On behalf of Changshu Polyester Co., Ltd.

Report on Life Cycle Assessment Study of Recycled Polyester Filament Products

Client: Changshu Polyester Co., Ltd.

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On behalf of Sphera Solutions, Inc., and its subsidiaries

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List of Acronyms

ADP	Abiotic Depletion Potential
AP	Acidification Potential
CML	Centre of Environmental Science at Leiden
ELCD	European Life Cycle Database
EoL	End-of-Life
EP	Eutrophication Potential
ETP	Effluent Treatment Plant
GHG	Greenhouse Gas
GWP	Global Warming Potential
ILCD	International Cycle Data System
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCA FE	Life Cycle Assessment for Experts
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
NMVOC	Non-Methane Volatile Organic Compound
ODP	Ozone Depletion Potential
POCP	Photochemical Ozone Creation Potential
R-32	Difluoromethane
SFP	Smog Formation Potential
VOC	Volatile Organic Compound
WTP	Water Treatment Plant

Glossary

ISO 14040:2006, Environmental management - Life cycle assessment - Principles and framework, International Organization for Standardization (ISO), Geneva.

Agricultural land occupation

An indicator in the ReCiPe methodology that estimates the potential amount of agricultural area occupied (in m2) and at the time of occupation in years.

Allocation

Partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems

Functional Unit

Quantified performance of a product system for use as a reference unit

Closed loop & open loop

A closed-loop allocation procedure applies to closed-loop product systems. It also applies to open-loop product systems where no changes occur in the inherent properties of the recycled material. In such cases, the need for allocation is avoided since the use of secondary material displaces the use of virgin (primary) materials.

An open-loop allocation procedure applies to open-loop product systems where the material is recycled into other product systems, and the material undergoes a change to its inherent properties.

Cradle to grave

Addresses the environmental aspects and potential environmental impacts (e.g., use of resources and environmental consequences of releases) throughout a product's life cycle from raw material acquisition until the end of life.

Cradle to gate

Addresses the environmental aspects and potential environmental impacts (e.g., use of resources and environmental consequences of releases) throughout a product's life cycle from raw material acquisition until the end of the production process ("gate of the factory"). It may also include transportation until use phase.

IPCC GWP 100a

Global warming potential over a 100-year duration, as defined by the United Nation's Intergovernmental Panel on Climate Change. The indicator reflects the potential relative climate change effect per kg of a greenhouse gas and their potency on climate.

Life cycle

A unit operations view of consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal. This includes all materials and energy input as well as waste generated to air, land and water.

Life Cycle Assessment - LCA

Compilation and evaluation of the inputs, outputs, and the potential environmental impacts of a product system throughout its life cycle

Life Cycle Inventory - LCI

Phase of Life Cycle Assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle.

Life Cycle Impact assessment - LCIA

Phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product.

Life Cycle Interpretation

Phase of life cycle assessment in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations.

Sub System

A sub- system is a system that is part of some larger system, or it can also mean the coherent and some-what independent component of a larger system. In this study, the production of electrolyte, PVC cover, labels etc. are the sub-systems for the battery manufacturing process.

Statistical Unit

A unit in a statistical analysis refers to one member of a set of entities being studied. It is the material source for the mathematical abstraction of a "random variable". Common examples of a unit would be a single person, animal, plant, or manufactured item that belongs to a larger collection of such entities being studied.

Project Context

Changshu Polyester Co., Ltd. was founded in 1983. The company is located in Xu shi, Dongbang Town, Changshu City. It covers an area of more than 120 acres and construction area of 100,000 square meters. The company is a professional enterprise which is dedicated to the differentiated and functional fibers of high tenacity nylon 6, nylon 66 and polyester. The company is committed to manufacturing of recycled yarn, nylon 6 filament yarn, nylon 66 filament yarn. Over the past 40 years, the company has pursued the tenet of reaching far, winning with excellence, and has occupied a place in the domestic nylon and polyester differentiated chemical fiber industry. Adhering to the concept of green environmental protection, Changshu Polyester Co., Ltd. strengthens and researches the recycled fiber series products. The products have passed the global recycling standard system GRS certification and the European Union oekotex-100 certification, also are sold in China and other countries.

Changshu Polyester Co., Ltd. has entrusted Sphera Solutions (Thinkstep Sustainability Solutions Pvt Limited) to “assess and quantify the life cycle environmental impacts of recycled polyester filament products as per ISO 14040:2006 and ISO 14044:2006 standards”. The company seeks additional reliable scientific information to communicate the environmental performance of its products to government, customers or retailers, non-governmental organizations and more generally those requiring such data for environmental labelling purposes.

The objective of this study is to carry out life cycle assessment of recycled polyester filament products including various impact categories with its key focus on primary energy consumption, GHG emissions, acidification potential, blue water consumption, primary energy demand and photochemical ozone creation potential with a cradle to gate approach. The life cycle assessment has been conducted following the ISO 14040 and ISO 14044 by modelling different processes available in the manufacturing facility of Changshu Polyester Co., Ltd. using life cycle assessment software LCA For Experts (LCA FE) developed by Sphera.

1. Goal of the Study

The goal of this project is to carry out Life Cycle Assessment (LCA) study and quantify environmental impacts for Recycled Polyester Filament Products (manufactured by Changshu Polyester Co., Ltd. at Dongbang town, China) as per the standards ISO 14040:2006 (and its amendment 14040:2006/Amd 1:2020), and ISO 14044:2006 (and its amendments 14044:2006/Amd 1:2018 and 14044:2006/Amd 2:2020) requirements using cradle to gate approach.

This study provides Life Cycle Inventory (LCI) and Life Cycle Environmental Impact (LCIA) profile over cradle to gate assessment of “Recycled Polyester Filament Products”. The LCI data consist of the total inputs and outputs of the product system (e.g., carbon dioxide emissions); while the Life Cycle Impact Assessment (LCIA) uses the LCI data to assess impacts such as Global Warming, etc. Consistent methodology and modelling have been used for this study and are specific to “Recycled Polyester Filament Products” manufactured at Changshu Polyester Co., Ltd., Dongbang town, China.

This technical report will not be publicly available but can be made accessible to interested parties upon request to the study commissioner (Changshu Polyester Co., Ltd.). The study commissioner may use the study report to prepare and provide information materials, e.g.,a technical summary of the report, an article, a flyer addressing the major outcomes of the study, etc.

This is not a comparative study, and the results of this study are not intended to be used in comparative assertions intended to be disclosed to the public. The intended audience for this study includes the Changshu Polyester Co., Ltd.'s internal stakeholders such as design, research, marketing, communications, operations etc, while external stakeholders include customers, suppliers, government, environmental practitioners, and non-governmental organizations.

2. Scope of the Study

The following section describes the general scope of the project to achieve the stated goals. This includes the identification of specific products to be assessed, the supporting product systems (e.g., materials, technologies, etc.), and the boundary of systems under study, allocation procedures, and cut-off criteria.

2.1. Product Description

The products under study are three recycled polyester filament variants, each manufactured using polyester chips derived from distinct recycling methods: mechanical recycling, chemical recycling, and mechanical recycling enhanced with CICLO additives.

Table 2-1 Products under study

Products	Product Description
Recycled Polyester Filament	IDY of high tenacity from mechanically recycled from PET Chips
	IDY of high tenacity from chemically recycled polyester from textiles waste
	IDY of high tenacity from mechanically recycled PET chips with CiCLO additives

The production process of the filament products begins with the procurement of recycled polyester chips from various suppliers. The procured recycled polyester chips are fed into a hopper, where it is blended with a masterbatch and it is melted to form a homogeneous molten polymer. This molten polymer is then extruded under high pressure through spinnerets to form continuous filaments. During this stage, a spinning finish is applied to the filaments, functioning as both a lubricant and an antistatic agent. The process is followed by spinning and winding operations, resulting in the formation of industrial-grade polyester filament. Packaging process is also included in the study.

Functional Unit

The functional unit is a reference for the product whose lifecycle impact is being assessed.

The functional unit allows quantification of the environmental impacts of Recycled Polyester Filament production over the Cradle-to-Gate life cycle stage. These environmental impacts are calculated based on the declared unit wherein each flow related to material consumption, energy consumption, emissions, effluent and waste is scaled to the reference flow.

The Recycled polyester filament products find applications across a wide range of industries, including textiles, automotive, home furnishings, and industrial sectors, owing to their durability, sustainability, and performance characteristics.

The functional unit is Production and Packaging of 1 kg each of three Recycled Polyester Filament product.

The reference flow is 1 kg each of three recycled polyester filament products.

2.2. System Boundaries

The system boundary of Filament products represents a cradle-to-gate boundary, which covers the production phase of product. The production phase includes the production of the raw materials, auxiliary material production, upstream transportation, and manufacturing process. The transport of materials such as rPET chips, masterbatch, spin finish or Antistatic agent, etc, has been considered in the study.

