaging jute disposal	kg jute packaging	0,001	0,001	0,001	0,001	0,001	0,001			0,001	0,001	0,001	0,001	0,001	0,001		

4.6 Phase 6: End-of-life of product

4.6.1 Activity data

In DEA (2023) the Danish Energy Agency has attempted to make a mass flow analysis of the fate of textiles at their end-of-life in Denmark. The data from this mass flow analysis has been processed for this LCA and the following treatment percentages were calculated:

- 57% (65.650 tonnes/(65.500 tonnes+55.500 tonnes)) of textiles are discarded in the mixed waste. The 57% of textiles which are discarded in the mixed waste end up in Danish waste-to-energy (incineration) plants.
- 43% (55.500 tonnes/(65.500 tonnes+55.500 tonnes)) of textiles are collected separately: Out of the 43% textiles which are collected separately:
  - 28% (14.300 tonnes/55.500 tonnes) are reused
  - 6% (3.150 tonnes/55.500 tonnes) end up in Danish waste-to-energy (incineration) plants
  - 2% (1.150 tonnes/55.500 tonnes) are recycled in Denmark
  - 63% (31.900 tonnes/55.500 tonnes) are exported. Of the exported waste:
    - 10% (3.100 tonnes/31.900 tonnes) are incinerated
    - 90% (3.100 tonnes/28.800 tonnes) are either reused or recycled.

When adding up the treatment methods, this means that overall:

- 60,8% of the textile waste is incinerated
- 26,5% of the textile waste is recycled*
- 12,7% of the textile waste is reused*

*This is when assuming recycling for the exported waste, where it is unknown if it is reused or recycled.

Out of all the textiles which end up being incinerated, 96% of them are incinerated in Denmark. Therefore, a process for incineration in Denmark is modelled. The process 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.

Out of all the textiles which end up being recycled, 96% of them are recycled outside of Denmark. Therefore, a process for textile recycling outside of Denmark is modelled. 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 1043 km from Odense to Lodz (1,043 tkm/kg waste).

Reuse of textiles (13% of all textiles) is modelled without any environmental impacts in this LCA.

4.6.2 Background data

For waste transport in the incineration and recycling process flows, an ecoinvent 3.11 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 3.11 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 Denmark.

For recycling, the presorting energy consumption in Copenhagen is represented by an ecoinvent 3.11 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 and baling in Poland is represented by an ecoinvent 3.11 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 42 and Table 43.

4.6.3 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 41 for data quality rating (DQR).

Table 41 – Data quality rating (DQR) for EOL of textile products*.

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

*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'. Temporal representativeness is rated as follows: Very good = data is no more than 3 years old, Good = data is no more than 6 years old, Fair = data is no more than 10 years old, Poor = data is no more than 15 years old, Very poor = data is older than 15 years old or unknown.

4.6.4 Phase 6 – unit process overview

Table 42 – 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
		1,085	tkm	Transport, freight, lorry, unspecified {RER}| market for transport, freight, lorry, unspecified | Cut-off, U	41,5 km to first sorting point, 1043 km to second sorting/recycling point in Poland
6.3 Product EOL – reuse	kg textile to reuse	1	kg	-	

Table 43 – Amount of unit processes per product in phase 6 – end of life of product.

Unit process name	Unit	TT1	TT2	TT3	TT4	TT5	TT6	AP1	AP2	DC1	DC2	PH1	PH2	NK1	NK2	TC1	TC2
6.1 Product EOL - incineration	kg textiles to incineration	0,051	0,051	0,051	0,051	0,051	0,051	0,109	0,109	0,031	0,031	0,098	0,098	0,026	0,026	0,551	0,551
6.2 Product EOL - recycling	kg textiles to recycling	0,022	0,022	0,022	0,022	0,022	0,022	0,048	0,048	0,013	0,013	0,043	0,043	0,012	0,012	0,240	0,240
6.3 Product EOL – reuse	kg textile to reuse	0,011	0,011	0,011	0,011	0,011	0,011	0,023	0,023	0,006	0,006	0,021	0,021	0,006	0,006	0,115	0,115

5 Life cycle impact assessment (LCIA)

5.1 LCIA procedures and calculations

The LCIA method Environmental Footprint (EF) 3.1 was selected for this project. It is an internationally accepted LCIA method developed by the European Commission as part of the PEF initiative. EF 3.1 covers a broad range of environmental impact categories. No impact categories have been excluded from the study. All impact categories are listed below:

1. Climate change
2. Acidification
3. Ecotoxicity, freshwater
4. Particulate matter
5. Eutrophication, marine
6. Eutrophication, freshwater
7. Eutrophication, terrestrial
8. Human toxicity, cancer
9. Human toxicity, non-cancer
10. Ionising radiation
11. Land use
12. Ozone depletion
13. Photochemical ozone formation
14. Resource use, fossils
15. Resource use, minerals and metals
16. 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. 10.2.0.3 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.

5.2 LCIA results

The LCIA results per product can be seen in Table 44. 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 4 the climate change impact (kg CO_2e) per product is presented visually.

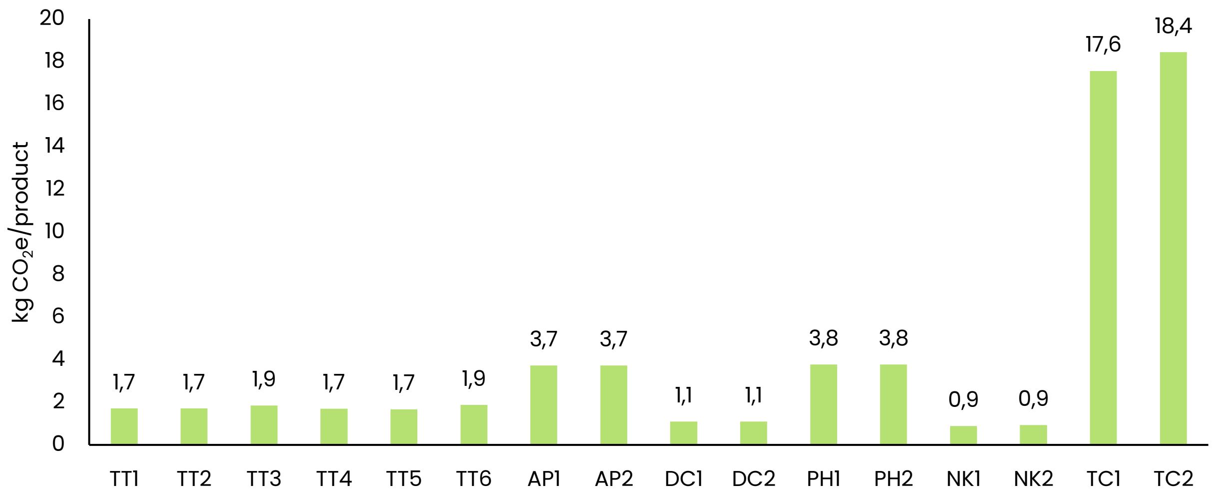

Figure 4 – Climate change impact of each product in the LCA across the whole life cycle

Table 44 LCIA results for the 19 impact categories assessed per product.

Impact category	Unit	TT1	TT2	TT3	TT4	TT5	TT6	AP1	AP2	DC1	DC2	PH1	PH2	NK1	NK2	TC1	TC2
Climate change	kg CO2 eq	1,7E+00	1,7E+00	1,9E+00	1,7E+00	1,7E+00	1,9E+00	3,7E+00	3,8E+00	1,1E+00	1,1E+00	3,8E+00	3,8E+00	8,9E-01	9,3E-01	1,8E+01	1,8E+01
Acidification	mol H+ eq	1,3E-02	1,3E-02	1,4E-02	1,3E-02	1,2E-02	1,4E-02	2,7E-02	2,7E-02	8,4E-03	8,4E-03	3,8E-02	3,8E-02	6,6E-03	6,9E-03	1,3E-01	1,3E-01
Ecotoxicity, freshwater	CTUe	1,7E+02	1,7E+02	1,8E+02	1,6E+02	1,6E+02	1,8E+02	3,6E+02	3,6E+02	1,0E+02	1,0E+02	3,3E+02	3,3E+02	8,4E+01	8,7E+01	1,7E+03	1,8E+03
Particulate matter	disease inc.	2,1E-07	2,1E-07	2,1E-07	2,1E-07	2,0E-07	2,1E-07	4,4E-07	4,4E-07	1,3E-07	1,3E-07	4,8E-07	4,8E-07	1,1E-07	1,1E-07	2,1E-06	2,2E-06
Eutrophication, marine	kg N eq	1,3E-02	1,3E-02	1,4E-02	1,3E-02	1,3E-02	1,4E-02	2,8E-02	2,8E-02	8,9E-03	8,9E-03	5,6E-02	5,6E-02	7,1E-03	7,2E-03	1,4E-01	1,4E-01
Eutrophication, freshwater	kg P eq	2,0E-03	2,0E-03	2,1E-03	2,0E-03	2,0E-03	2,1E-03	4,3E-03	4,3E-03	1,2E-03	1,2E-03	3,7E-03	3,7E-03	1,0E-03	1,1E-03	2,2E-02	2,2E-02
Eutrophication, terrestrial	mol N eq	4,2E-02	4,2E-02	4,5E-02	4,2E-02	4,1E-02	4,5E-02	9,0E-02	9,0E-02	2,8E-02	2,8E-02	1,4E-01	1,4E-01	2,2E-02	2,3E-02	4,2E-01	4,4E-01
Human toxicity, cancer	CTUh	5,1E-09	5,1E-09	5,5E-09	5,0E-09	5,0E-09	5,5E-09	1,1E-08	1,1E-08	3,2E-09	3,2E-09	1,0E-08	1,0E-08	2,5E-09	2,7E-09	5,3E-08	5,5E-08
Human toxicity, non-cancer	CTUh	4,6E-07	4,6E-07	5,0E-07	4,5E-07	4,5E-07	5,0E-07	9,9E-07	9,9E-07	2,9E-07	2,9E-07	9,2E-07	9,2E-07	2,3E-07	2,4E-07	4,8E-06	5,0E-06
Ionising radiation	kBq U-235 eq	2,4E-01	2,4E-01	2,5E-01	2,4E-01	2,3E-01	2,6E-01	5,2E-01	5,2E-01	1,5E-01	1,5E-01	4,5E-01	4,5E-01	1,2E-01	1,3E-01	2,5E+00	2,6E+00
Land use	Pt	1,1E+02	1,1E+02	1,1E+02	1,1E+02	1,1E+02	1,1E+02	2,4E+02	2,4E+02	6,5E+01	6,6E+01	2,0E+02	2,0E+02	5,7E+01	5,7E+01	1,2E+03	1,2E+03
Ozone depletion	kg CFC11 eq	5,9E-08	5,9E-08	6,2E-08	5,9E-08	5,9E-08	6,2E-08	1,1E-07	1,1E-07	7,9E-08	7,9E-08	1,3E-07	1,3E-07	4,5E-08	4,6E-08	3,7E-07	3,8E-07
Photochemical ozone formation	kg NMVOC eq	8,1E-03	8,1E-03	8,9E-03	8,0E-03	7,9E-03	9,1E-03	1,8E-02	1,8E-02	5,2E-03	5,2E-03	1,8E-02	1,8E-02	4,1E-03	4,3E-03	8,1E-02	8,6E-02
Resource use, fossils	MJ	2,2E+01	2,2E+01	2,4E+01	2,2E+01	2,2E+01	2,5E+01	4,9E+01	4,9E+01	1,4E+01	1,4E+01	4,6E+01	4,6E+01	1,2E+01	1,2E+01	2,3E+02	2,4E+02
Resource use, minerals and metals	kg Sb eq	1,8E-05	1,8E-05	1,9E-05	1,8E-05	1,7E-05	1,9E-05	3,8E-05	3,8E-05	1,1E-05	1,1E-05	3,7E-05	3,7E-05	9,3E-06	9,6E-06	1,9E-04	1,9E-04
Water use	m3 depriv.	1,3E+00	1,3E+00	1,3E+00	1,3E+00	1,2E+00	1,3E+00	1,7E+00	1,7E+00	1,9E+00	1,9E+00	3,8E+01	3,8E+01	1,0E+00	1,0E+00	5,2E+00	5,3E+00

5.3 Contribution analysis

The % contribution of each life cycle phase to the climate change impact can be seen in Figure 5 for each product. For all products, 'Phase 5 – use of product' is the most contributing life cycle phase contributing with 41-50% of the impact.

The second most contributing life cycle phase is 'Phase 1 – raw materials', for all products, contributing 22-35% of the impact.

The second most contributing life cycle phase is 'Phase 3 – production', for all products, contributing 16-21% of the impact.

Overall, 'Phase 1 – raw materials', 'Phase 3 – production', and 'Phase 5 - use of product' together account for 88-93% 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 7-12% 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 9.4 (appendix).

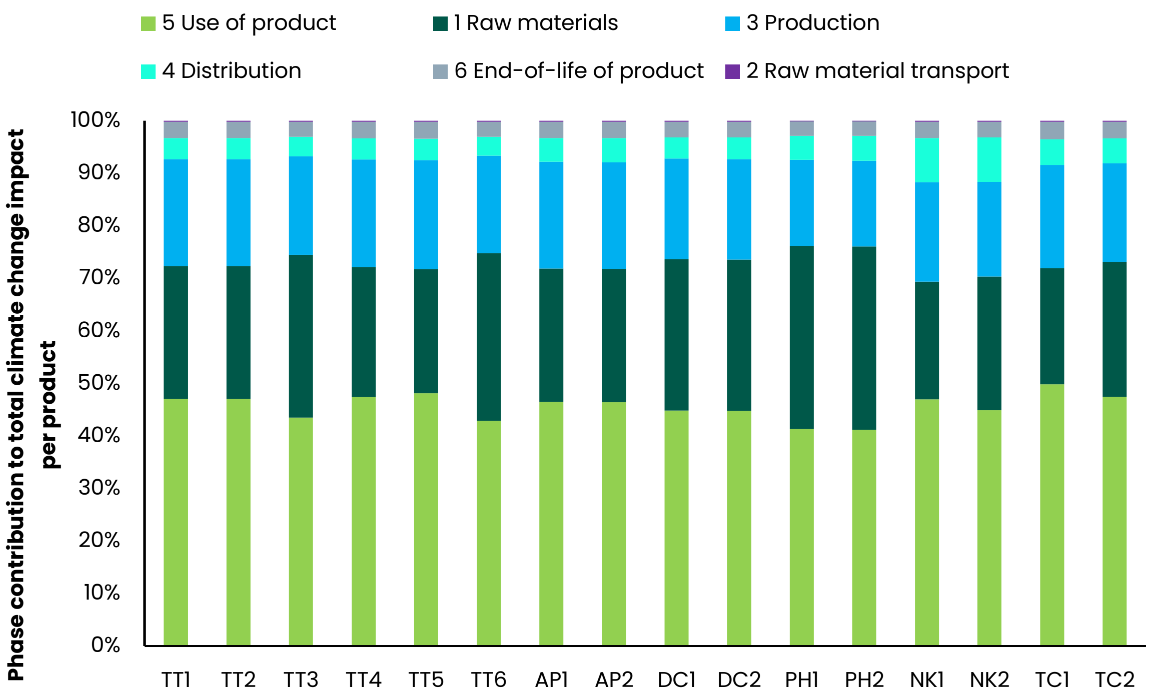

Figure 5 - Contribution of each life cycle phase to the 'climate change' impact category per product in the LCA.

5.3.1 Process contribution – phase 1 – climate change

In Figure 6 the contribution of processes in 'phase 1 – raw materials' to the total climate change impact in phase 1 can be seen. It shows that yarn spinning and cotton cultivation are the most contributing processes in this phase. For products that are bleached and dyed, this process contributes more to the impact in 'phase 1 – raw materials'.