Figure 2-1 below is a schematic diagram indicating the cradle to gate system boundary and scope of the Life Cycle Assessment. Changshu, China was chosen as the reference area for all processes in the production phase.

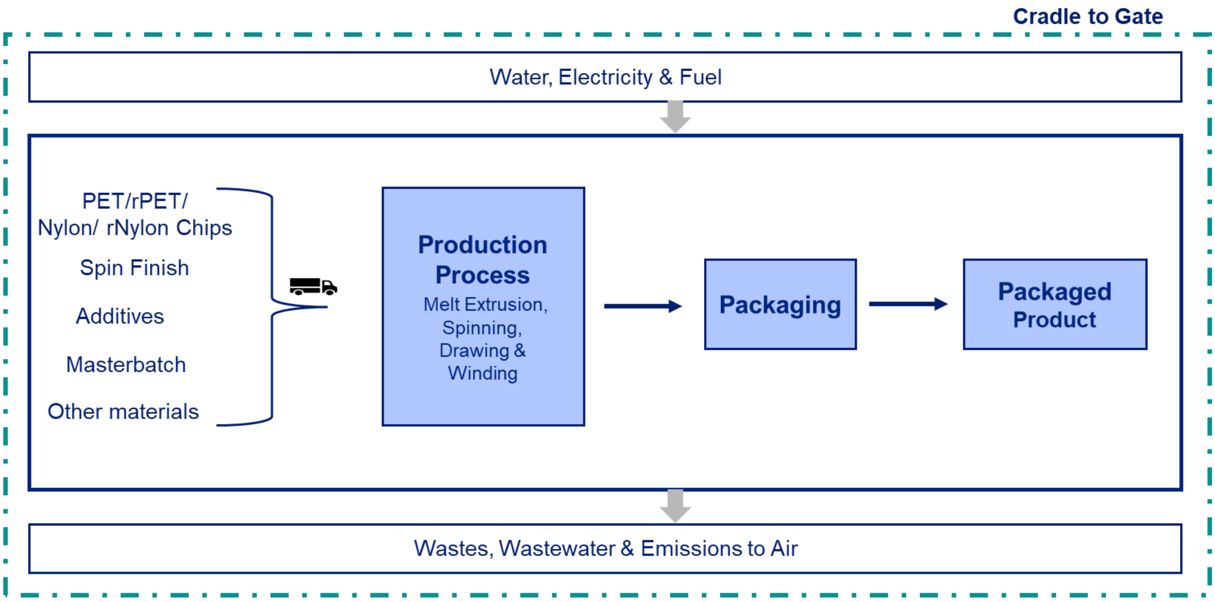

Figure 2-1 System boundary for recycled polyester filament product

The Table 2-2 below describes the Inclusion in the system boundary and exclusion as a cut-off are defined for our study.

Table 2-2 Inclusion and exclusion in system boundary

Included	Excluded
✓ Extraction of raw materials and fuel carriers ✓ Transport of raw materials and fuel carriers ✓ Filament production (melting, extrusion, spinning, winding) ✓ Packaging	× Human labour × Construction of capital equipment × Maintenance and operation of the unit × Services

2.2.1. Technology coverage

The exact technological configuration was used for the various processes' operation of its plant for efficient performance in production and minimizing environmental impacts. It was assumed that secondary data from databases that were used for this assessment, were temporally and technologically comparable to that of primary data and within the temporal coverage already addressed. The dataset is valid until substantial technological changes in the production chain occurs.

2.2.2. Geographic coverage

The geographical coverage of this study covers the production of recycled polyester filament product. Wherever possible, China specific boundaries have been adapted and in other cases dataset were chosen from Asian and other countries if no China specific datasets were available.

2.2.3. Time coverage

The data collection is related to one year of operation. All data were collected for the year June 2023-24 and is believed to be representative of recycled polyester filament production at Changshu Unit. The LCI data for production is collected for one-year averages to compensate seasonal influence of data. Background data have reference year between 2020 and 2023 – for electricity and thermal energy processes the reference year is 2020.

2.3. Allocation procedure

Multi-output allocation applied follows the requirements of ISO 14044, section 4.3.4.2. Allocation is applied to arrive at impacts of Recycled Polyester Filament Production. There are few by-products produced in the process that are sold in the market and because of the unavailability of the information for their potential downstream use, hence price-based allocation has been found appropriate. Mass-based allocation is not suitable and would allocate the environmental burdens not specific to their final use while properties and specifications of Recycled Polyester Filament products are not alike. The division of unit process to arrive at the processes with a single output was not possible as process data was available as a black box model, thus outputs cannot be dissociated from inputs. The revenue data used to perform allocation has been provided by Changshu team. The allocation applied is as given. Table 2-3

Table 2-3 Allocation Factor for the Product(s) /Waste(s)

Particulars (Outputs)	Allocation Factor (based on price)
Filament Production (from Mechanically Recycled PET from PET Bottles)	
Recycled Polyester Filament	99.19%
Yarn waste	0.81%
Filament Production (from Chemically Recycled PET from textiles waste)	
Recycled Polyester Filament	99.01%
Yarn waste	0.99%

Filament Production (from Mechanically Recycled PET from PET Bottles With CiCLO Additives)	
Recycled Polyester Filament	99.10%
Yarn waste	0.90%

For details of allocation procedures applied to the background data, please refer to the LCA FE Software and database for Life Cycle Engineering, Life Cycle Assessment Software and Data | Sphera (GaBi).

2.4. Cut-off Criteria

In the foreground processes, all relevant flows are considered, with no significant cut-off of material and energy flows. As summarized in section 2.2, the system boundary was defined based on relevance to the goal of the study. For the processes within the system boundary, all available energy and material flow data have been included in the model. In cases where no matching life cycle inventories are available to represent a flow, proxy data (see section 3.3) have been applied based on conservative assumptions regarding environmental impacts. The cut-off criteria for the background data have been documented online Managed LCA Content | Sphera.

In this assessment, construction of capital equipment, maintenance and operation of support equipment, human labour and services were excluded. For upstream system, all relevant raw materials and energy carriers used in manufacturing have been covered in the LCA calculation. The cut-off criteria for the background system have been documented online Managed LCA Content | Sphera.

2.5. Selection of LCIA Methodology and Impact Categories

The impact assessment categories and other metrics considered to be of high relevance to the goals of the project are shown in this chapter. Various impact assessment methodologies are applicable for use in European and Asian context including e.g., CML, ReCiPe, and selected methods recommended by the ILCD. This assessment is predominantly based on the CML2001 - Jan. 2016 impact assessment methodology framework.

CML 2001 (January 2016) method developed by Institute of Environmental Sciences, Leiden University, Netherlands have been selected for evaluation of environmental impacts. These indicators are scientifically and technically valid.

Table 2-4 and Table 2-5 provides the detailed description of each impact category applied in this study along with its reference to Sustainable Development Goals.

Table 2-4 Description of various environmental impact categories

Impact Category	Description	Unit	Reference
Global Warming Potential (GWP100),	A measure of greenhouse gas emissions such as CO_2 and methane. These emissions are causing an increase in the absorption of	kg CO_2 equivalent	(IPCC, 2013)

100 years' timeframe	radiation emitted by the earth, increasing the natural greenhouse effect. This may in turn have adverse impacts on ecosystem health, human health, and material welfare.		
Abiotic Resource Depletion (ADP elements)	The consumption of non-renewable resources leads to a decrease in the future availability of the functions supplied by these resources. Depletion of mineral resources are reported separately. Depletion of mineral resources is assessed based on ultimate reserves.	kg Sb equivalent	(van Oers, de Koning, Guinée, & Huppes, 2002)
Abiotic Resource Depletion (ADP Fossil)	This impact category indicator is related to extraction of fossil fuels due to inputs in the system. The Abiotic Depletion Factor (ADF) is determined for each extraction of fossil fuels (MJ) based on concentration reserves and rate of de-accumulation. The geographic scope of this indicator is at global scale	MJ	(Guinée, et al., 2002)
Eutrophication Potential (EP)	Eutrophication covers all potential impacts of excessively high levels of macronutrients, the most important of which are nitrogen (N) and phosphorus (P). Nutrient enrichment may cause an undesirable shift in species composition and elevated biomass production in both aquatic and terrestrial ecosystems. In aquatic ecosystems increased biomass production may lead to depressed oxygen levels because of the additional consumption of oxygen in biomass decomposition.	kg PO_4^{3-} equivalent	(Guinée, et al., 2002)
Acidification Potential (AP)	A measure of emissions that cause acidifying effects in the environment. The acidification potential is a measure of a molecule's capacity to increase the hydrogen ion (H^+) concentration in the presence of water, thus decreasing the pH value. Potential effects include fish mortality, forest decline, and the deterioration of building materials.	kg SO_2 equivalent	(Guinée, et al., 2002)
Photochemical Ozone Creation Potential (POCP)	A measure of emissions of precursors that contribute to ground level smog formation (mainly ozone O_3), produced by the reaction of VOC and carbon monoxide in the presence of nitrogen oxides under the influence of UV light. Ground level ozone may be injurious to human health and ecosystems and may also damage crops.	kg Ethene equivalent	(Guinée, et al., 2002)