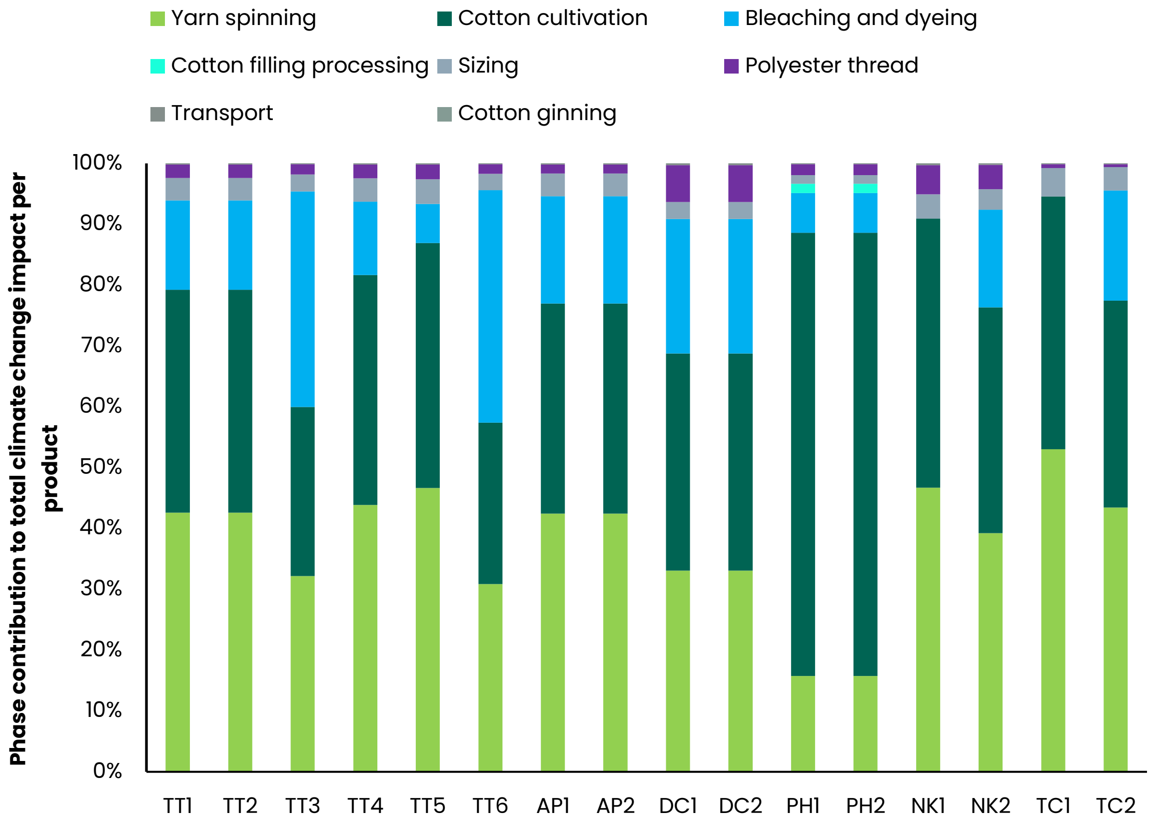

Figure 6 - Contribution of processes in 'phase 1 – raw materials' to the total 'climate change' impact category for 'phase 1 – raw materials'.

5.3.2 Process contribution – phase 3 - climate change

In Figure 7 the contribution of processes in 'phase 3 – production' to the total climate change impact in phase 3 can be seen. It shows that for all products, gas is the most contributing process. Packaging, electricity, and biomass consumption also contribute notably. Diesel, gasoline, waste and wastewater, water, chemicals, and inputs of other materials contribute very little. Here it should be noted that these processes may have a higher contribution to other environmental impact categories. The packaging has a lower percentage contribution for PH1, PH2, NK1, NK2, TC1 and TC2, which is due to lower packaging amounts per kg of these products.

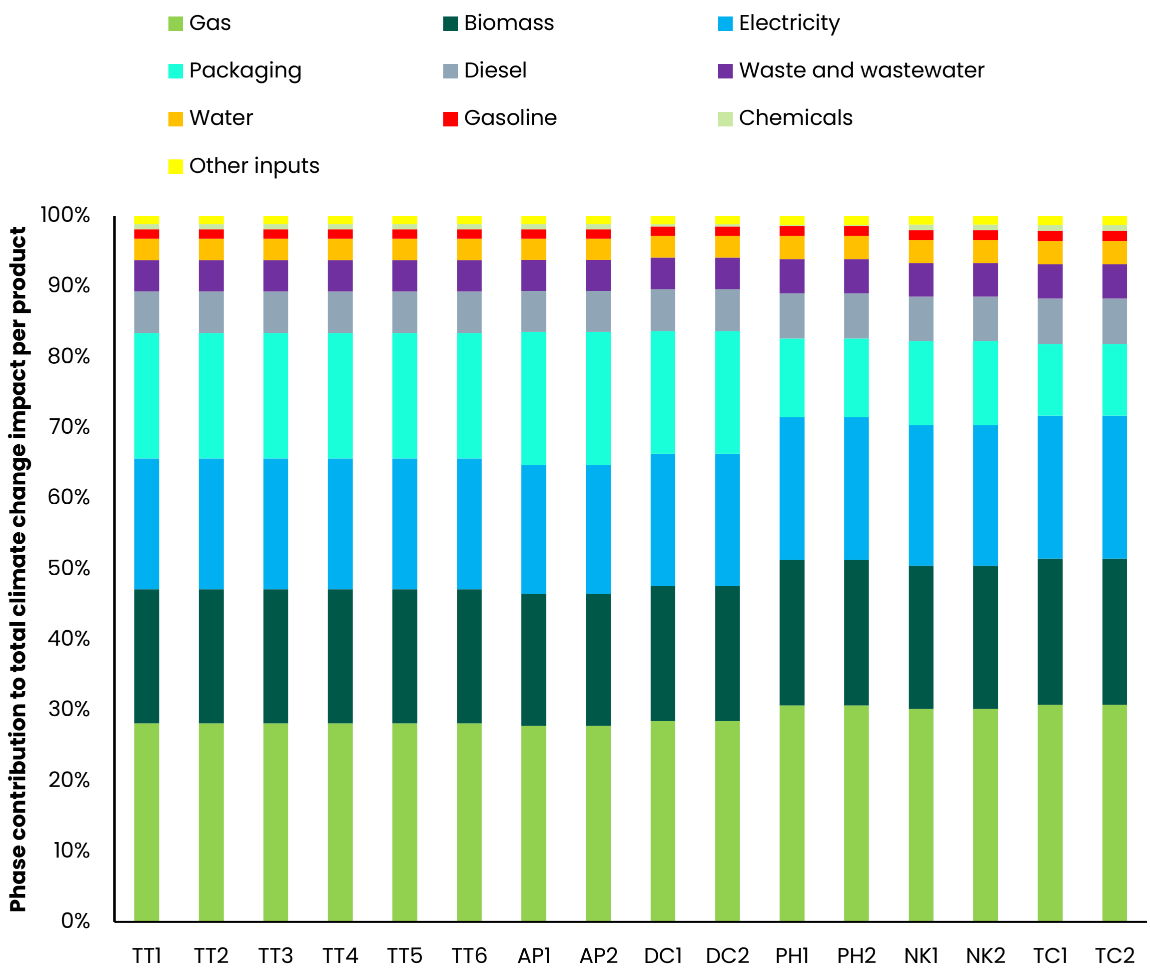

Figure 7 - Contribution of processes in 'phase 3 – production' to the total 'climate change' impact category for 'phase 3 – production'.

5.3.3 Process contribution – phase 5 – climate change

In Figure 8 the contribution of washing and drying in 'phase 5 – use of product' to the total climate change impact in phase 5 can be seen. The contribution from disposal of consumer packaging is not included in the contribution analysis, since it contributed <1% of the climate change impact to phase 5. Figure 8 shows that electricity and detergent are the most contributing processes in this phase.

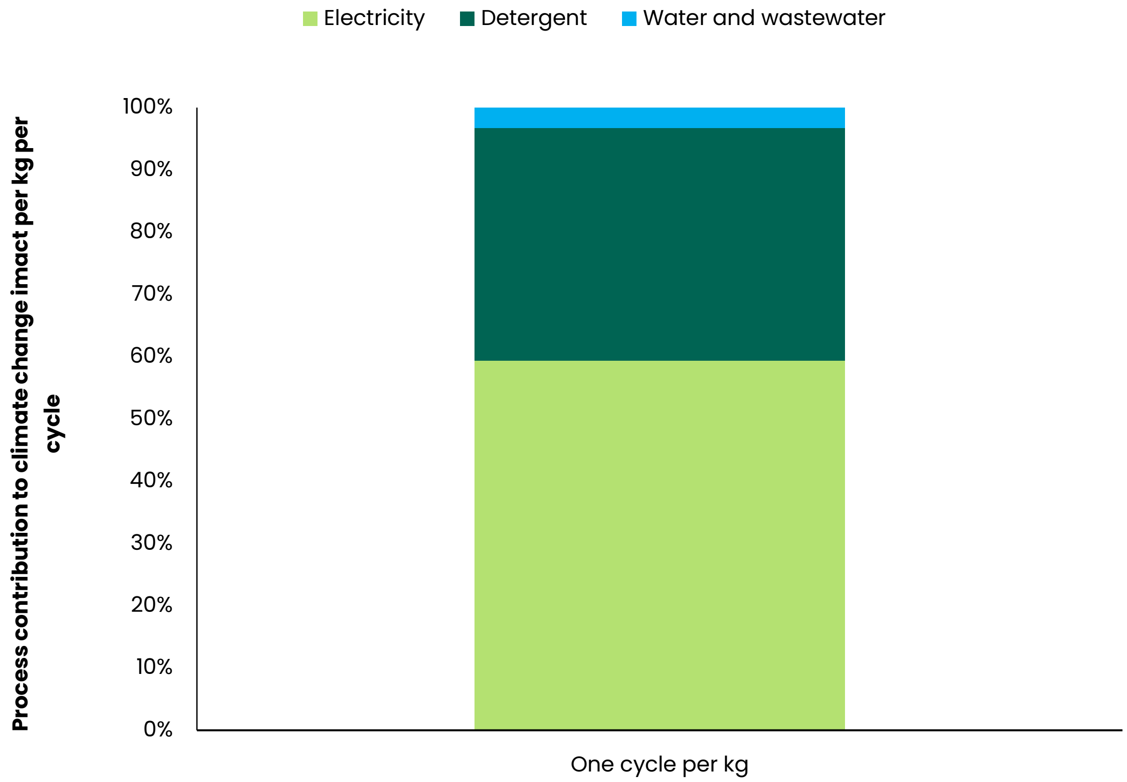

Figure 8 - Contribution of processes in washing and drying in 'phase 5 – use of product' to the total 'climate change' impact category for washing and drying.

5.3.4 Contribution to other environmental impacts

The contribution of each life cycle stage to each of the environmental impact categories aside from climate change are shown in Section 9.4 (appendix).

'Phase 1 – raw materials', 'Phase 3 – production', and 'Phase 5 - use of product' are the most contributing phases across all impact categories. Together they contribute >88% to the overall impact of all products in all impact categories. In Table 45 the most contributing life cycle phase across impact categories in shown.

Table 45 – Overview of the most contributing life cycle phase for each impact category

Impact category	Most contributing life cycle phase
Climate change	5 – Use of product
Acidification	1 – Raw materials, expect for TC1 it is 5 – Use of product
Ecotoxicity, freshwater	3- Production
Particulate matter	3- Production
Eutrophication, marine	1 – Raw materials
Eutrophication, freshwater	1 – Raw materials
Eutrophication, terrestrial	1 – Raw materials
Human toxicity, cancer	3- Production
Human toxicity, non-cancer	3- Production
Ionising radiation	5 – Use of product
Land use	1 – Raw materials
Ozone depletion	1 – Raw materials, expect for TC1 and TC2 it is 5 – Use of product
Photochemical ozone formation	5 – Use of product
Resource use, fossils	5 – Use of product
Resource use, minerals and metals	5 – Use of product
Water use	1 – Raw materials, expect for TC1 and TC2 it is 5 – Use of product

6 Life cycle interpretation

6.1 Data quality assessment

The data quality has been rated for all processes in the LCA for the accuracy of the input data and the geographical, temporal and technological representativity of the secondary datasets (background datasets from ecoinvent). The ratings have been assigned a numerical value as follows: Very poor = 5, Poor = 4, Fair = 3, Good = 2 and Very good = 1. See section 9.3 (Appendix) for an overview of the numerical values per process and data quality parameter. Furthermore, each process was weighted based on its average contribution to the climate change impact across all products to account for how much the data quality of each process affects the overall data quality in the LCA.

The overall data quality numerical score of the LCA is determined as 1,99 (Good).

6.2 Significant findings

The use of products contributes highly to climate change impact

For all products 'Phase 5 – use of product' is the most contributing life cycle phase to the climate change impact, contributing with 41-50% of the impact.

Raw material transport, distribution and end-of-life have little climate change contribution

Overall, 'Phase 1 – raw materials', 'Phase 3 – production', and 'Phase 5 - use of product' together account for 88-93% 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 7-12% of the total climate change impact per product.

Production has the highest contribution to 'human toxicity'

Production has a particularly high contribution in the impact categories 'human toxicity, cancer and non-cancer' for all products. This is due to heavy metals in the sewage sludge.

Raw materials and use of product have the highest contributions to water use

Use of product and raw materials are the most contributing phases to 'water use'. The high impact from 'phase 5 – use of product' is due to the water consumption used for washing. The high impact from 'phase 1 – raw materials' is due to irrigation of cotton fields in conventional cotton cultivation.

6.3 Sensitivity analysis

Sensitivity was evaluated by comparing baseline scenarios to alternative scenarios and calculating sensitivity coefficients. The sensitivity coefficient is defined as the ratio between relative change in results and relative change in input parameters. Parameters with coefficients below 0.1 were considered to have low influence on results, values between 0.1 and 0.5 moderate influence, and values above 0.5 high influence. For scenario analyses where multiple input parameters were changed simultaneously, and it was not possible to determine a single sensitivity coefficient, absolute changes below 10% were considered to have low influence on the results, absolute changes between 10-20% were considered to have moderate influence, and absolute changes above 20% were considered to have high influence.

The sensitivity analysis was focused on the change in climate change impact. This is chosen because the climate change impact will be used for communication to the end-consumer and is used for comparative statements, which means that the influence of uncertain or variable parameters on this impact category is particularly important.

6.3.1 Cotton cultivation

A sensitivity scenario using a different secondary dataset for organic cotton cultivation in the geography "Rest of World" (RoW) instead of India (IN) has been analyzed. This dataset is the only other option for organic cotton growing in ecoinvent. See Figure 9. The RoW dataset has a 58% lower climate change impact than the Indian dataset applied in this LCA. It was found that changing from the IN dataset to the RoW dataset for organic cotton cultivation decreased the total climate change impact with 1,3-3,9% for all products, resulting in a sensitivity coefficient between 0,02-0,07 (low sensitivity). This shows that geography of the secondary dataset has a low influence on the overall climate change impact of the products when changing from India to Rest of World.

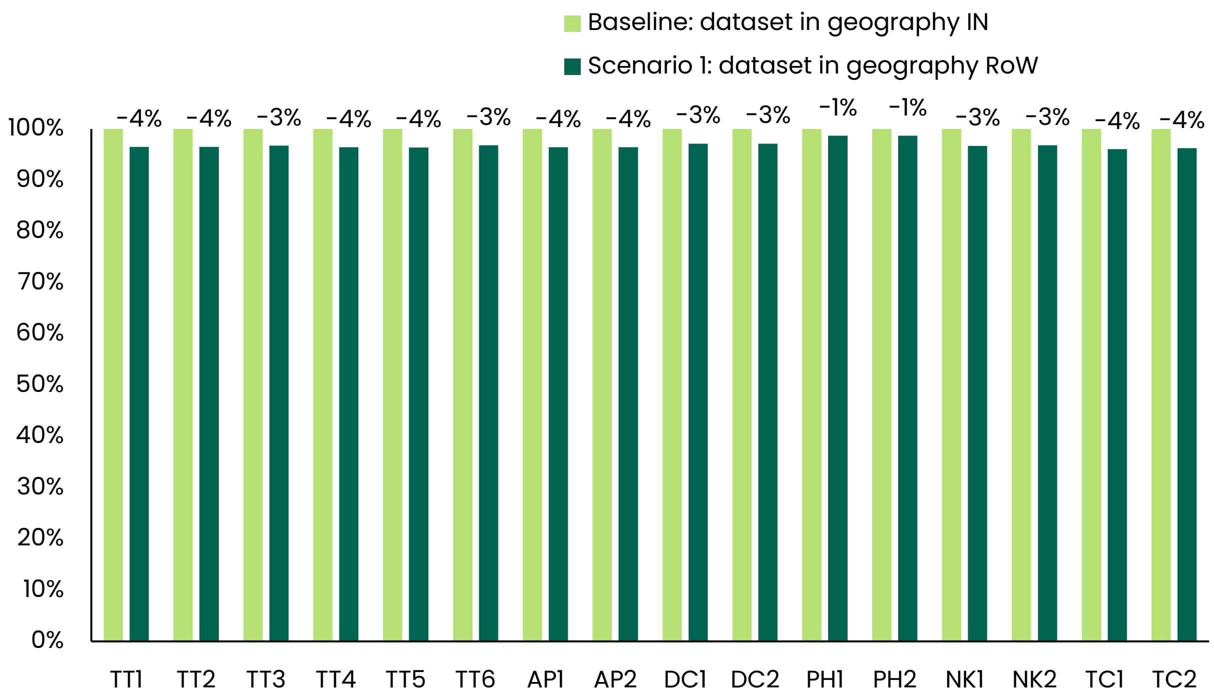

Figure 9 - Scenario evaluating the change in the total climate change impact when changing the geography for the dataset for organic cotton cultivation in the raw materials phase.