Ozone Depletion Potential (ODP)	A measure of air emissions that contribute to the depletion of the stratospheric ozone layer. Depletion of the ozone leads to higher levels of UVB ultraviolet rays reaching the earth's surface, with detrimental effects on humans and plants.	kg R-11 equivalent	(Guinée, et al., 2002)

Table 2-5 Other environmental categories

Indicator	Description	Unit	Reference
Primary Energy Demand (PED)	A measure of the total amount of primary energy extracted from the earth. PED is expressed in energy demand from non-renewable resources (e.g., petroleum, natural gas, etc.) and energy demand from renewable resources (e.g., hydropower, wind energy, solar, etc.). Efficiencies in energy conversion (e.g., power, heat, steam, etc.) are taken into account.	MJ (lower heating value)	(Guinée, et al., 2002)
Human toxicity (recommended only)	Human effect factors relate the quantity taken into the potential risk of cancerous effects expressing cases per kg of chemical emitted.	CTUh	USEtox™
Ecotoxicity (recommended only)	Effect factors for freshwater ecosystems are based on species-specific data of conc. At which 50% of a population displays an effect, expressed as an estimate of the potentially affected fraction of species (PAF) integrated over time and volume per unit mass of a chemical emitted (PAF m3-day/ kg). The final unit is comparative toxic units (CTUe)	CTUe	USEtox™
Blue Water Consumption (BWC)	A measure of the net intake and release of fresh water across the life of the product system. This is not an indicator of environmental impact without the addition of information about regional water availability.	kg	(Sphera, 2020)

It shall be noted that the above impact categories represent impact potentials, i.e., they are approximations of environmental impacts that could occur if the emissions would (a) follow the underlying impact pathway and (b) meet certain conditions in the receiving environment while doing so. In addition, the inventory only captures that fraction of the total environmental load that corresponds to the functional unit (relative approach). LCIA results are therefore relative expressions only and do not predict actual impacts, the exceeding of thresholds, safety margins, or risks.

2.6. Interpretation to be Used

The results of the LCI and LCIA were interpreted according to the Goal and Scope. The interpretation addresses the following topics:

- Identification of significant findings, such as the main process step(s), material(s), and/or emission(s) contributing to the overall results.
- Evaluation of completeness, sensitivity, and consistency to justify the exclusion of data from the system boundaries as well as the use of proxy data.
- Conclusions, limitations and recommendations.

Note that in situations where no product outperforms all its alternatives in each of the impact categories, some form of cross-category evaluation is necessary to draw conclusions regarding the environmental superiority of one product over the other.

2.7. Data quality requirements

It is important that data quality is in accordance with the requirements of the study 's goal and scope. This is essential to the reliability of the study and achievement of the intended application. The quality of the LCI data for modelling the life cycle stages at Changshu unit has been assessed according to ISO 14044 (ISO, 2006 b). Data quality is judged by its precision (measured, calculated or estimated), completeness (e.g., are there unreported emissions?), consistency (degree of uniformity of the methodology applied on a study serving as a data source) and representativeness (geographical, time period, technology). To cover these requirements and to ensure reliable results, first-hand industry data in combination with consistent, upstream LCA information is used. The datasets have been used in LCA-models worldwide for several years in industrial and scientific applications for internal as well as critically reviewed studies. In the process of providing these datasets, they have been cross-checked with other databases and values from industry and science.

- **Precision and completeness**
  Precision: All the relevant foreground (gate-to-gate) data is primary data for office workstation life cycle. All upstream data is consistently LCA FE professional data with documented precision.
  Completeness: All relevant, specific processes for the different options are considered and modelled to represent each specific situation. All upstream processes are taken from the LCA FE databases. Every effort was made to ensure that the models accurately represented the production processes and associated environmental burdens. A rather conservative approach with respect to emissions to air and waste treatment was selected. The total percentage of flows excluded due to cutoff criteria was less than 1% for mass and 0.05% for energy.
- **Consistency and reproducibility**
  Consistency: A qualitative assessment of whether the study methodology is applied uniformly to the various components of the analysis was conducted. To ensure consistency only primary data of the same level of detail and upstream data from the LCA FE databases are used. While building up the model, cross-checks concerning the plausibility of mass and energy flows are continuously conducted. The provided primary data of the

technology representatives was checked and recalculated. Conservative assumptions were made, and efforts taken to get them as consistent as possible were applied so that the results remain valid.
Reproducibility: The reproducibility is given for internal use since the owner of the technology provided the data, and the models are stored and available in a database. Sub-systems are modelled by ´state of art´ technology using data from a publicly available and internationally accepted database. For the external audience it is possible that no full reproducibility in any degree of detail was available for confidentiality reasons. However, experienced experts were able to easily recalculate and reproduce suitable portions of the life cycle system as well as key indicators.

- **Uncertainties**
  These are typically caused by model assumptions, data gaps or lack of accuracy; efforts were made to minimize any uncertainties. Precision, accuracy and completeness of LCI data have been assessed.

2.8. Type and Format of the Report

In accordance with the ISO requirements (ISO, 2006) this document aims to report the results and conclusions of the LCA completely, accurately and without bias to the intended audience. The results, data, methods, assumptions and limitations are presented in a transparent manner and in sufficient detail to convey the complexities, limitations, and trade-offs inherent in the LCA to the reader. This allows the results to be interpreted and used in a manner consistent with the goals of the study.

2.9. Software and Database

The LCA model was created using the LCA FE 10.9 Software system for life cycle engineering, developed by Sphera. The LCA FE database i.e., MLC 2024.2 provides the life cycle inventory data for several of the raw and process materials obtained from the upstream system. Detailed database documentation for LCA FE datasets can be accessed at Product Sustainability (LCA FE) Data Search | Sphera.

2.10. Critical Review

No review is conducted for this study.

3. Life Cycle Inventory Analysis

This section presents the Data inventory of the product according used in the study.

3.1. Data collection procedure

Primary data were collected using customized data collection templates, which were sent out by email to the respective data providers. Upon receipt, questionnaire was cross-checked for completeness. If gaps, outliers, or other inconsistencies occurred, Sphera engaged with the data provider to resolve any open issues.

3.2. Product Description

3.2.1. Overview of Product System

For the considered product, a LCA FE model representing the Cradle to Gate life cycle was prepared and explained in following sub sections.

3.2.2. Raw Material Consumption

Raw material consumptions for Recycled Polyester Filament Products are summarised in the Annex A.

3.2.3. Manufacturing Phase

The LCA model for 1 kg of Recycled Polyester Filament Production with Packaging has been set up in LCA FE 10.9 LCA software tool. A Cradle to Gate model has been created to generate results by feeding the production data for period for the year June 2023-24.

LCA FE model Snapshot for the Cradle to Gate with the packaging model and created in LCA FE 10.9 software for the three products under study as given in Figure 3-1, Figure 3-4 and Figure 3-3. Similarly models were prepared for the filament manufacturing process as illustrated in Figure 3-4, Figure 3-5 and Figure 3-6.

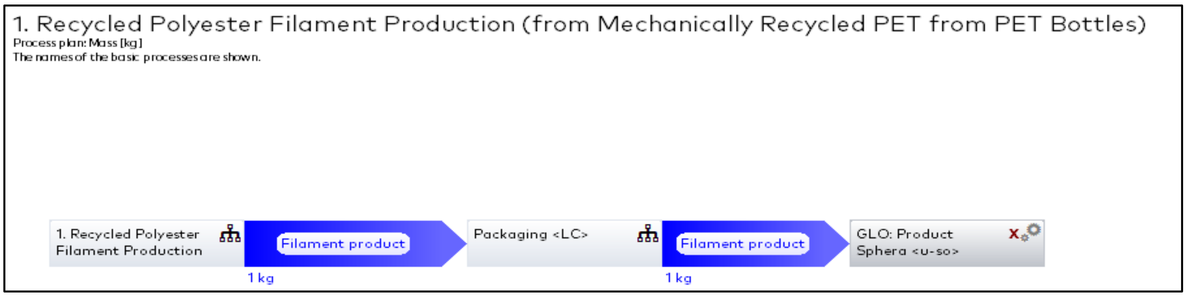

Figure 3-1 LCA FE model snapshot of Cradle to Gate Recycled Polyester Filament Production (from mechanically recycled PET from bottles) including packaging

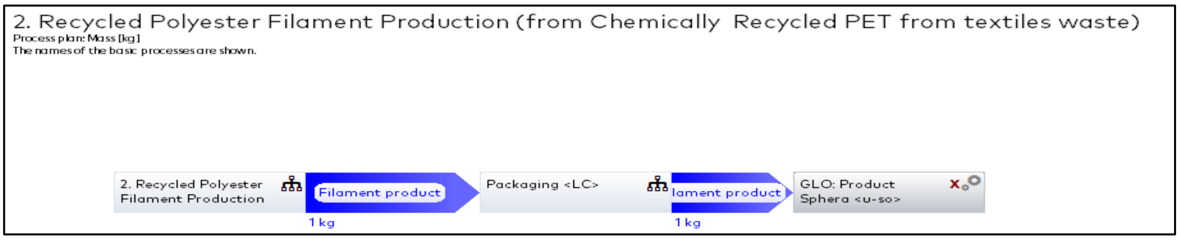

Figure 3-2 LCA FE model snapshot of Cradle to Gate Recycled Polyester Filament Production (from chemicallly recycled PET from textile waste) including packaging

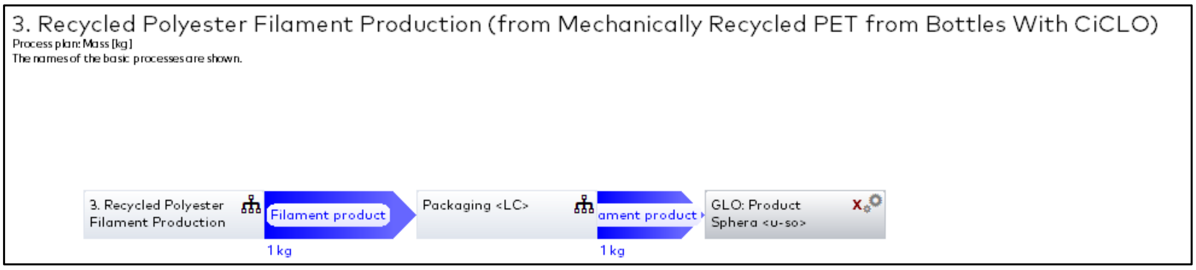

Figure 3-3 LCA FE model snapshot of Cradle to Gate Recycled Polyester Filament Production (from mechanically recycled PET from bottles with CiCLO) including packaging

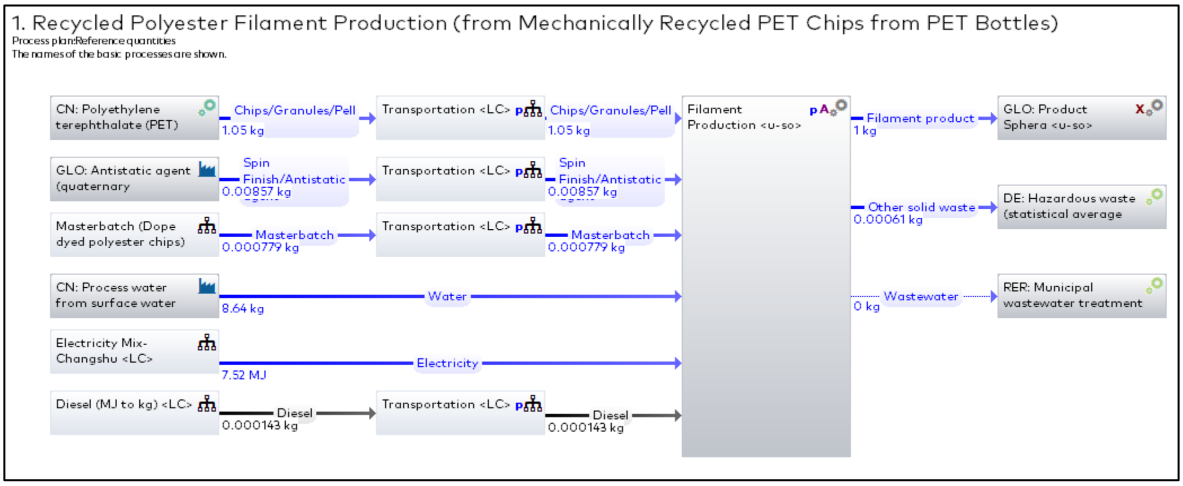

Figure 3-4 LCA FE model snapshot of Recycled Polyester Filament Production (from Mechanically Recycled PET from PET Bottles)

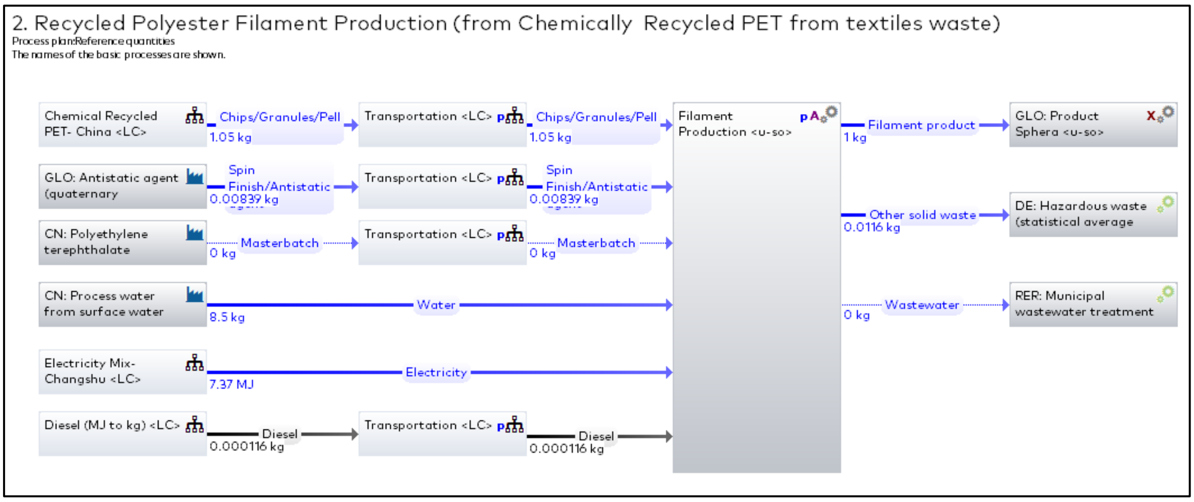

Figure 3-5 LCA FE model snapshot of Recycled Filament Production (from Chemically Recycled PET from textile waste)

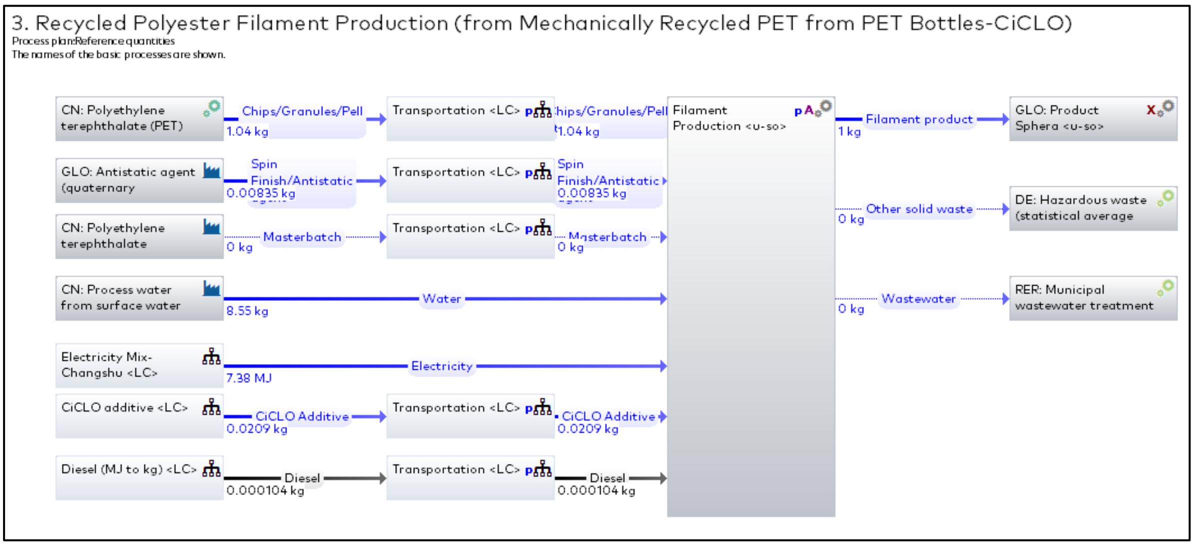

Figure 3-6 LCA FE model snapshot of Recycled Polyester Filament Production (from Mechanically Recycled PET from PET Bottles-CiCLO)

The Figure 3-7 below shows the generic transportation model used for the transportation of raw materials and packaging materials.