6.3.2 Energy consumption

The effects of increasing the electricity, gas, and biomass consumption in Phase 3 - production by 10% was analyzed – see Figure 10. It was found that increasing the energy consumption by 10% increased the total climate change impact with 1,2% to 1,4% for all products. This is an absolute change below 10%, and therefore this shows that the energy consumption for production has low influence on the overall climate change impact of the products.

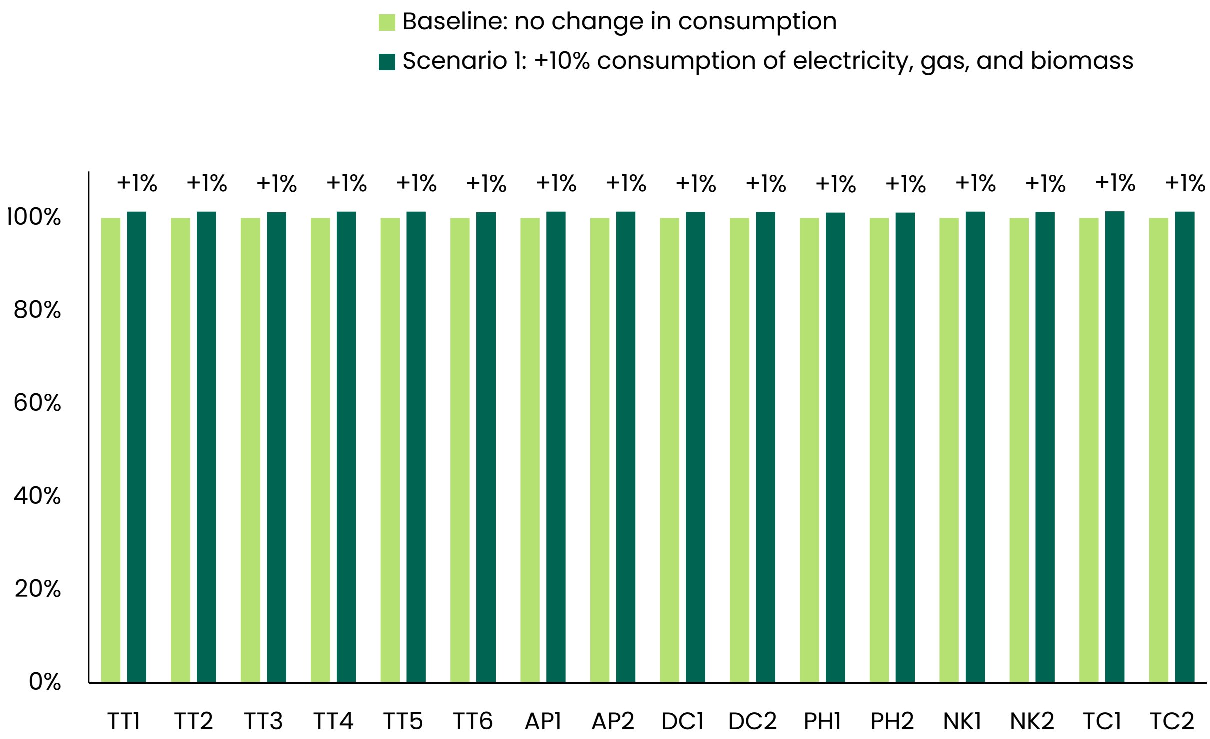

Figure 10: Scenario evaluating the change in the total climate change impact when increasing the electricity, gas, and biomass consumption by 10% in the production phase.

6.3.3 Machine drying vs. airdrying of textiles

The effect of using 100% machine drying instead of 58% machine drying and 42% air drying (as assumed in this LCA) was analyzed. See Figure 11. It was found that changing from 58% machine drying to 100% machine drying (equaling a 72% parameter increase) increased the total climate change impact with 13,2-16,1% for all products, resulting in a sensitivity coefficient between 0,18-0,22 (moderate sensitivity). This shows that consumer behavior regarding drying methods has a significant influence on the overall climate change impact of the products.

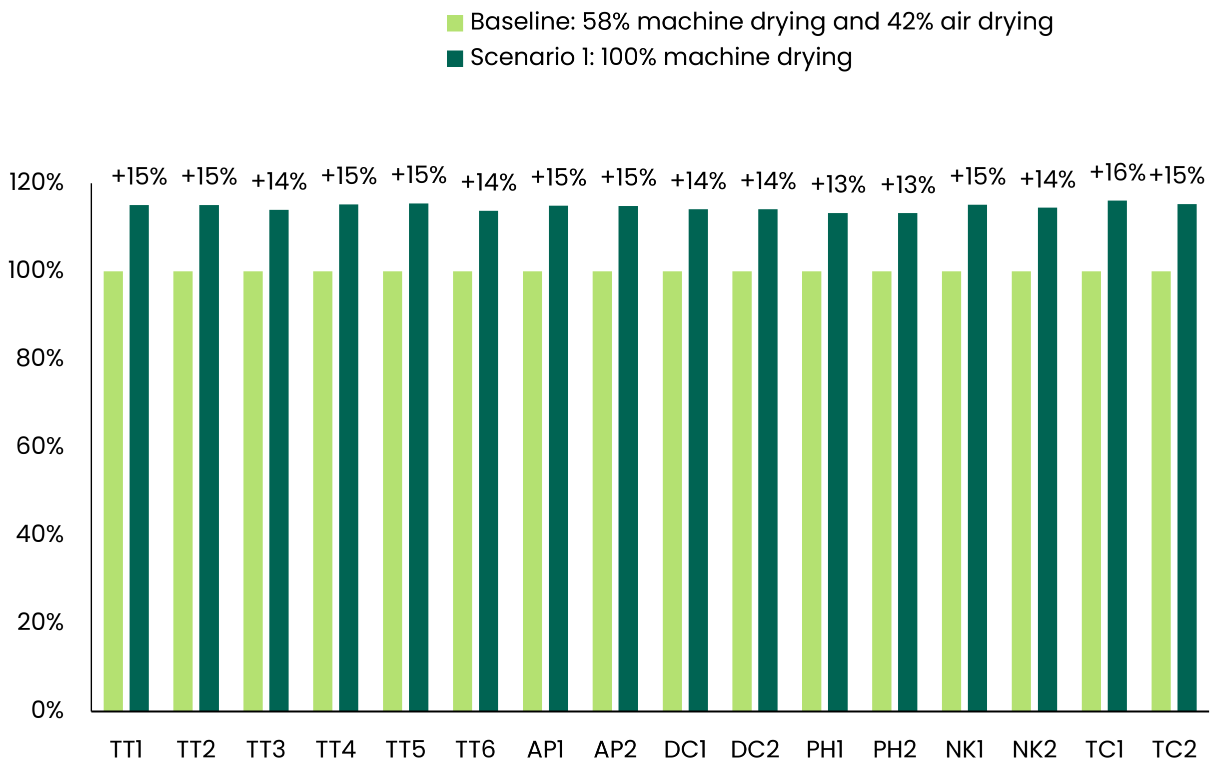

Figure 11: Scenario evaluating the change in the total climate change impact when changing from 58% machine drying to 100% machine drying in the use phase.

6.3.4 Washing-drying frequency

The effect of increasing the washing-drying frequency by 10% was analyzed – see Figure 12. It was found that increasing the frequency of washing and drying by 10% increased the total climate change impact with 4,1% to 5,0% for all products, resulting in a sensitivity coefficient between 0,41-0,50 (high sensitivity for TC1, moderate sensitivity for all other products). This shows that consumer behavior regarding washing and drying frequency has a very significant influence on the overall climate change impact of the products.

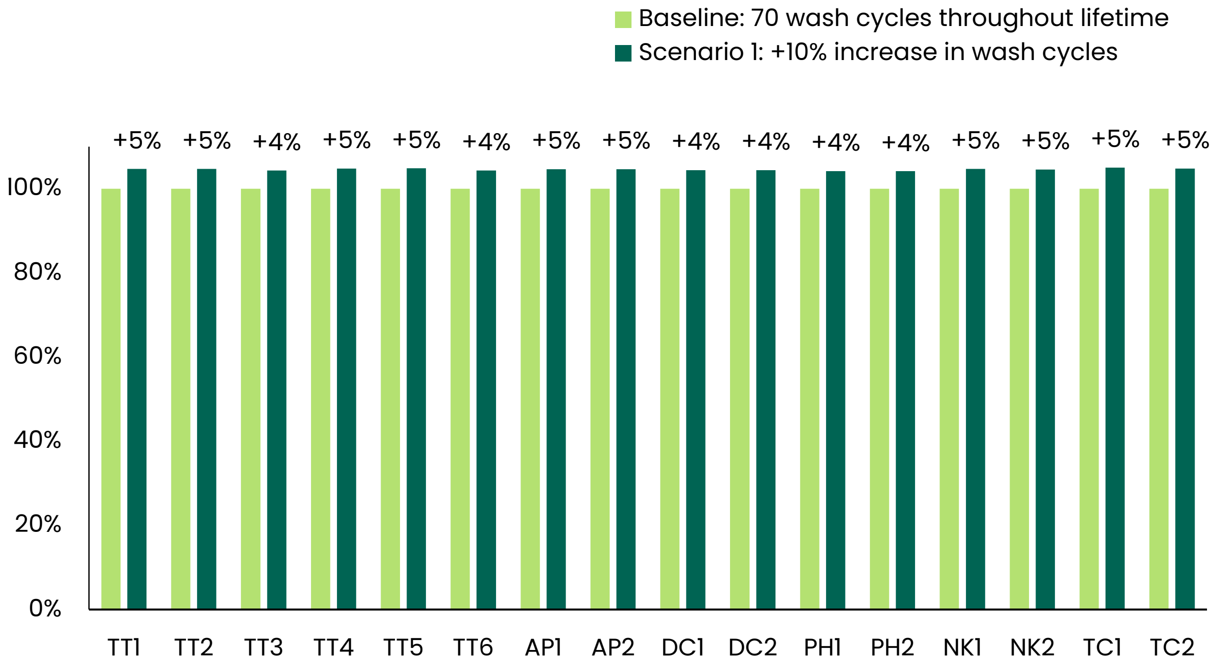

Figure 12: Scenario evaluating the change in the total climate change impact when increasing the washing-drying frequency by 10% in the use phase.

6.3.5 End-of-life scenario

The effect of sending 100% of the product to incineration instead of a mix of incineration, recycling and reuse in phase 6 – End-of-life was analyzed. See Figure 11. It was found that changing to 100% incineration instead of 61% incineration decreased the total climate change impact with 3% for all products. It may seem surprising that the impact decreases when including more incineration and less recycling. This is related to the recycling data used for this LCA study having a higher climate change impact per kg than incineration, which may indicate that the recycling data is too conservative in terms of the energy use related to recycling. It is also important to note that the benefits related to recycling such as avoided production of new textile materials are not accounted for in this LCA. Nonetheless, an absolute change of 3% for this scenario means that the end-of-life treatment method cannot be considered a sensitive parameter regarding the climate change impact of the products.

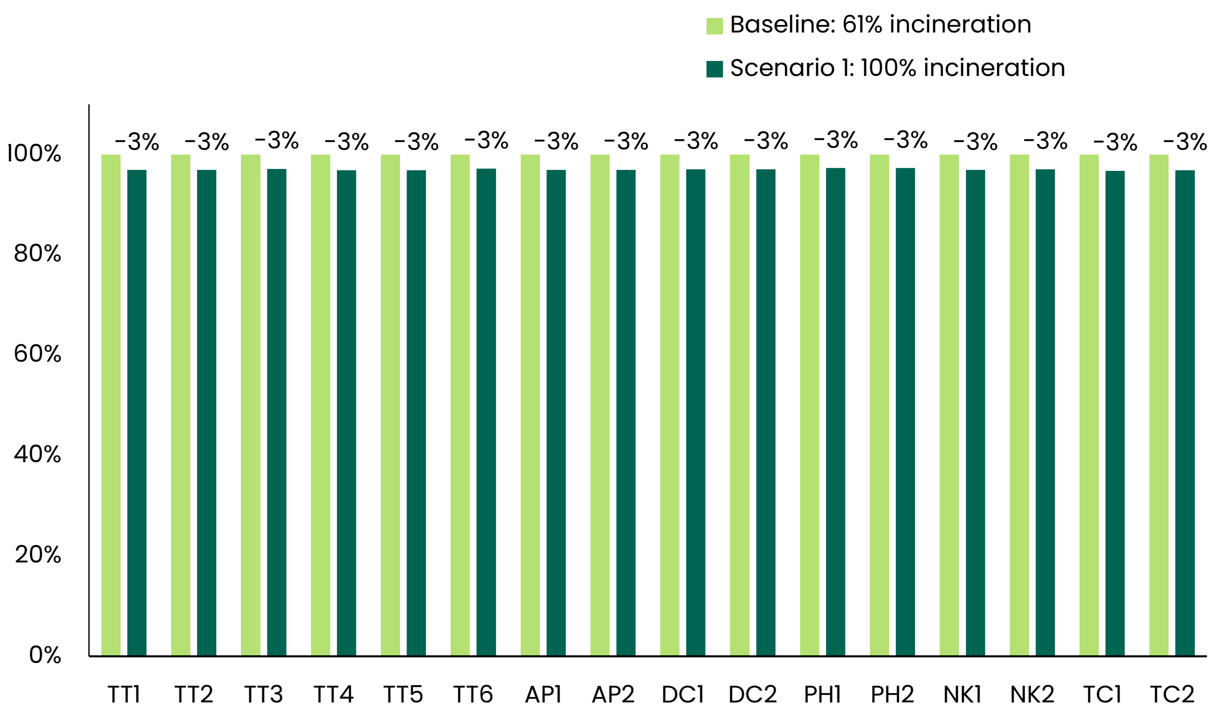

Figure 13 - Scenario evaluating the change in the total climate change impact when sending 100% of the product waste to incineration instead of a mix of incineration, recycling and reuse in the end-of-life phase.

6.4 Uncertainty analysis

The uncertainty in the LCA has been evaluated qualitatively by performing the following steps:

- Identifying key parameters and assumptions that may influence the results
- Classifying each parameter's uncertainty level (low/medium/high) based on data quality
- Assessing how sensitive the results are to these uncertain parameters (low/moderate/high influence)

See Table 46 for the identified key parameters.

Table 46 – Key parameters affecting the uncertainty of the LCA results

Key parameters and assumptions	Uncertainty level (qualitative estimate)	Sensitivity
Cotton cultivation	Medium – based on data from India instead of Pakistan.	Low – geography of dataset tested in sensitivity analysis
Energy consumption in the production	Low-medium	Moderate – energy consumption tested in sensitivity analysis.
Use phase washing scenario	High – based on scenario.	Moderate/high – tested in sensitivity analysis.

The data used for cotton cultivation is a key parameter. This parameter has a medium uncertainty and low sensitivity. Since more accurate data was not available it was not possible to mitigate the uncertainty stemming from these parameters.

The energy consumption in the production is a key parameter. Those parameters have a low-to-medium uncertainty since most are based on measurements, while some were allocated based on the data from the factory. The sensitivity of the energy consumption was evaluated as moderate.

The use phase is highly uncertain while the LCA results are moderately/highly sensitive to changes in the use phase. As it is not possible to collect primary data for the use phase of the products, this level of uncertainty must be accepted, and it is important to account for this uncertainty when interpreting the results.

6.5 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	• It is assumed that ginning takes place near the cotton farms. • It is assumed that bleaching, dyeing, and sizing take place at det same facility as yarn spinning. • Consumption of starch for sizing per kg cotton is based on an ecoinvent 3.11 dataset for weaving. • A major limitation in the raw materials phase is the lack of regionalized datasets for organic and conventional cotton. Therefore, a secondary dataset from ecoinvent for cotton cultivation in India was used.
3 Production	• 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.
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 that the consumer buys 10 kg of products in the trip.
5 Use of product	• It is assumed that for 42% of the use cycles the products are air dried and for 58% 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 3.11 dataset for commercial laundry operation. • It is assumed that all the products go through 70 wash cycles in their lifetime based on data for a cotton napkin according to Vision Linens (2019).
6 End-of-life of product	• Waste treatment scenario is based on information from the Danish Energy Agency: 60,8% of the products are sent to incineration, 26,5% of the products are sent to recycling and 12,7% of the products are reused. Reuse has no environmental impacts in the LCA. • Energy consumption for sorting, shredding, and baling is based on literature values from a Swedish textile recycling scenario. • The sorting and recycling location in Poland is unknown. A city located centrally in Poland (Lodz) is assumed.

7 Conclusions

A life cycle assessment (LCA) was carried out to investigate the environmental impacts arising in the full life cycle of kitchen textiles from the fall 2026 line of Nord Harmony. 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 of the products and/or the obtained reduction in climate change impact.

The environmental impact of the products was evaluated across 16 impact categories according to the EF3.1 LCIA method. The climate change impact of both products is shown in Table 48.

Table 48 – Climate change impact of the 16 products evaluated in the life cycle assessment (LCA)

ID	Product type	Pattern	Color	Climate change impact (kg CO_2e/product)	
				Cradle-to-consumer	Cradle-to-grave
TT1	Tea Towel	All-over stripes	Lemon pepper/unbleached	0,9	1,7
TT2		All-over stripes	Anthracite/unbleached	0,9	1,7
TT3		Checks	Lemon pepper/unbleached	1,0	1,9
TT4		Checks	Slate grey/unbleached	0,8	1,7
TT5		Panel stripes	Anthracite/unbleached	0,8	1,7
TT6		Panel stripes	Slate grey/unbleached	1,0	1,9
AP1	Apron	All-over stripes	Anthracite/unbleached	1,9	3,7
AP2		All-over stripes	Lemon pepper/unbleached	1,9	3,8
DC1	Dishcloth (2-pack)	Checks	Anthracite/unbleached	0,6	1,1
DC2		Checks	Lemon pepper/unbleached	0,6	1,1
PH1	Potholder	All-over stripes	Anthracite/unbleached	2,1	3,8
PH2		All-over stripes	Lemon pepper/unbleached	2,1	3,8
NK1	Napkin (2-pack)	Solid	Unbleached	0,4	0,9
NK2		All-over stripes	Slate grey/unbleached	0,5	0,9
TC1	Tablecloth	Solid	Unbleached	8,2	17,6
TC2		All-over stripes	Slate grey/unbleached	9,1	18,4

It was found that 'Phase 5 – use of product' is the most contributing life cycle phase to climate change for all products, contributing with 41-50% of the impact. This is due to the many wash cycles in the life cycle of the 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 both products, especially the cotton cultivation process and yarn spinning process. Since it was not possible to obtain data for organic cotton cultivation in 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. This is mainly due to electricity, gas, and biomass consumption.

In a sensitivity scenario, the geography of the secondary dataset for organic cotton cultivation was changed from India to Rest of World. The analysis showed that changing the dataset decreased the climate change impact for the entire life cycle with 1,3% to 3,9%. This parameter was considered to have low sensitivity for all products.

In another sensitivity scenario, the energy consumption during Phase 3 – production at the factory was analyzed. The analysis showed increasing the electricity, gas and biomass consumption with 10% increased the climate change impact for the entire life cycle with 1,2-1,4%. This parameter was considered to have low influence on the overall results.

In another sensitivity scenario, machine drying vs. air drying was analyzed. It was found that changing from 58% machine drying to 100% machine drying increased the climate change impact for the entire life cycle with 13,2-16,1%. This parameter was considered moderately sensitive for all products.

In another sensitivity scenario, the washing frequency was analyzed. The analysis showed increasing the washing frequency with 10% increased the climate change impact for the entire life cycle with 4,1% to 5,0%. This parameter was considered moderately sensitive for all products except for TC1 where it is considered highly sensitive. Therefore, it is concluded that consumer behavior regarding washing and drying frequency has a very significant influence on the overall climate change impact of the products and should be taken into consideration when interpreting the results.

Finally, the impact of increasing the incineration percentage in the end-of-life scenario to 100% instead of 62% was analyzed. It was found that this change decreased the climate change impact for the entire life cycle with 3% for all products, which shows a low sensitivity. This also shows that in this LCA the climate change impact of incineration is slightly lower than recycling, which may be due to conservative data used for the recycling scenario.

8 References

- Barnhardt, 2016, *Nonwoven Fabric Manufacturing Process: Air/Dry Laid and Carding,* https://barnhardt.net/nonwoven-fabric-manufacturing-process-airdry-laid-and-carding/ (accessed 2026-03-27)
- Cotton Incorporated, 2017, *LCA UPDATE OF COTTON FIBER AND FABRIC LIFE CYCLE INVENTORY,* Report version:1.0
- DEA, 2023, Danish Energy Agency, *Danmarks globale klimapåvirkning - Global afrapportering 2023 (GA23): Klimaaftryk af tekstilforbrug, Baggrundsnotat nr. 7, https://ens.dk/media/6584/download (accessed 2026-04-21)*
- DS/EN ISO 14040:2008, *Environmental management – Life cycle assessment – Principles and framework*
- DS/EN ISO 14044:2008, *Environmental management – Life cycle assessment – Requirements and guidelines*
- DST, 2023, *Elektronik i hjemmet 2023,* https://www.dst.dk/nytpdf/45877 (accessed 2026-01-29)
- (EU) 2019/2023, *Commission Regulation (EU) 2019/2023 of 1 October 2019 laying down ecodesign requirements for household washing machines and household washer-dryers pursuant to Directive 2009/125/EC of the European Parliament and of the Council, amending Commission Regulation (EC) No 1275/2008 and repealing Commission Regulation (EU) No 1015/2010*
- Food Standards Agency, 2023, Reusing a tea towel or cloth for multiple purposes, https://www.food.gov.uk/research/behaviour-and-perception/reusing-a-tea-towel-or-cloth-for-multiple-purposes# (accessed 2026-04-21)
- Index Mundi, n.d., *MMBTU*, https://www.indexmundi.com/commodities/glossary/mmbtu (accessed 2026-01-29)
- IVL (Swedish Environmental Research Institute), 2022, *Siptex WP5 report: Life cycle assessment of textile recycling products*
- IVL (Swedish Environmental Research Institute), 2024, *Life cycle assessment of mechanical textile recycling in Sweden*
- Københavns Kommune, 2025, *Sådan sorterer du tekstilaffald*, https://affald.kk.dk/affaldsfraktion/saadan-sorterer-du-tekstilaffald (accessed 2025-03-06)
- S. Palamutcu, 2010, *Electric energy consumption in the cotton textile processing stages,* Energy, Volume 35, Issue 7, https://doi.org/10.1016/j.energy.2010.03.029.
- PEF, 2021, *Annex I. Product Environmental Footprint Method*

- PEFCR, 2018, *Product Environmental Footprint Category Rules Guidance*
- PEFCR Apparel and Footwear, 2025, *Product Environmental Footprint Category Rules for Apparel and Footwear*
- PEF-RP A&FW, 2024, *Product Environmental Footprint Representative Product (PEF-RP) Study Report for Apparel and Footwear*
- Textile Engineering, 2025, *Carding Process in Textile: Definition, Objectives, and Functions,* https://textileengineering.net/carding-process-in-textile-definition-objectives-and-functions/ (accessed 2026-03-27)
- The Engineering ToolBox, 2003, *Fuels - Densities and Specific Volumes,* *https://www.engineeringtoolbox.com/fuels-densities-specific-volumes-d_166.html (accessed 2026-03-30)*
- TSE, N.D, *Energy needed to produce steam,* https://thundersaidenergy.com/downloads/energy-needed-to-produce-steam-enthalpy-and-entropy-data/ (accessed 2025-03-06)
- Vision Linens, 2019, *Linen and Textile Care: A Breakdown of Lifespans and Wash Cycles* https://www.visionlinens.com/blog/linen-textile-care-lifespans-wash-cycles (accessed 2026-04-21)
- Weidema, B.P., Bauer, Ch., Hischier, R., Mutel, Ch., Nemecek, T., Reinhard, J., Vadenbo, C.O., Wernet, G, 2013, *The ecoinvent database: Overview and methodology, Data quality guideline for the ecoinvent database version 3*, www.ecoinvent.org

9 Appendix

9.1 Factory data - determination of inputs and outputs

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

Input	Procedure for determining input per kg final product
Electricity for weaving (sub-meter)	Electricity for weaving (65.413 kWh) was divided by the amount of fabric woven in the factory (239.616 kg) and multiplied by 1,05 to account for losses in the cut and sew step.
Electricity for cut and sew (sub-meter)	Electricity for cut and sew (112.942 kWh) was divided by the amount of fabric for the cut and sew process in the factory (123.382 kg).
Electricity for other (sub-meter)	Electricity for other processes (6.426 kWh) was divided by the amount of fabric for the cut and sew process in the factory (123.382 kg).
Natural gas for cut and sew (sub-meter)	Natural gas consumption for cut and sew was 210 mmBTU = 5.935 m^3. This was divided by the amount of fabric for the cut and sew process in the factory (123.382 kg).
Natural gas for other (sub meter)	Natural gas consumption for other processes (546.767 m^3) was divided by the amount of fabric for the cut and sew process in the factory (123.382 kg).
Diesel for generator	Total diesel consumption (8.260 L) was divided by the amount of fabric for the cut and sew process in the factory (123.382 kg).
Gasoline for company vehicles	Total gasoline consumption (8.920 L) was divided by the amount of fabric for the cut and sew process in the factory (123.382 kg).
Clean water for weaving (sub-meter)	Clean water consumption for weaving (5.610 m^3) was divided by the amount of fabric woven in the factory (239.616 kg) and multiplied by 1,05 to account for losses in the cut and sew step.
Biomass for heat for cut and sew (sub-meter)	Biomass for heat for cut and sew (392 ton) was divided by the amount of fabric for the cut and sew process in the factory (123.382 kg).
Clean water for cut and sew (sub-meter)	Clean water consumption for cut and sew (9.946 m^3) was divided by the amount of fabric for the cut and sew process in the factory (123.382 kg).
Lubricants	Lubricant (775 liter, assumed 775 kg) was divided by the amount of fabric for the cut and sew process in the factory (123.382 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.
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.
Acid for desizing	Amount needed per product provided by the factory.
Enzyme for desizing	Amount needed per product provided by the factory.
Sodium hydroxide for scouring	Amount needed per product provided by the factory.

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

Output	Procedure for determining input per kg final product
Plastic waste	Plastic waste (400 kg) was divided by the amount of fabric for the cut and sew process in the factory (123.382 kg).
Paper waste	Paper waste (2.730 kg) was divided by the amount of fabric for the cut and sew process in the factory (123.382 kg).

Output	Procedure for determining input per kg final product
Wastewater	Wastewater to treatment was calculated as 125% of the clean water input to the factory. Clean water consumption for cut and sew (9.946 m^3) was divided by the amount of fabric for the cut and sew process in the factory (123.382 kg) and scaled to 125%. Clean water consumption for weaving (5.610 m^3) was divided by the amount of fabric woven in the factory (239.616 kg) and multiplied by 1,05 to account for losses in the cut and sew step and scaled to 125%
Textile waste	The amount of textile waste was calculated from the loss rates according to the factory (2% in weaving and 5% in cut and sew).

9.2 Washing frequency calculation

The data shown in Table 51 and Table 52 is taken from a survey carried out by Food Standards Agency (2023). In this survey the washing frequency for tea towels and dishcloths were surveyed across 60 households. For this LCA, the survey answers were translated to a specific frequency per week (see Table 51 and Table 52) and a weighted average was calculated based on the number of households per answer:

For tea towels:

$$\frac{10x7 + 24x2{,}5 + 16x1 + 7x0{,}5}{10 + 24 + 16 + 7 + 1 + 2} = 2{,}6$$

For dishcloths:

$$\frac{8x7 + 13x2{,}5 + 13x1 + 13x0{,}5}{8 + 13 + 13 + 13} = 2{,}3$$

Table 51 – Answers from survey of washing frequency of tea towels (Food Standards Agency, 2023).

Number of households in survey	Survey answer (Washing frequency per week)	Assumptions in this LCA
10	"At least once or multiple times per day"	Assumed 7 times per week
24	"2 or 3 times per week"	Assumed 2,5 times per week
16	"At least once a week"	Assumed 1 time per week
7	"Fortnightly or longer"	Assumed 0,5 times per week
1	"Don't know"	Excluded from calculation
2	"Don't use this item"	Excluded from calculation

Table 52 – Answers from survey of washing frequency of dishcloths (Food Standards Agency, 2023).

Number of households in survey	Survey answer (Washing frequency per week)	Assumptions in this LCA
8	"At least once or multiple times per day"	Assumed 7 times per week
13	"2 or 3 times per week"	Assumed 2,5 times per week

Number of households in survey	Survey answer (Washing frequency per week)	Assumptions in this LCA
13	"At least once a week"	Assumed 1 time per week
13	"Fortnightly or longer"	Assumed 0,5 times per week
0	"Don't know"	Excluded from calculation
13	"Don't use this item"	Excluded from calculation

9.3 Data quality numerical rating

Table 53 - Numerical data quality rating per process in the LCA. The weighing is based on the average contribution of each process to the overall climate change impact across all products. The weighted score is calculated as the product of the average DQR per process and the final DQR score is the sum of the weighted score for all processes.

Activity	Accuracy	Geography	Time	Technology	Average DQR	Weighing	Weighted score
Organic cotton growing	2	3	1	1	1,75	8%	0,132
Conventional cotton growing	2	3	1	1	1,75	4%	0,065
Ginning	2	2	1	1	1,5	0%	0,0000
Transport to final processing	2	4	1	2	2,25	0%	0,001
Ring spinning	2	4	1	1	2	10%	0,195
Open spinning	2	3	1	1	1,75	0%	0,002
Yarn bleaching and dyeing	3	3	1	2	2,25	4%	0,099
Yarn sizing	3	4	1	3	2,75	1%	0,024
Processing of filling	4	1	1	3	2,25	0%	0,002
Fiber production	2	3	1	3	2,25	1%	0,016
Transport of thread	2	4	1	2	2,25	0%	0,001
Transport by truck	2	4	1	2	2,25	0%	0,004
Electricity from grid	2	1	1	1	1,25	4%	0,046
Natural gas	2	4	1	2	2,25	6%	0,125
Diesel	2	4	1	2	2,25	1%	0,026
Gasoline	2	4	1	2	2,25	0%	0,006
Heat from biomass	2	4	1	2	2,25	4%	0,084

Clean water	2	4	1	2	2,25	1%	0,013
Lubricant	2	4	1	2	2,25	0%	0,001
Acid for desizing	2	4	1	2	2,25	0%	0,001
Enzymes for desizing	2	4	1	3	2,5	0%	0,001
Sodium hydroxide for scouring	2	4	1	1	2	0%	0,001
Plastic waste	2	4	1	2	2,25	0%	0,0003
Paper waste	2	4	1	2	2,25	0%	0,007
Textile waste	2	4	1	2	2,25	0%	0,006
Wastewater treatment	2	4	1	2	2,25	0%	0,007
Plastic input	3	4	1	2	2,5	0%	0,001
Paper input	3	4	1	2	2,5	0%	0,003
Unprinted cardboard	1	4	1	2	2	0%	0,004
Printed cardboard	1	4	1	2	2	2%	0,049
Jute rope	1	3	1	1	1,5	0%	0,002
LDPE bag	1	4	1	2	2	0%	0,003
Packaging tape	1	4	1	3	2,25	0%	0,004
Transport to DK	1	4	1	2	2	2%	0,041
Warehouse	3	1	1	1	1,5	0%	0,001
Retail	3	1	1	1	1,5	2%	0,025
Cardboard disposal	1	1	1	2	1,25	0%	0,001
LDPE disposal	1	1	1	2	1,25	0%	0,002
Car transport	5	2	1	3	2,75	1%	0,020
Electricity use	3	1	1	1	1,5	27%	0,406
Water use	3	2	1	2	2	1%	0,030

Detergent use	3	4	1	3	2,75	17%	0,468
Cardboard disposal	1	1	1	2	1,25	0%	0,0003
Jute rope disposal	1	3	1	2	1,75	0%	0,00003
Textile to incineration	3	3	1	1	2	2%	0,042
Textile to recycling	3	2	1	3	2,25	1%	0,021
Sum of processes	**-**	**-**	**-**	**-**	**-**	**100%**	**1,99**