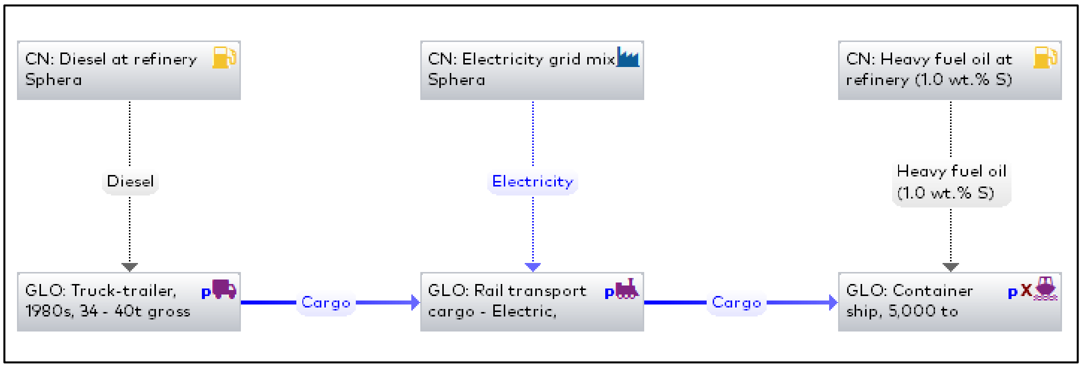

Figure 3-7 Transportation Model - LCA FE Snapshot

Transportation distances of raw Materials and the packaging Materials from their origin to the facility in China are given in the Annex A.

3.2.4. Use Phase

Not in the scope of the study.

3.2.5. End-of-Life

Not in the scope of the study.

3.3. Background Data

Documentation for all LCA FE datasets can be found online, (Sphera Solutions Inc., 2025). Every effort has been made to implement the most credible, representative, and up-to-date information available. The data of materials, fuels, water consumption and energy for all the models have been entered in LCA FE software.

3.3.1. Fuels and Energy

National/regional averages for fuel inputs and electricity grid mixes were obtained from the LCA FE 2024.2 database. Table 3-1 shows the most relevant LCI datasets used in modelling the product systems. Electricity consumption was modelled using national/regional grid mixes that account for imports from neighbouring countries/regions.

Table 3-1 Key Energy Datasets used in Inventory Analysis

Energy	Dataset	Data Provider	Reference Year
Electricity	CN: Electricity grid mix Sphera	Sphera Solutions GmbH	2020
	CN: Electricity from photovoltaic Sphera	Sphera Solutions GmbH	2020
Diesel	US: Thermal energy from diesel Sphera	Sphera Solutions GmbH	2020

3.3.2. Raw Materials and Processes

Data for upstream and downstream raw materials and unit processes were obtained from the LCA FE 2024.2 database. Table 3-2 shows the most relevant LCI datasets used in modelling the production of 1 kg of Recycled Polyester Filament products.

Table 3-2 Key Material and Process Datasets used in Inventory Analysis

Materials / Process	Dataset	Data Provider	Reference Year
Mechanically recycled Polyester chips	CN: Polyethylene terephthalate (PET) granulates secondary Sphera <p-agg>	Sphera Solutions GmbH	2023
Chemically recycled Polyester chips	CN: Chemical Recycled PET- China*	Literature, Sphera Solutions GmbH	2023
Spin Finish/Antistatic agent	GLO: Antistatic agent (quaternary ammonium compound) Sphera	Sphera Solutions GmbH	2023
CiCLO Additive	DE: Polylactic acid (PLA) (Polylactide, continuous process) Sphera	Sphera Solutions GmbH	2023
	CN: Polyethylene terephthalate (PET) granulate secondary Sphera <p-agg>	Sphera Solutions GmbH	2023
Water	CN: Process water from surface water Sphera	Sphera Solutions GmbH	2023
Other solid waste treatment	DE: Hazardous waste (statistical average composition) treatment mix (incineration and landfill) Sphera	Sphera Solutions GmbH	2023
Wastewater treatment	RER: Municipal wastewater treatment (mix) Sphera	Sphera Solutions GmbH	2023
Wooden Pallets	RER: Wooden pallets (EURO, 120x80x14 cm, 22% moisture, 18% H2O content) Sphera	Sphera Solutions GmbH	2023
Paper Tubes	IN: Corrugated board incl. paper production, average composition Sphera <p-agg>	Sphera Solutions GmbH	2023
Carton Divider Plates	IN: Corrugated board incl. paper production, average composition Sphera <p-agg>	Sphera Solutions GmbH	2023
Stretch Foil	CN: Polyethylene Film (without additives) Sphera	Sphera Solutions GmbH	2023

** The model is based on literature study of Nordon "Gaining benefits from discarded textiles: LCA of different treatment pathways" and raw material and energy datasets used from Sphera's MLC 2024.2 (Source:Link).*

3.3.3. Transportation

Average transportation distances and modes of transport are included for the transport of the raw materials, operating materials, and auxiliary materials to production and assembly facilities.

The LCA FE 2024.2 database was used to model transportation. Fuels were modelled using the geographically appropriate datasets. Table 3-3 shows the most relevant LCI datasets used in modelling the product systems.

Table 3-3 Transport and Fuel Datasets used in Inventory Analysis

Mode/ Fuels	Dataset	Data Provider	Reference Year
Ship	GLO: Container ship, 5,000 to 200,000 dwt payload capacity, deep sea Sphera <u-so>	Sphera Solutions GmbH	2023
Rail	GLO: Rail transport cargo - Electric, average train, gross tonne weight 1,000t / 726t payload capacity Sphera <u-so>	Sphera Solutions GmbH	2023
Truck	GLO: Truck-trailer, 1980s, 34 - 40t gross weight / 27t payload capacity Sphera <u-so>	Sphera Solutions GmbH	2023
Heavy fuel oil	CN: Heavy fuel oil at refinery (1.0 wt.% S) Sphera	Sphera Solutions GmbH	2020
Electricity	CN: Electricity grid mix Sphera	Sphera Solutions GmbH	2020
Diesel	CN: Diesel at refinery Sphera	Sphera Solutions GmbH	2020

4. LCIA Results

This chapter contains the results for the impact categories and additional metrics defined in Selection of LCIA Methodology and Impact Categories. It shall be reiterated at this point that the reported impact categories represent impact potentials, i.e., they are approximations of environmental impacts that could occur if the emissions would (a) follow the underlying impact pathway and (b) meet certain conditions in the receiving environment while doing so. In addition, the inventory only captures that fraction of the total environmental load that corresponds to the chosen functional unit (relative approach).

Given the limitations of the characterization model for toxicity-related impact categories are amongst the most uncertain in LCA studies and results must be taken with even greater caution. LCIA results are therefore relative expressions only and do not predict actual impacts, the exceeding of thresholds, safety margins, or risks.

4.1. Overall Results – Recycled Polyester Filament Product (from Mechanically Recycled PET)

The Table 4-1 below shows the Cradle to Gate with Packaging LCIA results for 1 kg of Recycled Polyester Filament (from Mechanically Recycled PET from PET Bottles) Product.

Table 4-1 LCIA Results for Recycled Polyester Filament Product (from Mechanically Recycled PET from PET Bottles)

Environmental Quantities	Unit	Total
ADP elements	kg Sb eq.	4.31E-07
ADP fossil	MJ	23.41
Acidification Potential	kg SO_2 eq.	0.01
Eutrophication Potential	kg Phosphate eq.	7.77E-04
GWP (100 years), Incl biogenic carbon	kg CO_2 eq.	2.14
GWP (100 years), excl biogenic carbon	kg CO_2 eq.	2.21
Ozone Layer Depletion Potential	kg R11 eq.	3.41E-11
Photochem. Ozone Creation Potential	kg Ethene eq.	6.17E-04
Primary energy demand (net cal. value)	MJ	36.60
Ecotoxicity (recommended only)	CTUe	0.01
Human toxicity, cancer (recommended only)	CTUh	3.29E-10
Human toxicity, non-canc. (recommended only)	CTUh	2.55E-11
Blue Water Consumption	kg	23.21

Global Warming (GWP 100 years), excluding biogenic carbon for 1 kg of Recycled Polyester Filament Product (from Mechanically Recycled PET from PET Bottles) is 2.21 kg CO_2 eq. and Global Warming (GWP 100 years), including biogenic carbon is 2.14 kg CO_2 eq. The blue water consumption is 23.21 kg and primary energy demand is 36.60 MJ. The detailed results are explained in sections below.

4.1.1. Process-wise results for Recycled Polyester Filament Product (from Mechanically Recycled PET)

The Table 4-2 below shows the process wise life cycle environmental impacts for production and packaging of 1 kg of Recycled Polyester Filament (from Mechanically Recycled PET from PET Bottles) Product. Filament production process includes impact for recycled chips/granulates, electricity, masterbatch, spin finishing agent, water, and packaging, transport (raw and packaging material).