9.4 Contribution analysis for all environmental impacts

9.4.1 TT1 – all environmental indicators

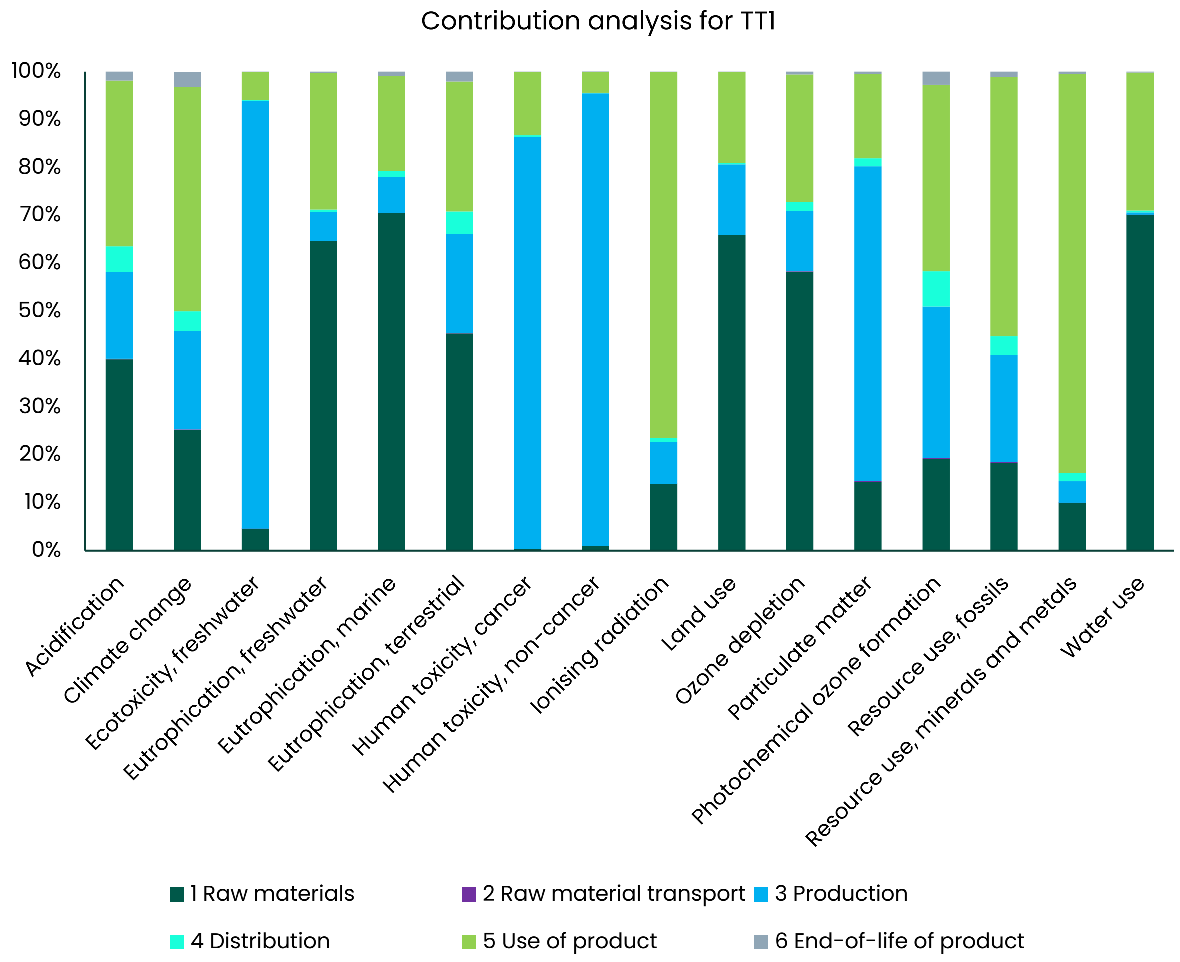

Figure 14 – Environmental impact per indicator for TT1 per life cycle phase.

9.4.2 TT2 – all environmental indicators

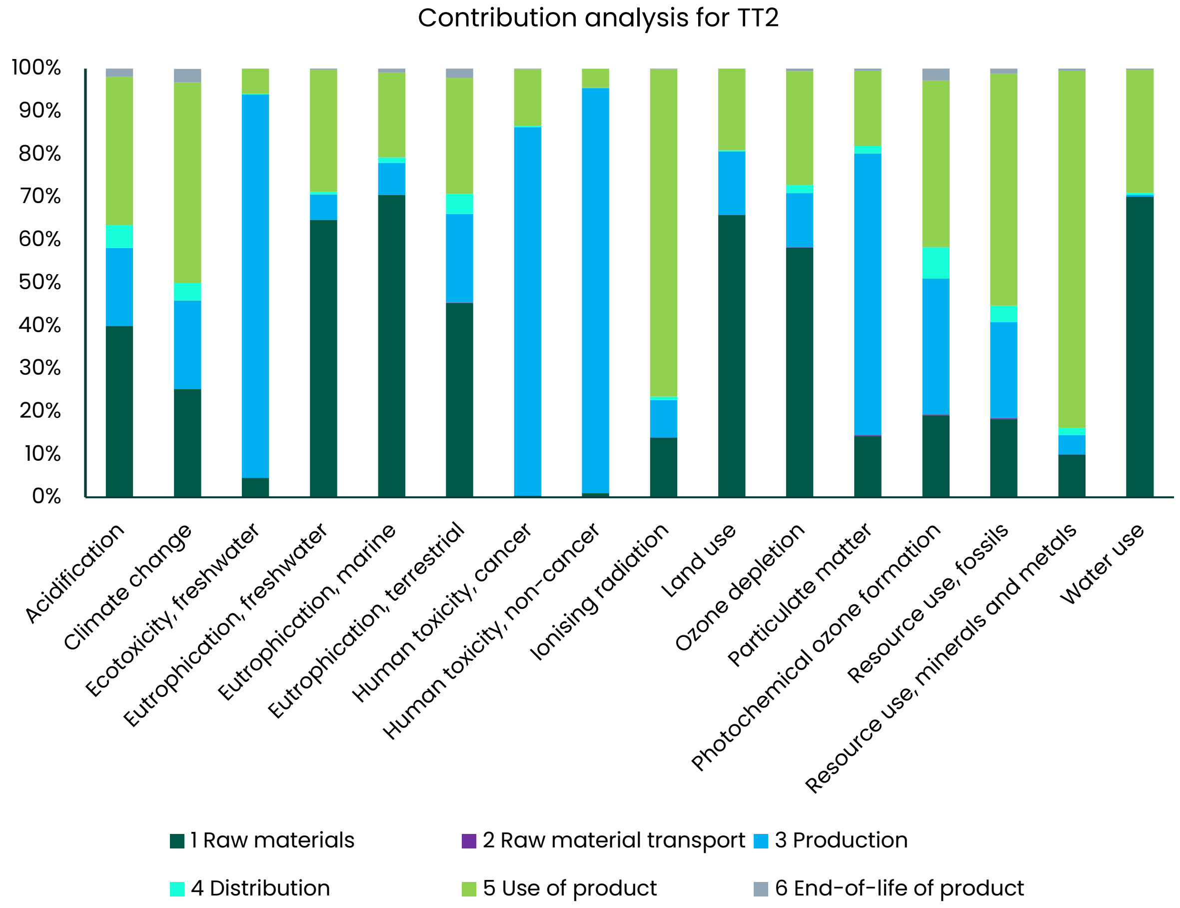

Figure 15 – Environmental impact per indicator for TT2 per life cycle phase.

9.4.3 TT3 – all environmental indicators

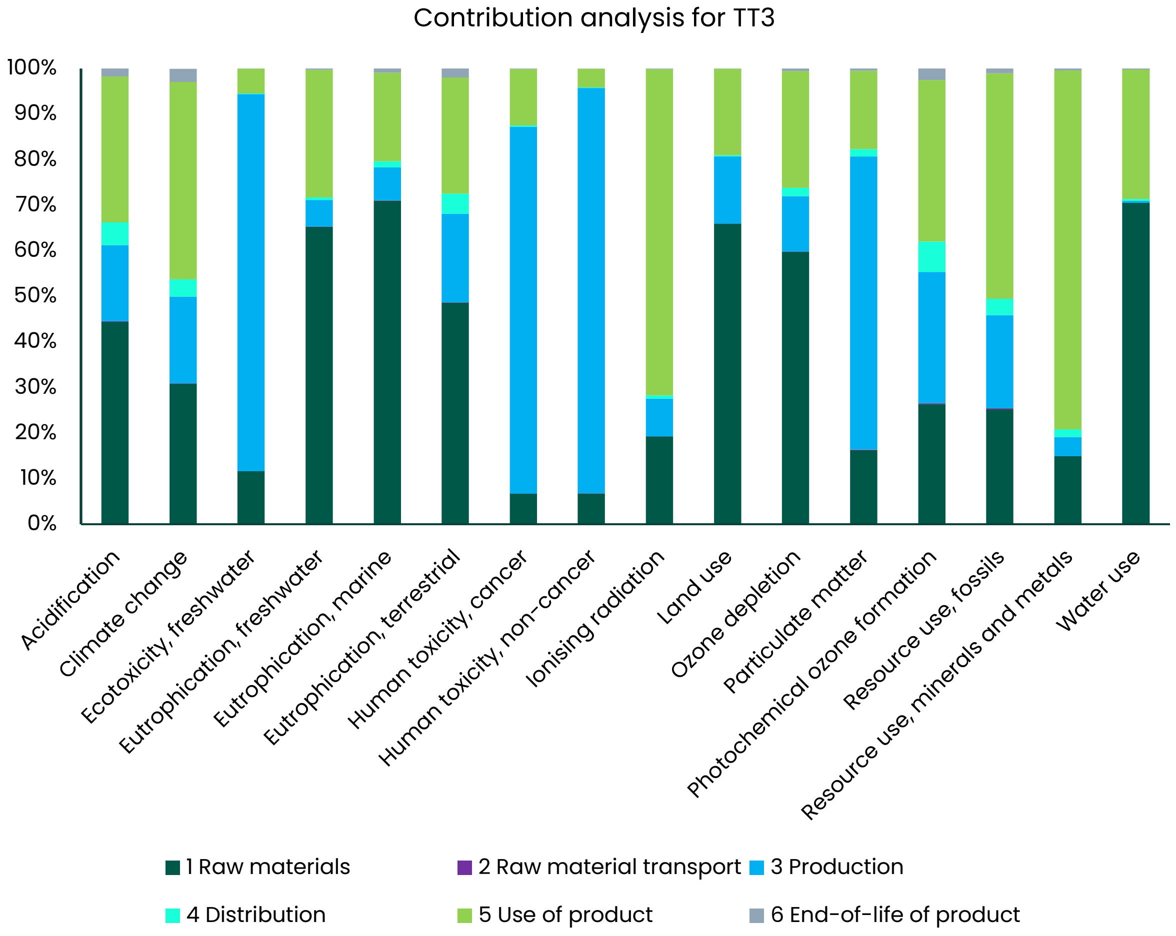

Figure 16 – Environmental impact per indicator for TT3 per life cycle phase.

9.4.4 TT4 – all environmental indicators

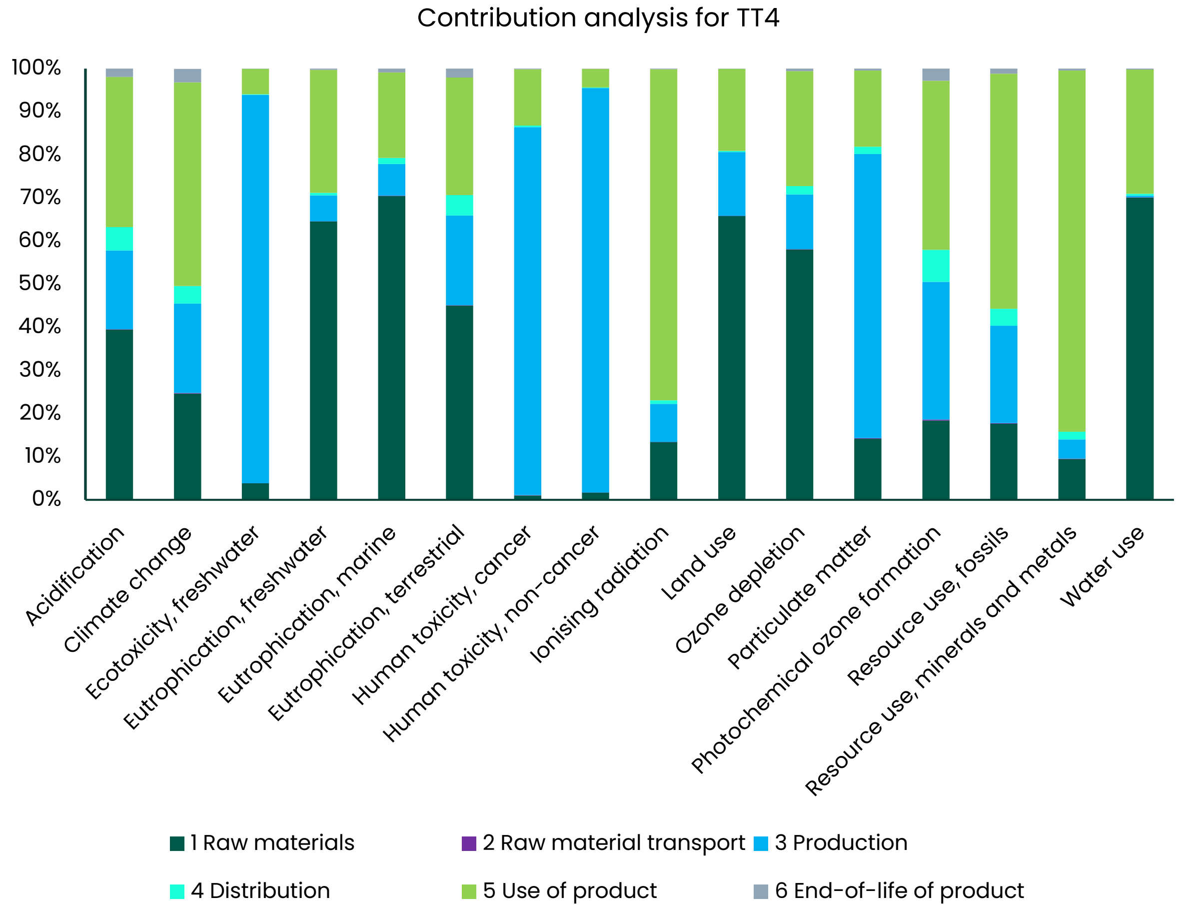

Figure 17 – Environmental impact per indicator for TT4 per life cycle phase.

9.4.5 TT5 – all environmental indicators

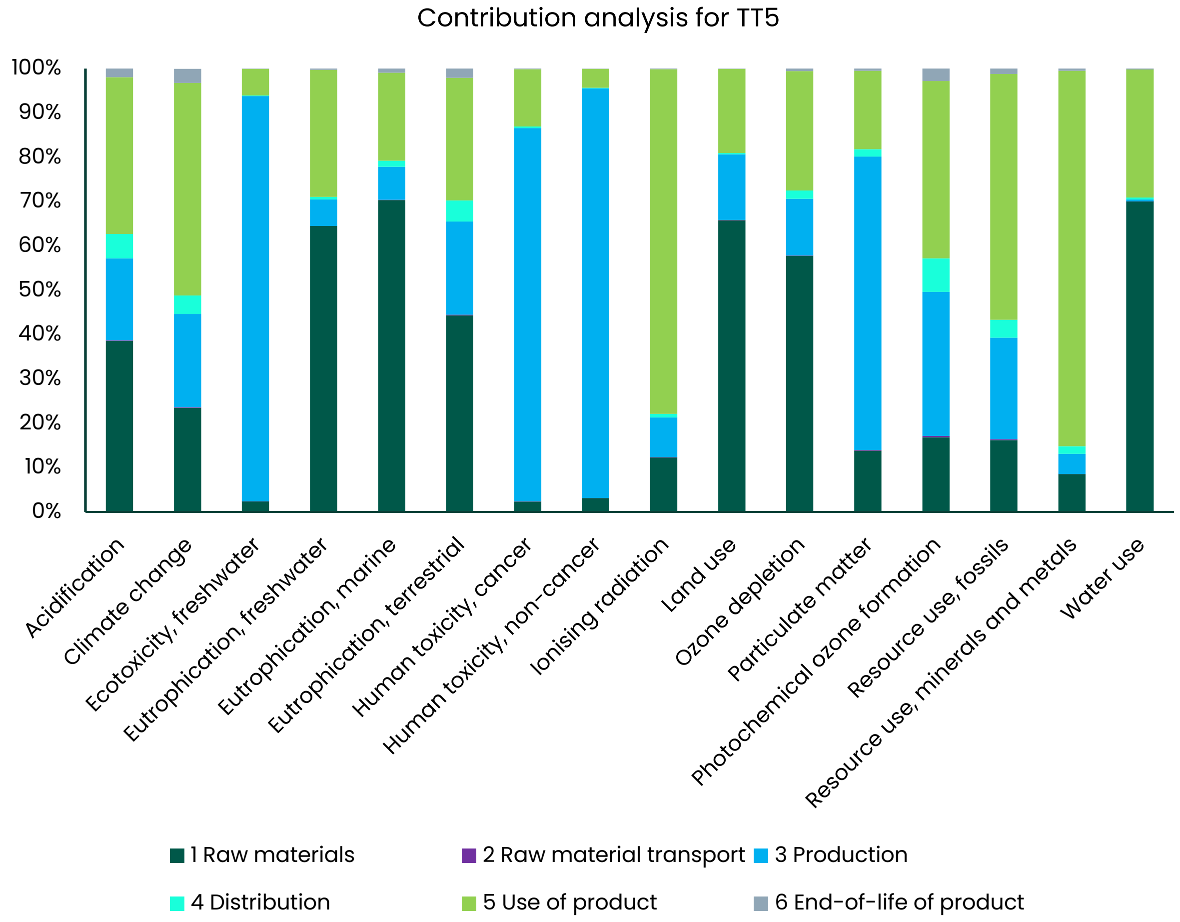

Figure 18 – Environmental impact per indicator for TT5 per life cycle phase.