Table 4-2 Process-wise results for Recycled Polyester Filament Product (from Mechanically Recycled PET) Production

Environmental Quantities	Unit	Total	Filament production	Packaging
ADP elements	kg Sb eq.	4.31E-07	3.66E-07	6.49E-08
ADP fossil	MJ	23.41	21.52	1.89
Acidification Potential	kg SO_2 eq.	0.01	0.01	8.94E-04
Eutrophication Potential	kg Phosphate eq.	7.77E-04	6.71E-04	1.06E-04
GWP (100 years), Incl biogenic carbon	kg CO_2 eq.	2.14	2.10	0.04
GWP (100 years), excl biogenic carbon	kg CO_2 eq.	2.21	2.07	0.14
Ozone Layer Depletion Potential	kg R11 eq.	3.41E-11	3.38E-11	3.93E-13
Photochem. Ozone Creation Potential	kg Ethene eq.	6.17E-04	5.55E-04	6.20E-05
Primary energy demand (net cal. value)	MJ	36.60	32.21	4.39
Ecotoxicity (recommended only)	CTUe	0.01	1.14E-03	0.01
Human toxicity, cancer (recommended only)	CTUh	3.29E-10	3.20E-10	9.05E-12
Human toxicity, non-canc. (recommended only)	CTUh	2.55E-11	2.38E-11	1.72E-12
Blue Water Consumption	kg	23.21	22.58	0.62

Global Warming (100 years), excl. biogenic carbon for 1 kg of filament product is 2.21 kg CO2 eq. with major contribution from the Filament production process (~93.67%) followed by the packaging (~6.33%).

4.1.2. Detailed Results from Filament Production Process for Recycled Polyester Filament Product (from Mechanically Recycled PET)

The Table 4-3 shows the detailed results from filament production process for Recycled Polyester Filament Product (from Mechanically Recycled PET) product. Filament production process includes impact for recycled chips/granulates, electricity, masterbatch, spin finishing agent, water, and packaging, transport (raw and packaging material).

Table 4-3 Detailed Results from Filament Production Process for Recycled Polyester Filament Product (from Mechanically Recycled PET)

Environmental Quantities	Unit	Total	rPET Chips	Electricity	Spin finish	Water	Transport	Others
ADP elements	kg Sb eq.	3.66E-07	2.67E-08	1.65E-07	6.56E-08	1.07E-07	2.13E-10	1.06E-09
ADP fossil	MJ	21.52	5.90	14.92	0.27	0.18	0.18	0.07
Acidification Potential	kg SO_2 eq.	5.82E-03	1.15E-03	4.38E-03	1.02E-04	4.21E-05	1.26E-04	1.64E-05
Eutrophication Potential	kg Phos-phate eq.	6.71E-04	1.72E-04	4.33E-04	2.42E-05	7.88E-06	3.25E-05	2.09E-06
GWP (100 years), Incl biogenic carbon	kg CO_2 eq.	2.10	0.58	1.49	1.53E-03	0.02	0.01	4.26E-03
GWP (100 years), excl biogenic carbon	kg CO_2 eq.	2.07	0.52	1.49	0.02	0.02	0.01	4.26E-03
Ozone Layer Depletion Potential	kg R11 eq.	3.38E-11	1.47E-12	3.22E-11	1.85E-17	7.04E-14	4.84E-16	1.01E-14
Photochem. Ozone Creation Potential	kg Ethene eq.	5.55E-04	8.62E-05	5.17E-04	5.48E-06	4.97E-06	-6.00E-05	1.66E-06
Primary energy demand (net cal. value)	MJ	32.21	6.88	24.51	0.34	0.22	0.18	0.08
Ecotoxicity (recommended only)	CTUe	1.14E-03	3.50E-04	2.95E-04	3.94E-04	1.20E-05	6.87E-05	1.54E-05
Human toxicity, cancer (recommended only)	CTUh	3.20E-10	7.04E-11	2.46E-10	6.50E-13	2.26E-12	9.05E-14	4.35E-13
Human toxicity, non-canc. (recom-mended only)	CTUh	2.38E-11	3.79E-12	1.98E-11	3.17E-14	1.63E-13	2.37E-14	4.83E-14
Blue Water Consumption	kg	22.58	2.22	11.51	0.10	8.73	8.66E-04	0.03

Global Warming (GWP 100 years), excl. biogenic carbon impact for 1 kg of product from filament production process is 2.07 kg CO2 eq. with major contribution from consumption of Electricity (~72.20%) and Chips/Granulates (~25.24%).

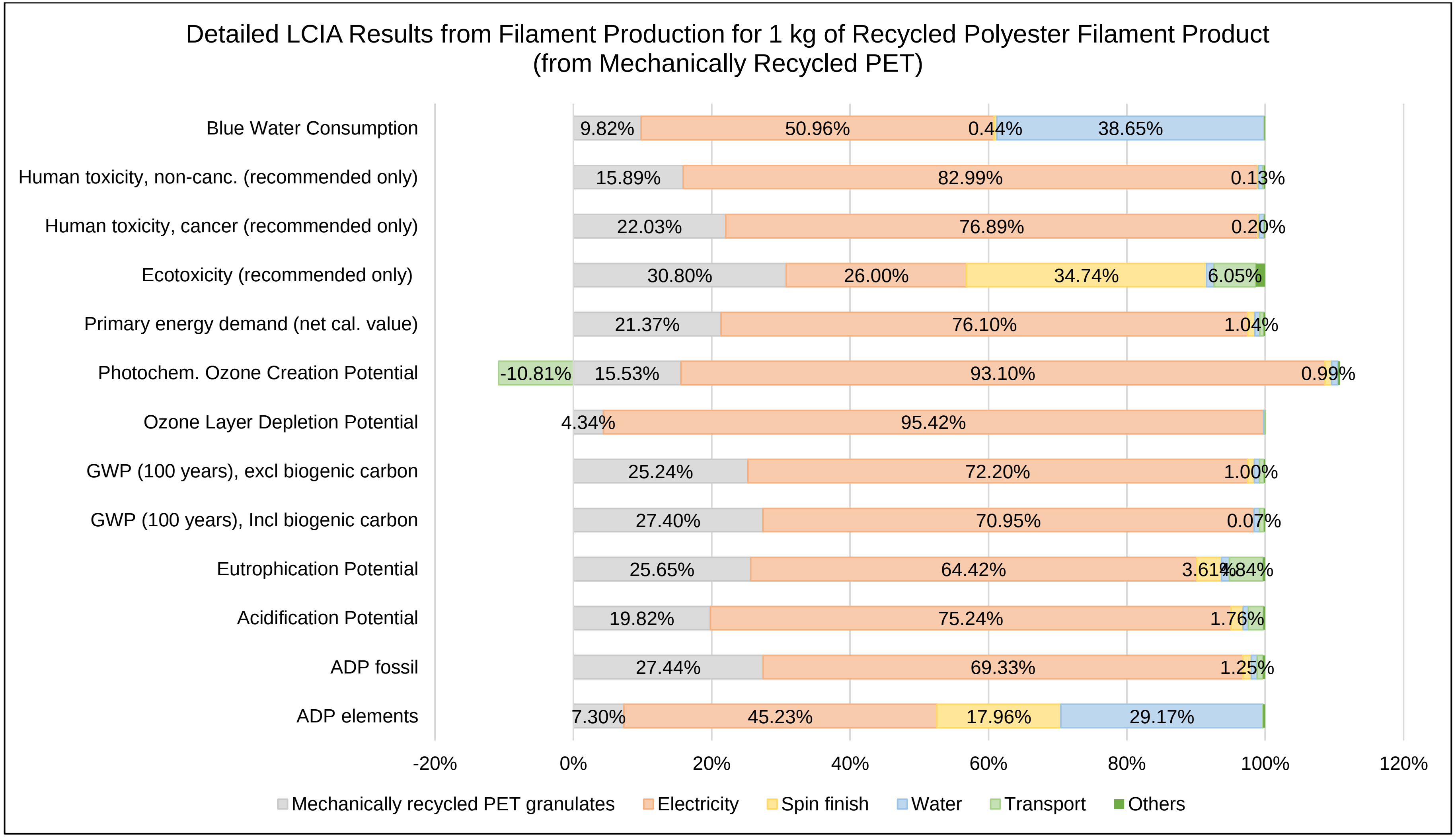

Figure 4-1 Detailed LCIA Results from Filament Production for Recycled Polyester Filament Product

Hotspots Identification:

The hotspots in the Cradle to Gate life cycle environmental impacts of 1 kg of Recycled Polyester Filament (from Mechanically Recycled PET from PET Bottles) Product from filament manufacturing process, are summarised below:

- Abiotic Depletion (elements) is 3.66E-07 kg Sb eq. with major contribution from Electricity (~45.23%) followed by Water (~29.17%), Spin finish (~17.96%) and Mechanically recycled PET granulates (~7.3%)
- Abiotic Depletion (fossil) is 21.52 MJ with major contribution from Electricity (~69.33%) followed by Mechanically recycled PET granulates (~27.44%), Spin finish (~1.25%) and Transport (~0.83%)
- Acidification Potential is 5.82E-03 kg SO2 eq. with major contribution from Electricity (~75.24%) followed by Mechanically recycled PET granulates (~19.82%), Transport (~2.17%) and Spin finish (~1.76%)
- Eutrophication Potential is 6.71E-04 kg Phosphate eq. with major contribution from Electricity (~64.42%) followed by Mechanically recycled PET granulates (~25.65%), Transport (~4.84%) and Spin finish (~3.61%)
- Global Warming Potential (100 years) is 2.10 kg CO2 eq. with major contribution from Electricity (~70.95%) followed by Mechanically recycled PET granulates (~27.4%), Water (~0.75%) and Transport (~0.63%)
- Global Warming Potential (100 years) excluding biogenic carbon is 2.07 kg CO2 eq. with major contribution from Electricity (~72.2%) followed by Mechanically recycled PET granulates (~25.24%), Spin finish (~1%) and Water (~0.75%)
- Ozone Layer Depletion (steady state) is 3.38E-11 kg R11 eq. with major contribution from Electricity (~95.42%) followed by Mechanically recycled PET granulates (~4.34%), Water (~0.21%) and Others (~0.03%)
- Photochem. Ozone Creation Potential (POCP) is 5.55E-04 kg Ethene eq. with major contribution from Electricity (~93.1%) followed by Mechanically recycled PET granulates (~15.53%), Spin finish (~0.99%) and Water (~0.9%)
- Primary Energy Demand is 32.21 MJ with major contribution from Electricity (~76.1%) followed by Mechanically recycled PET granulates (~21.37%), Spin finish (~1.04%) and Water (~0.69%)
- Ecotoxicity (recommended only) is 1.14E-03 CTUe with major contribution from Spin finish (~34.74%) followed by Mechanically recycled PET granulates (~30.8%), Electricity (~26%) and Transport (~6.05%)
- Human toxicity, cancer (recommended only) is 3.20E-10 CTUh with major contribution from Electricity (~76.89%) followed by Mechanically recycled PET granulates (~22.03%), Water (~0.71%) and Spin finish (~0.2%)
- Human toxicity, non-canc. (recommended only) is 2.38E-11 CTUh with major contribution from Electricity (~82.99%) followed by Mechanically recycled PET granulates (~15.89%), Water (~0.68%) and Others (~0.2%)
- Blue Water Consumption is 22.58 kg with major contribution from Electricity (~50.96%) followed by Water (~38.65%), Mechanically recycled PET granulates (~9.82%) and Spin finish (~0.44%)

4.2. Overall Results–Recycled Polyester Filament Product (from Chemically Recycled PET from Textile waste)

The Table 4-4 below shows the Cradle to Gate with Packaging LCIA results for 1 kg of Recycled Polyester Filament (from Chemically Recycled PET from Textile waste) Product.

Table 4-4 LCIA Results for Recycled Polyester Filament Product (from Chemically Recycled PET from Textile waste)

Environmental Quantities	Unit	Total
ADP elements	kg Sb eq.	2.73E-05
ADP fossil	MJ	47.70
Acidification Potential	kg SO_2 eq.	0.01
Eutrophication Potential	kg Phosphate eq.	1.66E-03
GWP (100 years), Incl biogenic carbon	kg CO_2 eq.	4.08
GWP (100 years), excl biogenic carbon	kg CO_2 eq.	4.20
Ozone Layer Depletion Potential	kg R11 eq.	3.21E-11
Photochem. Ozone Creation Potential	kg Ethene eq.	1.09E-03
Primary energy demand (net cal. value)	MJ	59.72
Ecotoxicity (recommended only)	CTUe	0.02
Human toxicity, cancer (recommended only)	CTUh	3.95E-10
Human toxicity, non-canc. (recommended only)	CTUh	2.48E-11
Blue Water Consumption	kg	23.07

Global Warming (GWP 100 years), excluding biogenic carbon for 1 kg of Recycled Polyester Filament Product (from Chemically Recycled PET from Textile waste) is 4.20 kg CO_2 eq. and Global Warming (GWP 100 years), including biogenic carbon is 4.08 kg CO_2 eq. The blue water consumption is 23.07 kg and primary energy demand is 59.72 MJ. The detailed results are explained in sections below.

4.2.1. Process-wise results for Recycled Polyester Filament Product (from Chemically Recycled PET from Textile waste)

The Table 4-5 below shows the process wise life cycle environmental impacts for production and packaging of 1 kg of Recycled Polyester Filament (from Chemically Recycled Textile waste) Product. Filament production process includes impact for recycled chips/granulates, electricity, masterbatch, spin finishing agent, water, and packaging, transport (raw and packaging material).

Table 4-5 Process-wise results for Recycled Polyester Filament Product (from Chemically Recycled Textile waste) Production

Environmental Quantities	Unit	Total	Filament production	Packaging
ADP elements	kg Sb eq.	2.73E-05	2.72E-05	6.49E-08
ADP fossil	MJ	47.70	45.81	1.89
Acidification Potential	kg SO_2 eq.	0.01	0.01	8.94E-04
Eutrophication Potential	kg Phosphate eq.	1.66E-03	1.55E-03	1.06E-04
GWP (100 years), Incl biogenic carbon	kg CO_2 eq.	4.08	4.05	0.04
GWP (100 years), excl biogenic carbon	kg CO_2 eq.	4.20	4.07	0.14
Ozone Layer Depletion Potential	kg R11 eq.	3.21E-11	3.17E-11	3.93E-13
Photochem. Ozone Creation Potential	kg Ethene eq.	1.09E-03	1.02E-03	6.20E-05
Primary energy demand (net cal. value)	MJ	59.72	55.33	4.39
Ecotoxicity (recommended only)	CTUe	0.02	0.01	0.01
Human toxicity, cancer (recommended only)	CTUh	3.95E-10	3.86E-10	9.05E-12
Human toxicity, non-canc. (recommended only)	CTUh	2.48E-11	2.31E-11	1.72E-12
Blue Water Consumption	kg	23.07	22.45	0.62

Global Warming (100 years), excl. biogenic carbon for 1 kg of filament product is 4.20 kg CO2 eq. with major contribution from the Filament production process (96.68%) followed by the packaging (3.32%).

4.2.2. Detailed Results from Filament Production Process for Recycled Polyester Filament Product (from Chemically Recycled PET from Textile waste)

The Table 4-6 shows the detailed results from filament production process for Recycled Polyester Filament Product (from Chemically Recycled Textile waste) product. Filament production process includes impact for recycled chips/granulates, electricity, masterbatch, spin finishing agent, water, and packaging, transport (raw and packaging material).

Table 4-6 Detailed Results from Filament Production Process for Recycled Polyester Filament Product (from Chemically Recycled PET from Textile waste)

Environmental Quantities	Unit	Total	rPET chips	Electricity	Spin finish	Water	Transport	Others
ADP elements	kg Sb eq.	2.72E-05	2.69E-05	1.62E-07	6.43E-08	1.05E-07	3.14E-10	1.16E-08
ADP fossil	MJ	45.81	30.46	14.63	0.26	0.17	0.26	0.02
Acidification Potential	kg SO2 eq.	0.01	6.43E-03	4.29E-03	1.00E-04	4.14E-05	1.86E-04	2.62E-05
Eutrophication Potential	kg Phos-phate eq.	1.55E-03	1.05E-03	4.24E-04	2.37E-05	7.76E-06	4.79E-05	2.28E-06
GWP (100 years), Incl biogenic carbon	kg CO2 eq	4.05	2.54	1.46	1.50E-03	0.02	0.02	7.48E-03
GWP (100 years), excl biogenic carbon	kg CO2 eq.	4.07	2.54	1.46	0.02	0.02	0.02	7.51E-03
Ozone Layer Depletion Potential	kg R11 eq.	3.17E-11	-1.83E-14	3.16E-11	1.81E-17	6.93E-14	7.14E-16	2.73E-14
Photochem. Ozone Creation Potential	kg Ethene eq.	1.02E-03	5.96E-04	5.07E-04	5.37E-06	4.90E-06	-8.90E-05	8.86E-07
Primary energy demand (net cal. value)	MJ	55.33	30.45	24.03	0.33	0.22	0.26	0.04
Ecotoxicity (recommended only)	CTUe	8.68E-03	7.89E-03	2.89E-04	3.86E-04	1.18E-05	1.01E-04	6.18E-06
Human toxicity, cancer (recommended only)	CTUh	3.86E-10	1.42E-10	2.41E-10	6.36E-13	2.23E-12	1.34E-13	2.24E-13
Human toxicity, non-canc. (recom-mended only)	CTUh	2.31E-11	3.45E-12	1.94E-11	3.10E-14	1.60E-13	3.50E-14	1.79E-14
Blue Water Consumption	kg	22.45	2.45	11.29	0.10	8.59	1.28E-03	0.02

Global Warming (GWP 100 years), excl. biogenic carbon impact for 1 kg of product from filament production process is 4.07 kg CO2 eq. with major contribution from Chips/Granulates (~62.48%) followed by consumption of electricity (~36.01%).