9.4.6 TT6 – all environmental indicators

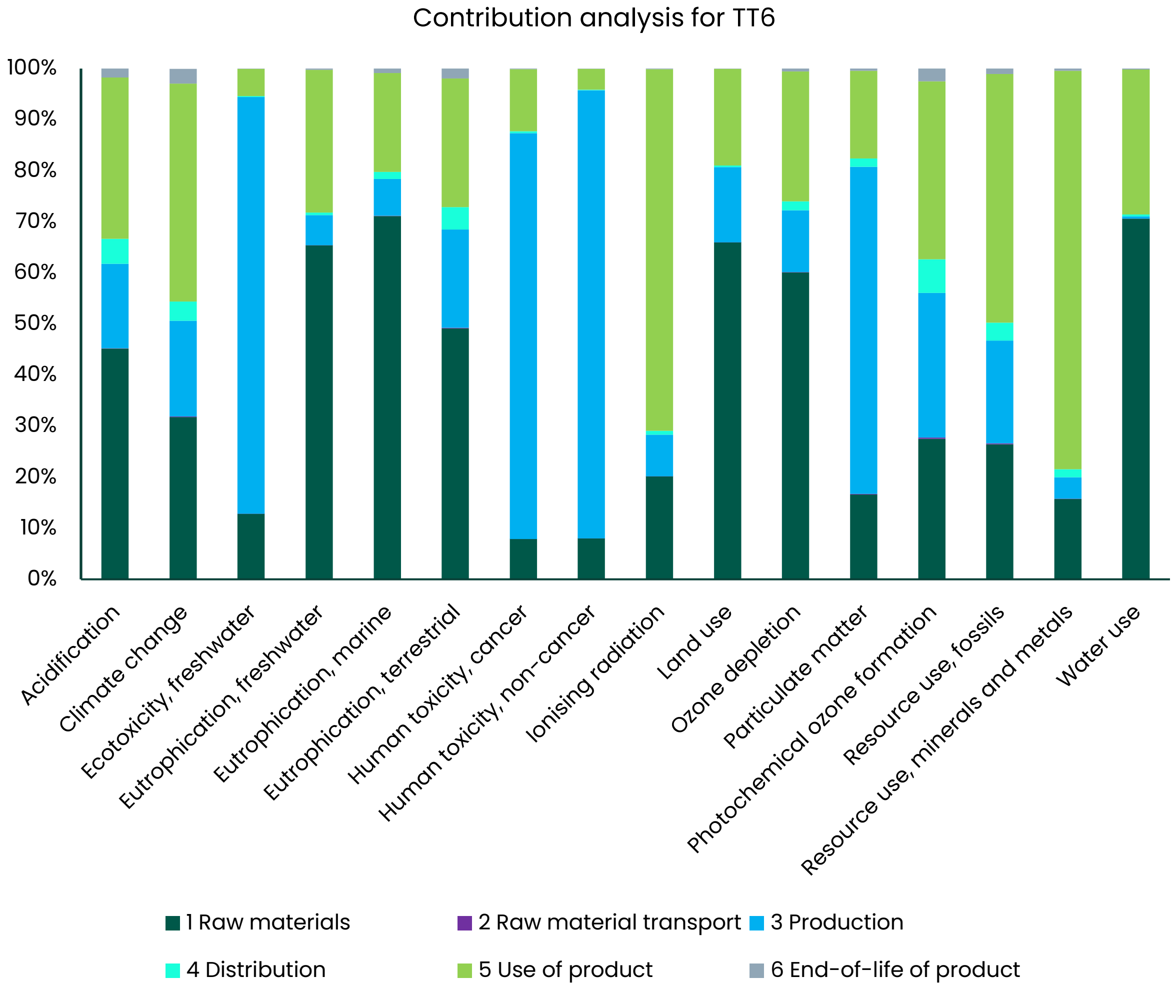

Figure 19 – Environmental impact per indicator for TT6 per life cycle phase.

9.4.7 AP1 – all environmental indicators

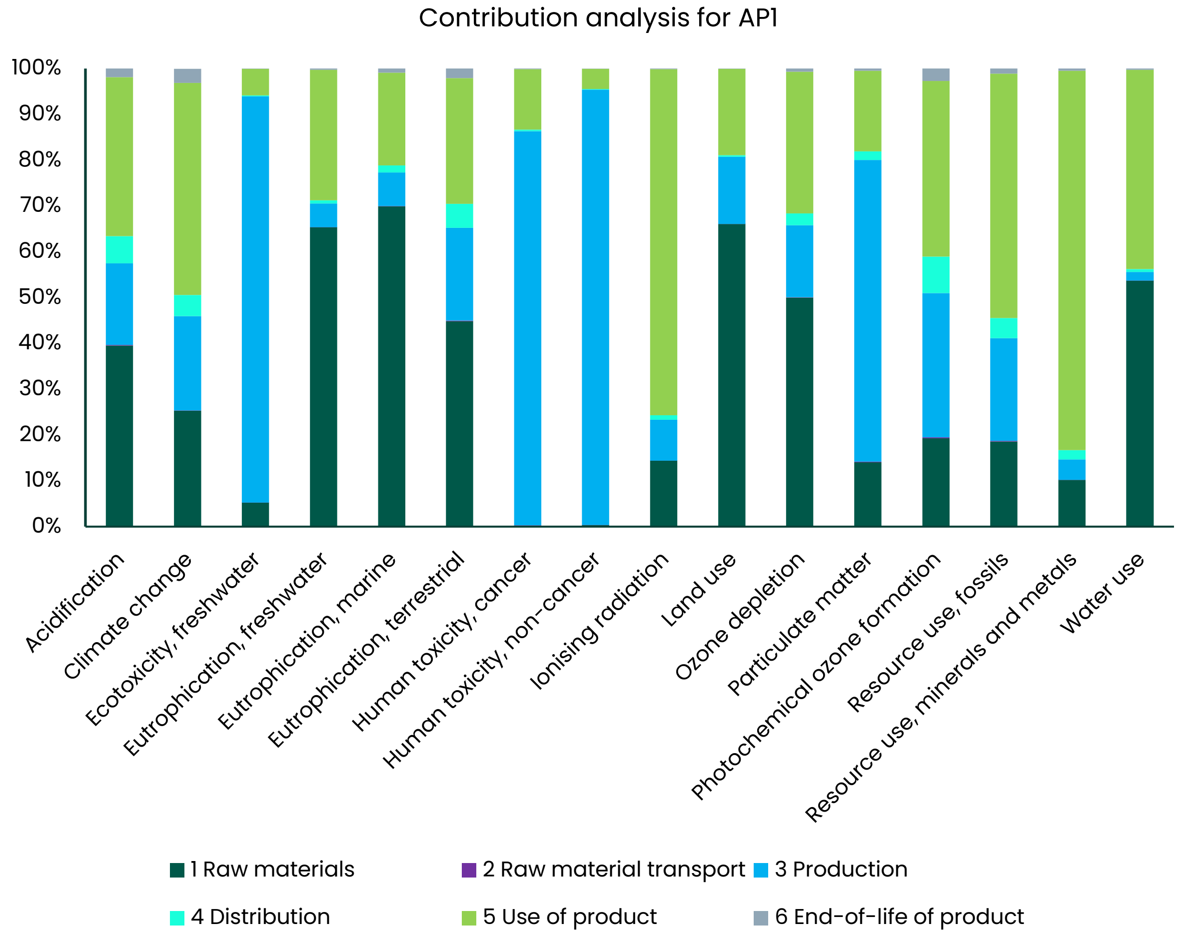

Figure 20 – Environmental impact per indicator for AP1 per life cycle phase.

9.4.8 AP2 – all environmental indicators

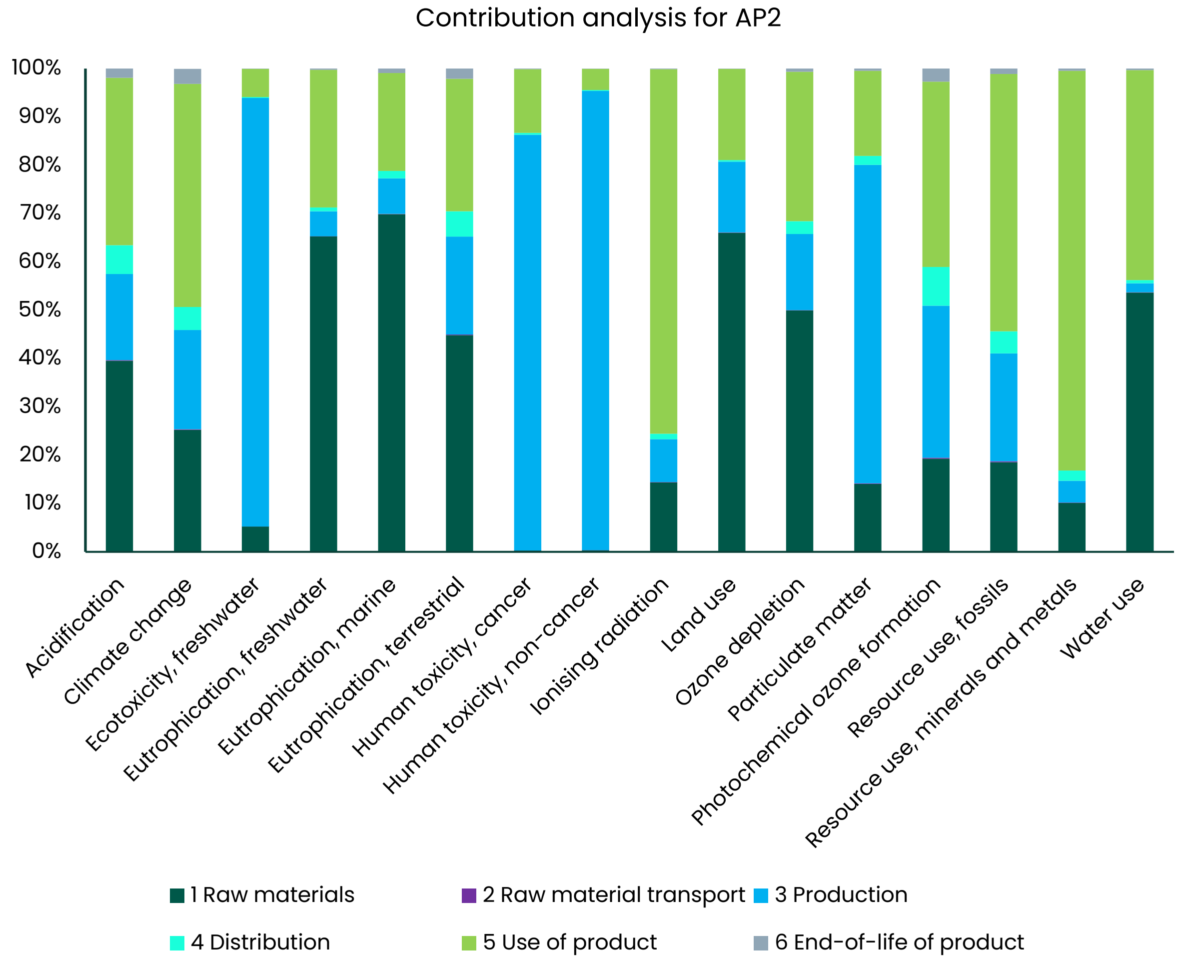

Figure 21 – Environmental impact per indicator for AP2 per life cycle phase.

9.4.9 DC1 – all environmental indicators

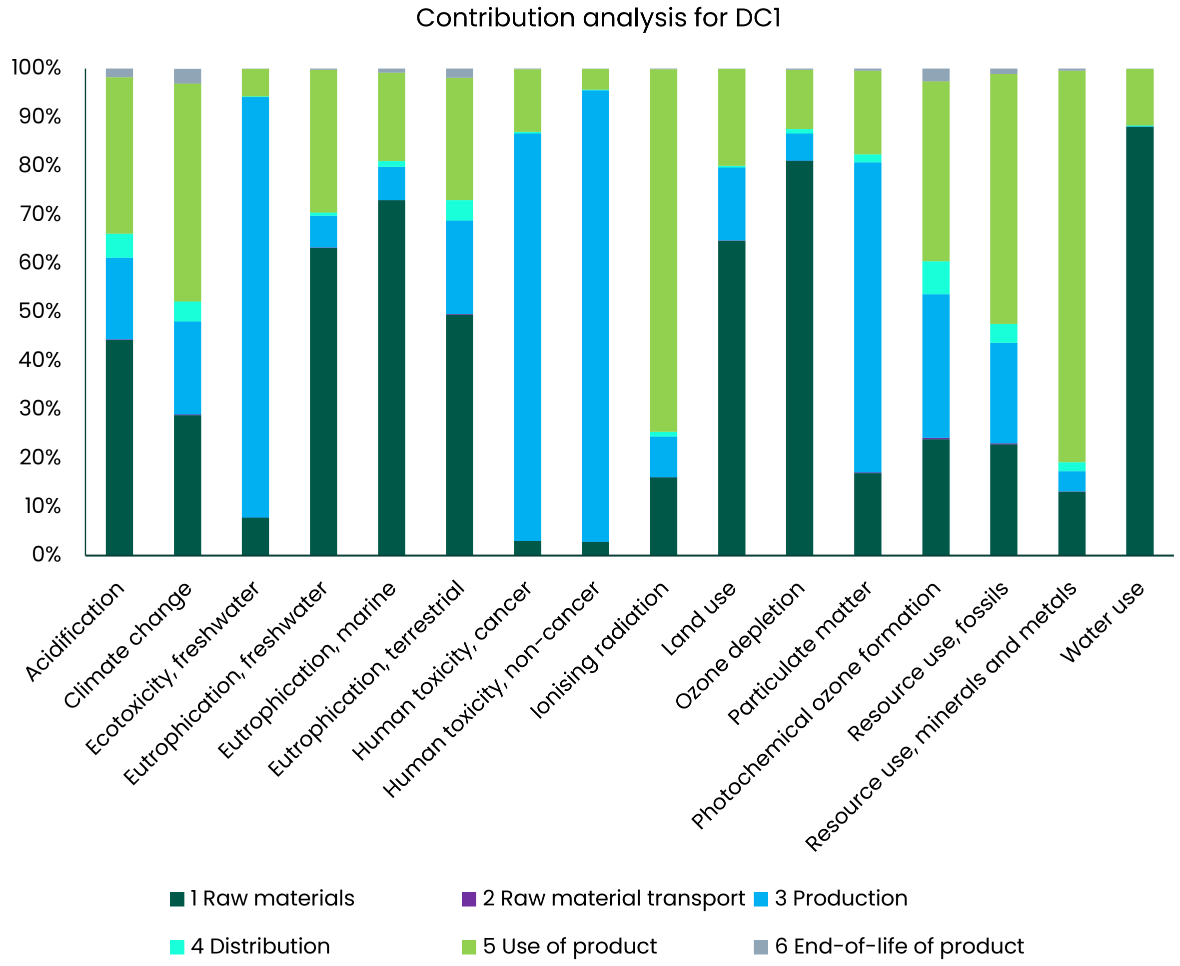

Figure 22 – Environmental impact per indicator for DC1 per life cycle phase.

9.4.10 DC2 – all environmental indicators

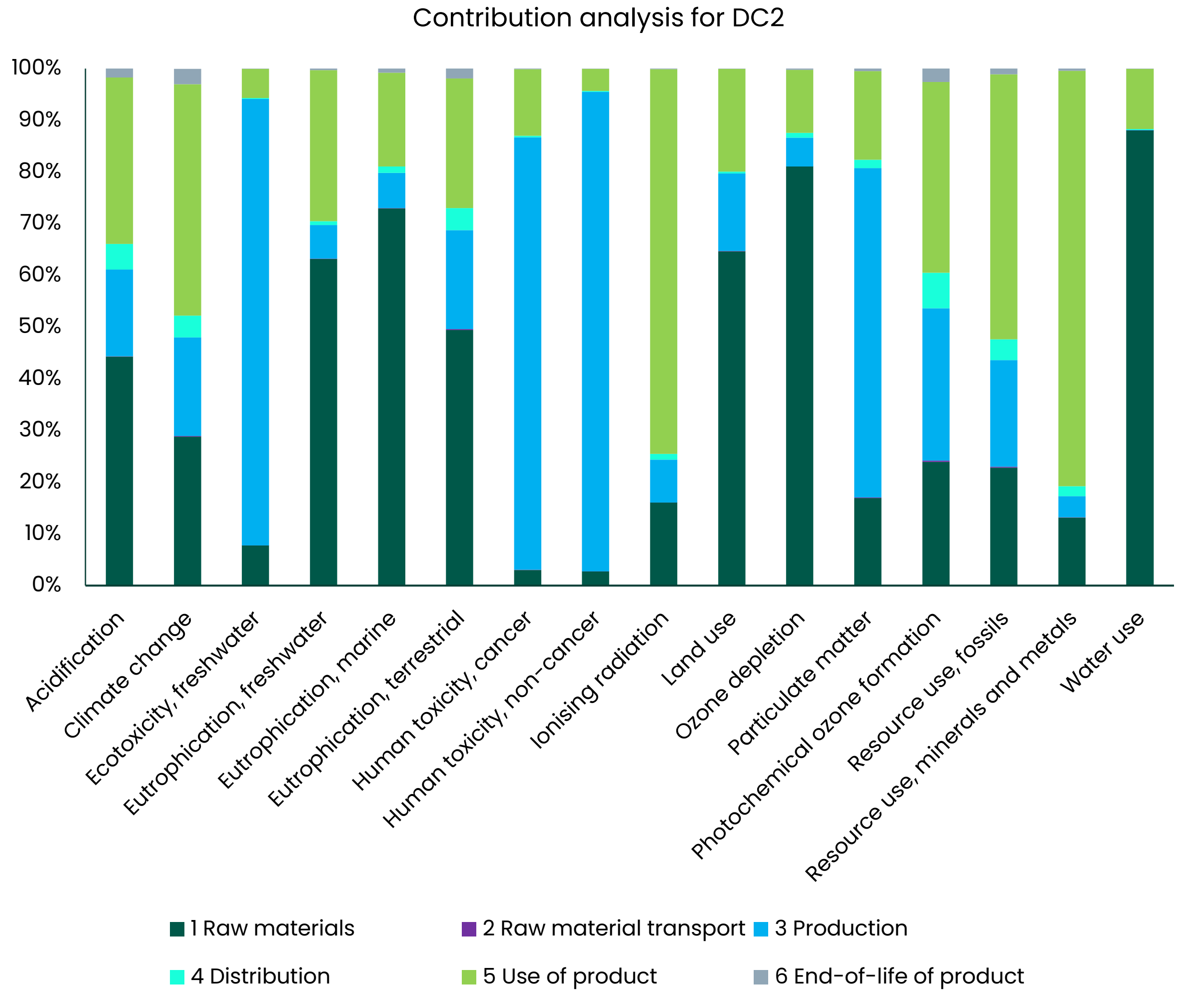

Figure 23 – Environmental impact per indicator for DC2 per life cycle phase.

9.4.11 PH1 – all environmental indicators

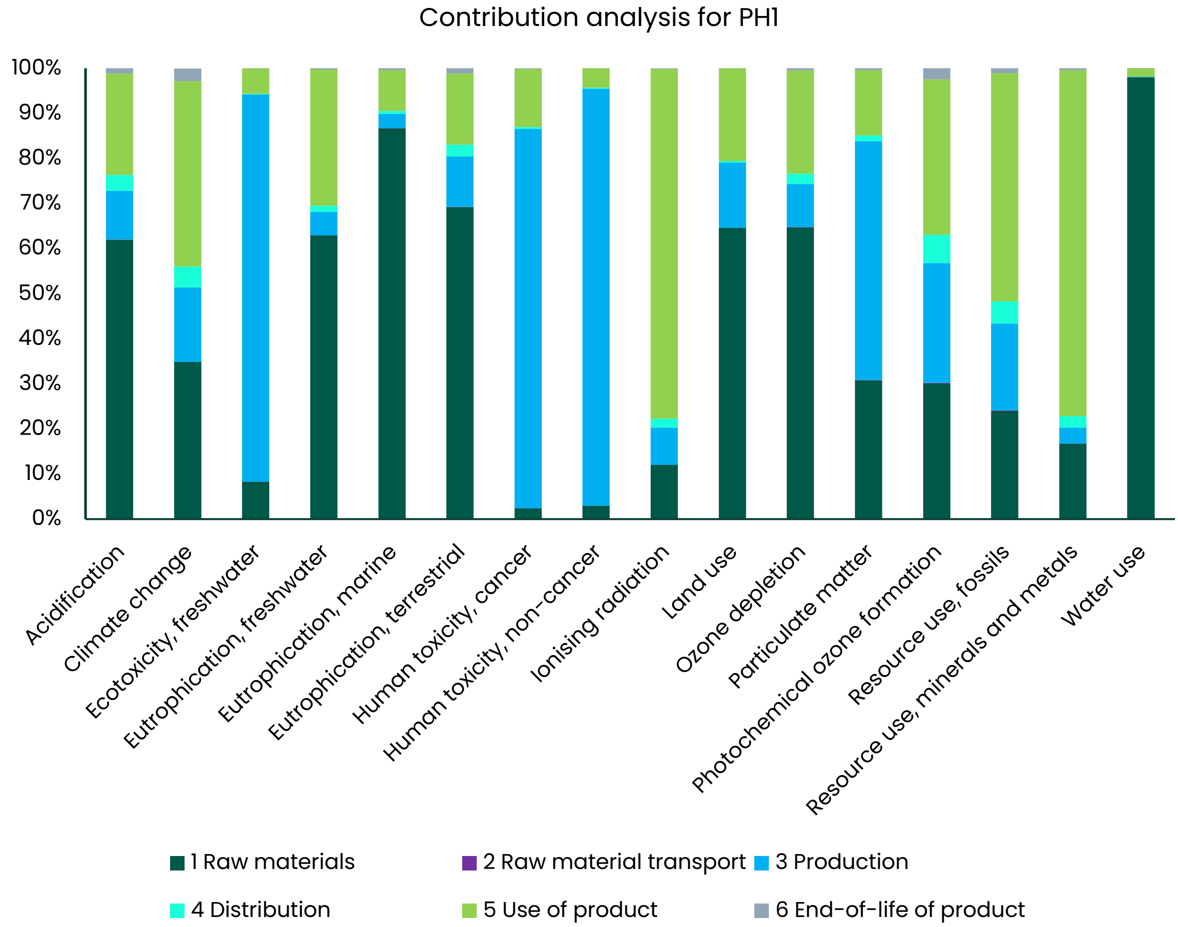

Figure 24 – Environmental impact per indicator for PH1 per life cycle phase.

9.4.12 PH2 – all environmental indicators

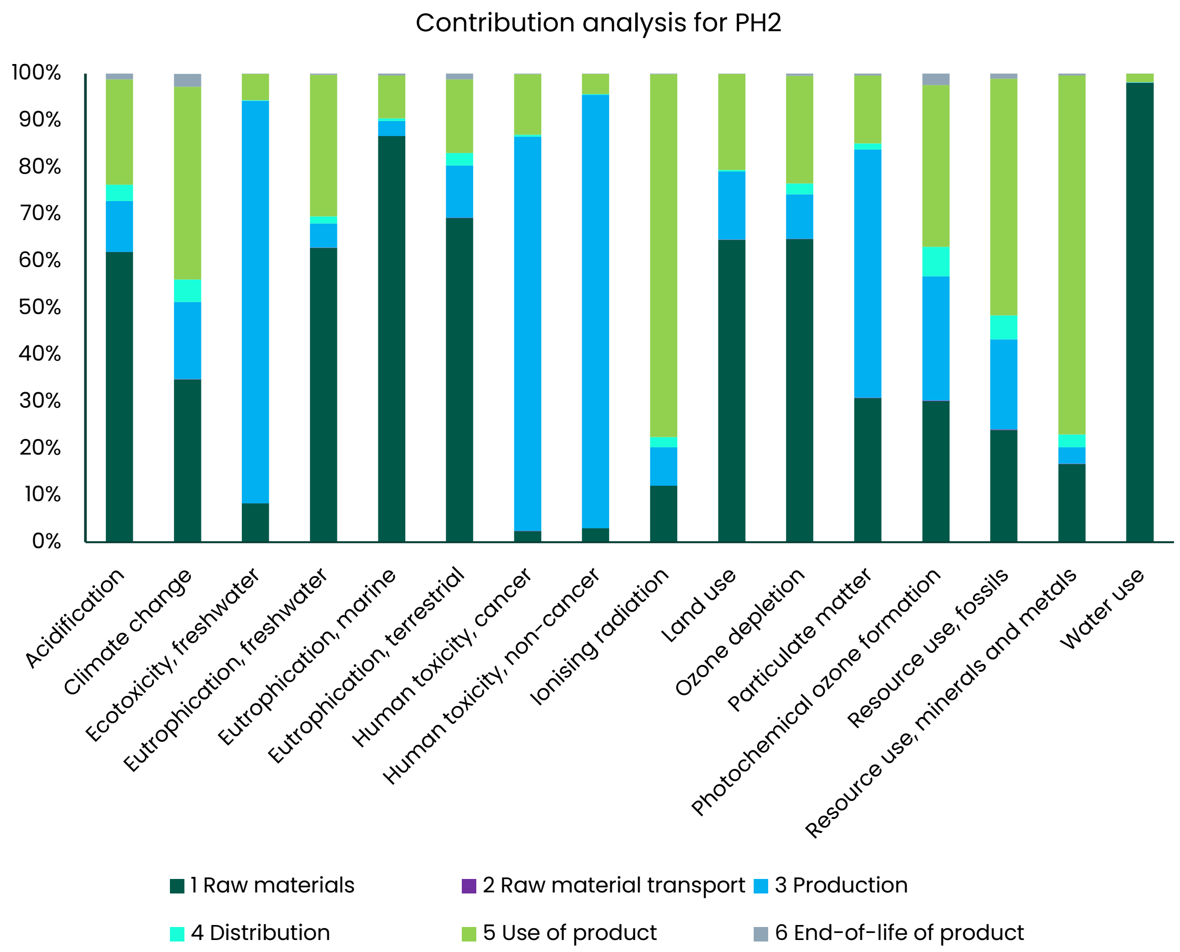

Figure 25 – Environmental impact per indicator for PH2 per life cycle phase.

9.4.13 NK1 – all environmental indicators

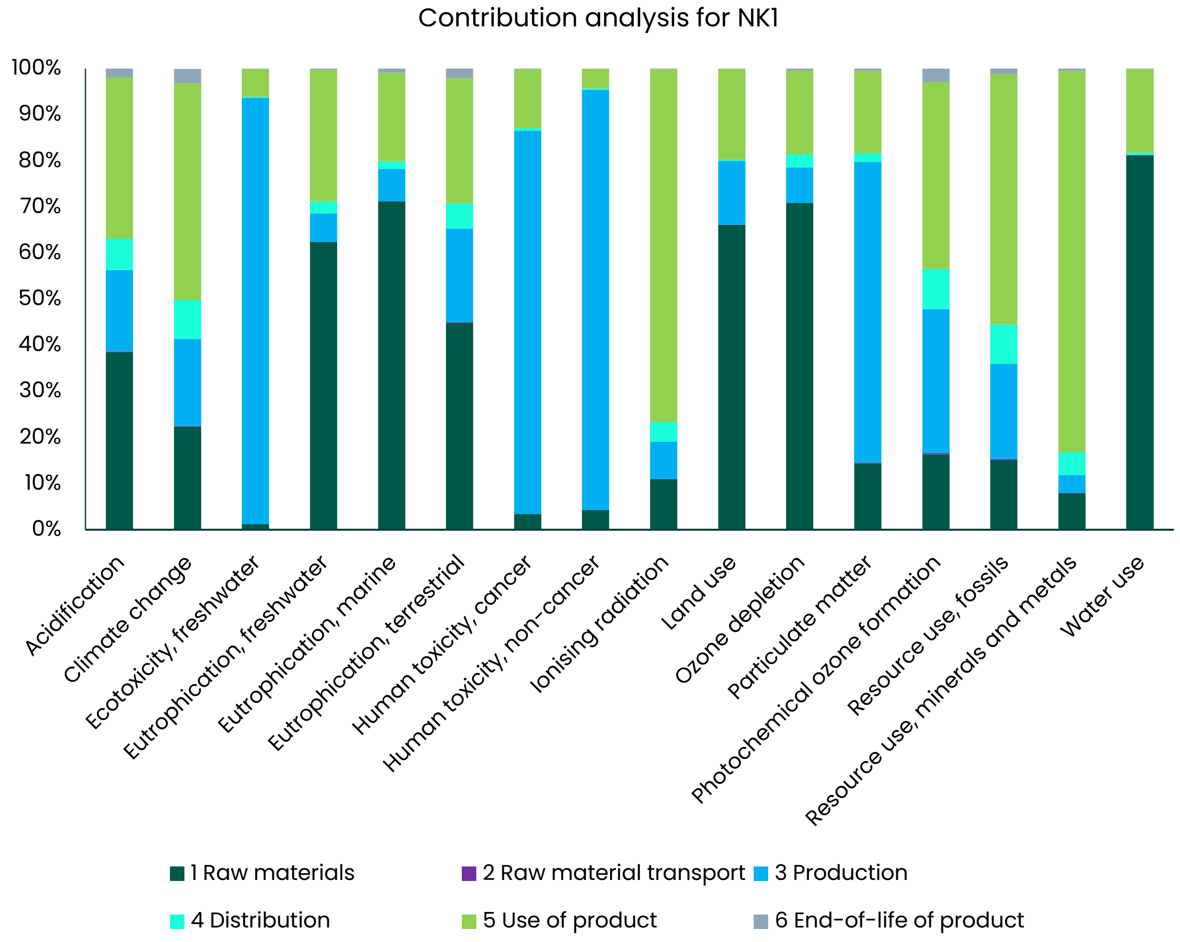

Figure 26 – Environmental impact per indicator for NK1 per life cycle phase.

9.4.14 NK2 – all environmental indicators

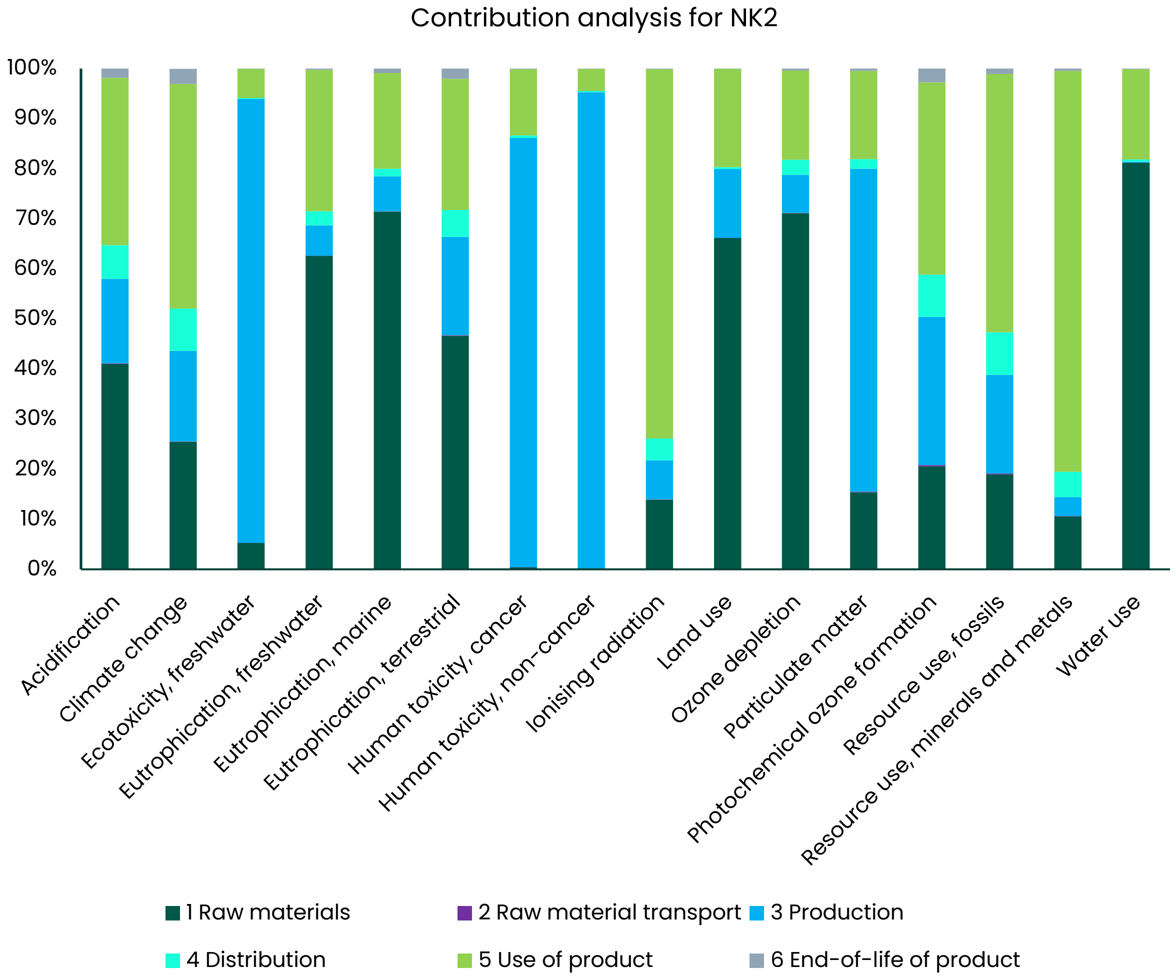

Figure 27 – Environmental impact per indicator for NK2 per life cycle phase.

9.4.15 TC1 – all environmental indicators

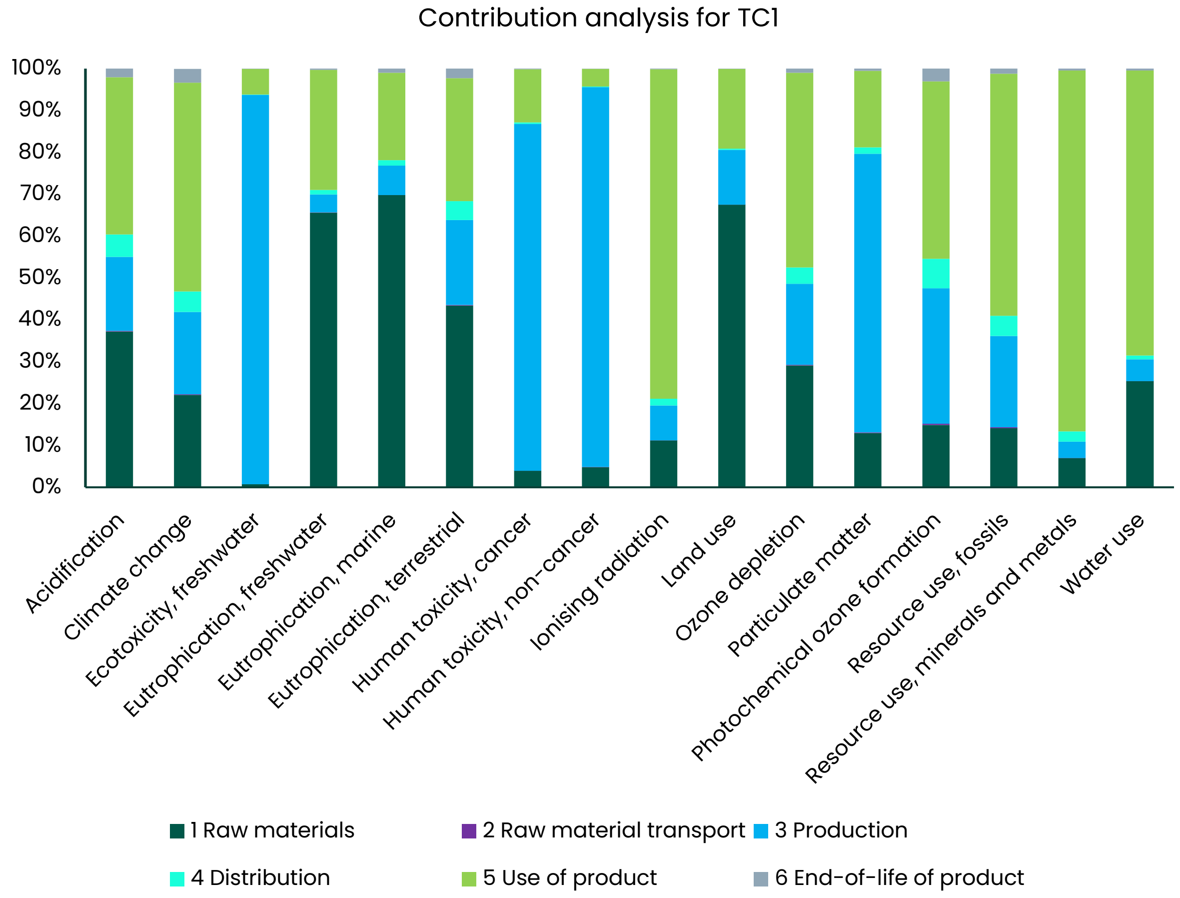

Figure 28 – Environmental impact per indicator for TC1 per life cycle phase.

9.4.16 TC2 – all environmental indicators

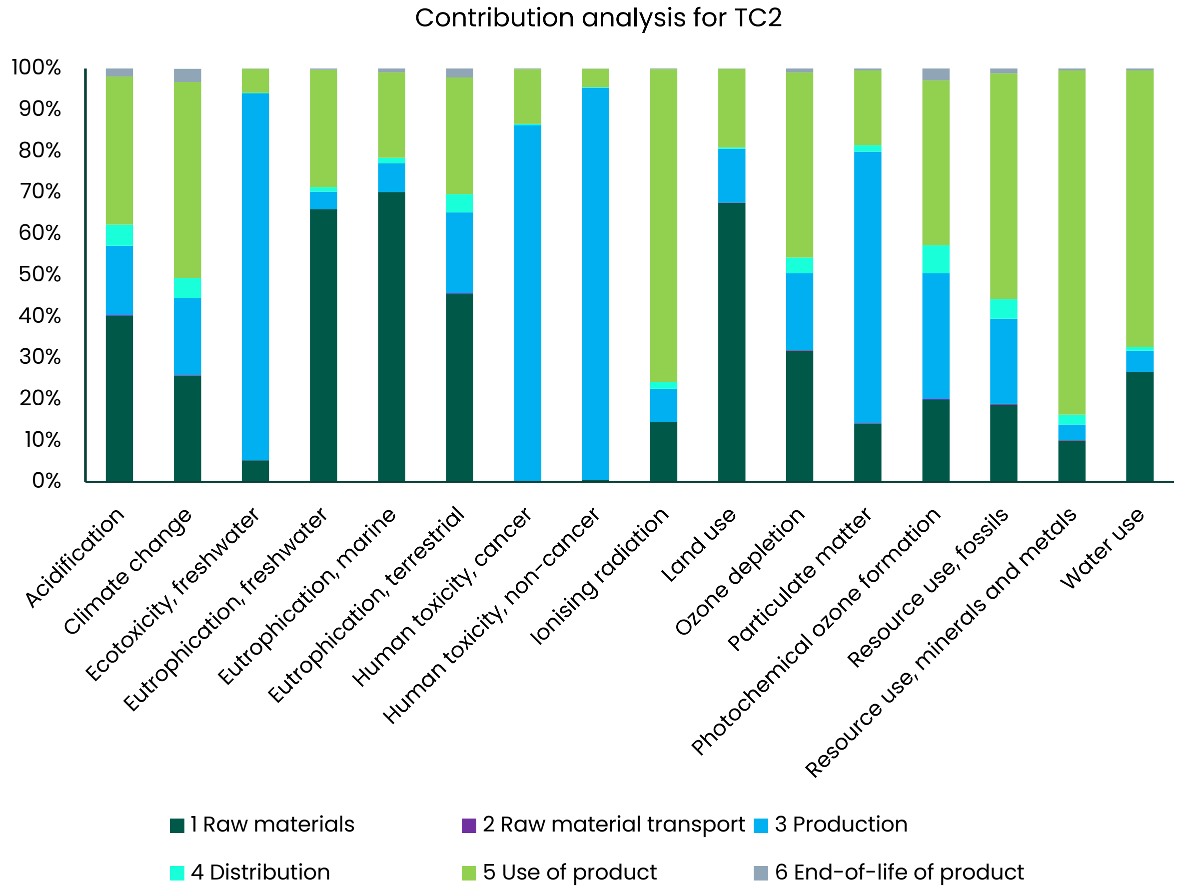

Figure 29 – Environmental impact per indicator for TC2 per life cycle phase.

9.5 Dialogue between critical reviewer and LCA practitioner

No.	PAGE NUMBER	REFERENCE TO CHECKLIST OR PROGRAMME INSTRUCTIONS	REVIEWER COMMENT AND RECOMMENDATION	LCA PRACTITIONER ANSWER	FINAL REVIEWER STATEMENT
1	4	ISO 14044:2008	The review can run into may, but this as already been discussed.	If that is the case we will update the text.	Report prioritised. OK, approved.
2	7	ISO 14044:2008	Please provide certificates for the use of organic cotton. **Round 2:** Waiting for certificates	Mørkegaard will provide these. Certificates provided.	OK, approved
3	11	ISO 14044:2008	Is the remaining material conventional? Are the 25% only of the organic cotton? Please clarify. Please also add the polyester fraction. It is unclear how polyester is used in the product.	The percentage was meant as '% of cotton that is organic' meaning for TT1 98,2% of the cotton is organic and 1,8% is coventional. But there is also polyester, so to avoid confusion we have changed the table to show the percentage composition including the polyester.	OK, approved
4	17	ISO 14044:2008	Combosition should be mentioned earlier, when polyester is first mentioned.	The composition is already mentioned on page 7. Based on a previous comment it is now also included in a table in the scope (section 3.1).	OK, approved
5	19	ISO 14044:2008	Why are the all still rated the same here, when one was increased? Please expain.	Good point. The ginning process which was improved for geographical representativeness, has been reassessed to "Good".	OK, approved
6	21	ISO 14044:2008	GLO should be rated poor and not very poor.	Corrected across the whole LCA and the numerical DQR has also been updated accordingly.	OK, approved
7	22	ISO 14044:2008	Why is this rated so low? Please explain the choice?	GLO has been reassessed from "Very poor" to "Poor" across the whole LCA.	OK, approved
8	22	ISO 14044:2008	It should be stated that the sudy has undergone criticla review, even through the certificate is not avaliable and that it is 9 years old.	It is now included. Furthermore the age of the source has been discussed.	OK, approved
9	30	ISO 14044:2008	Is the waste percentage primary data from the factory?	Yes. This has been clarified.	OK, approved
10	30	ISO 14044:2008	Are the additional mass for desizing taken from storage?	The factory processes fabric that is woven in-house <u>and</u> fabric that is woven at other factories. This is the explanation for higher amounts being desized than woven. Short description added to text.	OK, approved
11	34	ISO 14044:2008	Why is this diesel rated so low when a GLO dataset is used?	GLO has been reassessed from "Very poor" to "Poor" across the whole LCA.	OK, approved
12	34	ISO 14044:2008	Why are enzymes ratred to low when a GLO dataset is used?	GLO has been reassessed from "Very poor" to "Poor" across the whole LCA.	OK, approved
13	34	ISO 14044:2008	Why is plastic rated so low?	GLO has been reassessed from "Very poor" to "Poor" across the whole LCA.	OK, approved
14	35	ISO 14044:2008	I have generally commented on why GLO is rated so low, please justify such a low rating for the study.	GLO has been reassessed from "Very poor" to "Poor" across the whole LCA.	OK, approved

No.	PAGE NUMBER	REFERENCE TO CHECKLIST OR PROGRAMME INSTRUCTIONS	REVIEWER COMMENT AND RECOMMENDATION	LCA PRACTITIONER ANSWER	FINAL REVIEWER STATEMENT
15	40	ISO 14044:2008	Odense does have a centrla locationand can be representative, but it is not the central location. This should be added in the text.	We have elaborated so it is clear that we don't claim that it is the most geographically central location. "	OK, approved
16	41	ISO 14044:2008	The text does not match with what is written in the table for Geo and temp. Please correct.	The text has been adapted to fit with the table.	OK, approved
17	48	ISO 14044:2008	This report is not listed in the list of sources and shall be added.	It has been added.	OK, approved
18	48	ISO 14044:2008	The value cannot be found in the listed source "Reusing a tea towel or cloth for multiple purposes". Please add the calculation.	Appendix showing the calculation has been added.	OK, approved
19	48	ISO 14044:2008	Source is not listed, please add.	Added.	OK, approved
20	48	ISO 14044:2008	Value cannot be found in the listed source, and source is not listed in the list of sources. I might be looking in the wrong place, but I cannot directly find the correct value. Please update or point me in the right direction.	See above answers.	OK, approved
21	48	ISO 14044:2008	What is this assumption based on? Please explain and expand.	There is no data available and it is essentially a guess from the authors. Furthermore, it can vary significantly from consumer to consumer. The assumption does not affect the LCA results, since 70 wash cycles is included in the LCA - see description in text above the table. This table is added to show what 70 wash cycles will likely look like in terms of life time in years.	OK, approved
22	49	ISO 14044:2008	See comment above about sources.	See answers above.	OK, approved
23	50	ISO 14044:2008	Geography rated low, justify.	GLO reassessed to "poor" instead of "very poor"	OK, approved
24	50	ISO 14044:2008	Possible wrong table reference, please check.	It is the correct table reference. It references the table showing the amount of packaging per product, which is the same amount disposed of in this life cycle phase.	OK, approved
25	52	ISO 14044:2008	Can you please point out the pages these values are taken from in the source? **Round 2:** To product against link rot the full name of the document shall be added so the reader can search for it. Please add "baggrundsnotat 7".	https://ens.dk/media/6584/download This is the source and the values are calculated based on the Sankey Diagram on page 4. Calculations added to text. **Round 2:** Good point, we had overlooked that. "Baggrundsnotat 7 added" to the reference.	OK, approved
26	53	ISO 14044:2008	Please double check table numbers. They don't seem to mathc with the text.	This one has been updated and the rest of the references have been	OK, approved

No.	PAGE NUMBER	REFERENCE TO CHECKLIST OR PROGRAMME INSTRUCTIONS	REVIEWER COMMENT AND RECOMMENDATION	LCA PRACTITIONER ANSWER	FINAL REVIEWER STATEMENT
				checked (a few more table references were corrected).	
27	57	ISO 14044:2008	Error in reference. Please add.	Added.	OK, approved
28	61	ISO 14044:2008	Why are there a slight increase for the last 6 products, for gas use? Please explain further.	It is not an increased gas use, the gas just has a higher percentage contribution, which is due to lower amounts of packaging for these products (per kg of products) compared to the other products.	OK, approved
29	65	ISO 14044:2008	Reference error, please correct.	Corrected.	OK, approved
30	68	ISO 14044:2008	There seem to be an error here with the percentages. The increase is much lowert than 10%. Please correct or explain.	It is not an error, we believe. The washing frequency has been increased by 10% in the LCA and this yields increases in the range 4,1-5,0% in the climate change indicator. So we are talking about about a 10% change in the input yielding a 4-5% change in the output.	Misunderstanding from my side. OK, approved
31	71	ISO 14044:2008	Waste treatment should be tested in sensitivity due to consumer choices being shown to be sensitive.	A scenario has been added.	OK, approved
32	73	ISO 14044:2008	See comment above for sensitivity.	See answer above.	OK, approved
33	Figure 10+11+12 (Page 78)	ISO 14044:2008	**Round 2:** Remember to update the baseline scenario with the weight change.	**Round 2:** The sensitivity scenario figures have been corrected.	OK, approved