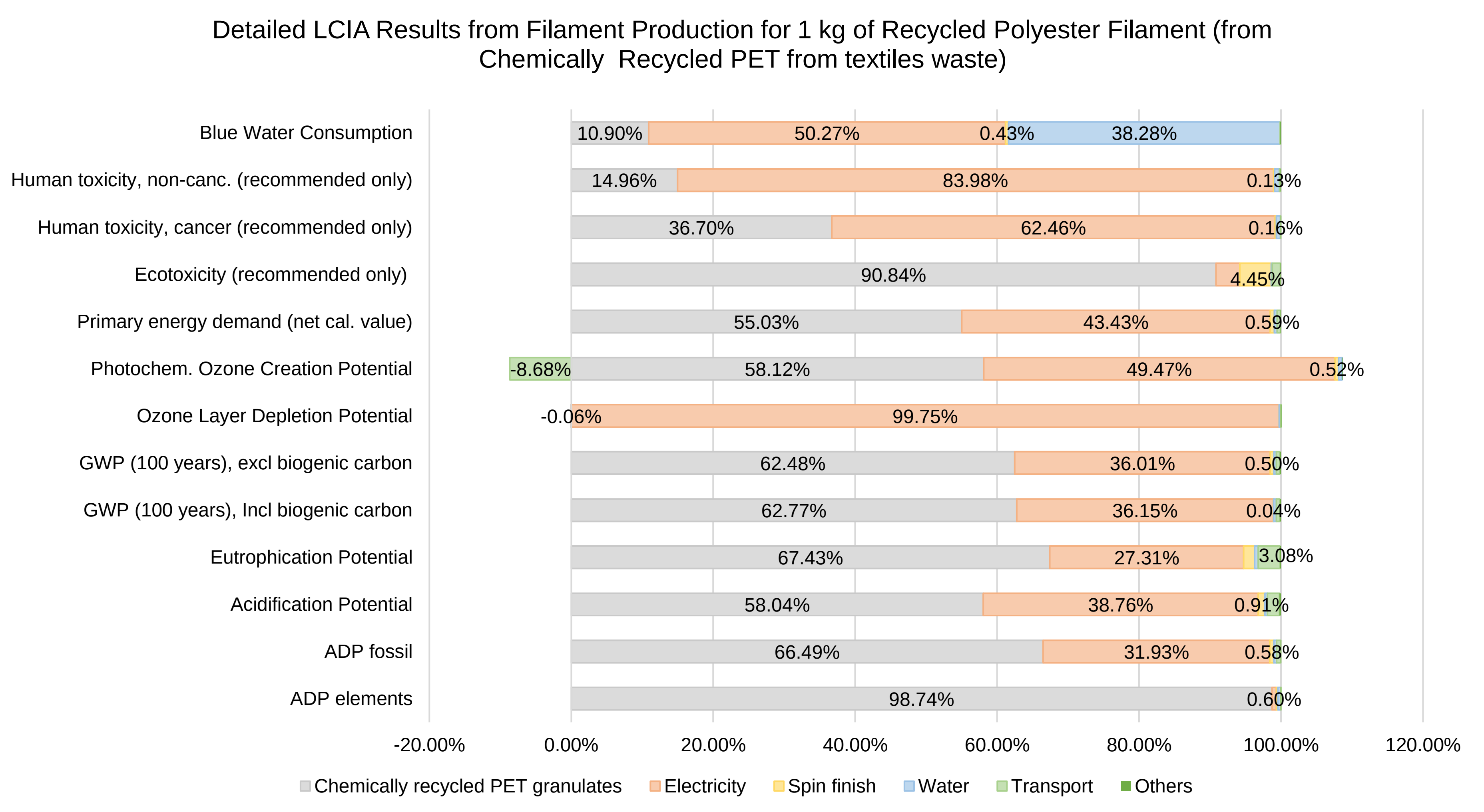

Figure 4-2 Detailed LCIA Results from Filament Production Process for Recycled Polyester Filament Product (from chemically recycled PET from textile waste)

Hotspots Identification:

The hotspots in the Cradle to Gate life cycle environmental impacts of 1 kg of Recycled Polyester Filament (from Chemically Recycled PET from textile waste) Product from filament manufacturing process, are summarised below:

- Abiotic Depletion (elements) is 2.72E-05 kg Sb eq. with major contribution from Chemically recycled PET granulates (~98.74%) followed by Electricity (~0.6%) and Water (~0.39%)
- Abiotic Depletion (fossil) is 45.81 MJ with major contribution from Chemically recycled PET granulates (~66.49%) followed by Electricity (~31.93%) and Spin finish (~0.58%)
- Acidification Potential is 0.01 kg SO2 eq. with major contribution from Chemically recycled PET granulates (~58.04%) followed by Electricity (~38.76%) and Transport (~1.68%)
- Eutrophication Potential is 1.55E-03 kg Phosphate eq. with major contribution from Chemically recycled PET granulates (~67.43%) followed by Electricity (~27.31%) and Transport (~3.08%)
- Global Warming Potential (100 years) is 4.05 kg CO2 eq. with major contribution from Chemically recycled PET granulates (~62.77%) followed by Electricity (~36.15%) and Transport (~0.48%)
- Global Warming Potential (100 years) excluding biogenic carbon is 4.07 kg CO2 eq. with major contribution from Chemically recycled PET granulates (~62.48%) followed by Electricity (~36.01%) and Spin finish (~0.5%)
- Ozone Layer Depletion (steady state) is 3.17E-11 kg R11 eq. with major contribution from Electricity (~99.75%) followed by Water (~0.22%) and Others (~0.09%)
- Photochem. Ozone Creation Potential (POCP) is 1.02E-03 kg Ethene eq. with major contribution from Chemically recycled PET granulates (~58.12%) followed by Electricity (~49.47%) and Spin finish (~0.52%)
- Primary Energy Demand is 55.33 MJ with major contribution from Chemically recycled PET granulates (~55.03%) followed by Electricity (~43.43%) and Spin finish (~0.59%)
- Ecotoxicity (recommended only) is 8.68E-03 CTUe with major contribution from Chemically recycled PET granulates (~90.84%) followed by Spin finish (~4.45%) and Electricity (~3.33%)
- Human toxicity, cancer (recommended only) is 3.86E-10 CTUh with major contribution from Electricity (~62.46%) followed by Chemically recycled PET granulates (~36.7%) and Water (~0.58%)
- Human toxicity, non-canc. (recommended only) is 2.31E-11 CTUh with major contribution from Electricity (~83.98%) followed by Chemically recycled PET granulates (~14.96%) and Water (~0.69%)
- Blue Water Consumption is 22.45 kg with major contribution from Electricity (~50.27%) followed by Water (~38.28%) and Chemically recycled PET granulates (~10.9%)

4.3. Overall Results – Recycled Polyester Filament Product (from Mechanically Recycled PET from Bottles with CICLO)

The Table 4-7 below shows the Cradle to Gate with Packaging LCIA results for 1 kg of Recycled Polyester Filament (from Mechanically Recycled PET from Bottles with CICLO) Product.

Table 4-7 Cradle to Gate LCIA Results for 1 kg of Recycled Polyester Filament Product (from Mechanically Recycled PET from Bottles with CICLO)

Environmental Quantities	Unit	Total
ADP elements	kg Sb eq.	4.29E-07
ADP fossil	MJ	24.29
Acidification Potential (AP)	kg SO_2 eq.	0.01
Eutrophication Potential (EP)	kg Phosphate eq.	9.81E-04
GWP (100 years), incl. biogenic carbon	kg CO_2 eq.	2.20
GWP (100 years), excl biogenic carbon	kg CO_2 eq.	2.26
Ozone Layer Depletion Potential (ODP, steady state)	kg R11 eq.	3.36E-11
Photochem. Ozone Creation Potential (POCP)	kg Ethene eq.	2.33E-04
Primary energy demand from ren. and non ren. resources (net cal. value)	MJ	37.33
Ecotoxicity (recommended only)	CTUe	0.01
Human toxicity, cancer (recommended only)	CTUh	3.25E-10
Human toxicity, non-canc. (recommended only)	CTUh	2.55E-11
Blue Water Consumption	kg	22.93

Global Warming (GWP 100 years), excluding biogenic carbon for 1 kg of Recycled Polyester Filament Product (from Mechanically Recycled PET from PET Bottles with CiCLO) is 2.26 kg CO_2 eq. and Global Warming (GWP 100 years), including biogenic carbon is 2.20 kg CO_2 eq. The blue water consumption is 22.93 kg and primary energy demand is 37.33 MJ. The detailed results are explained in sections below.

4.3.1. Process-wise results for Recycled Polyester Filament Product (from Mechanically Recycled PET from Bottles with CICLO)

The Table 4-8 below shows the process wise life cycle environmental impacts for production and packaging of 1 kg of Recycled Polyester Filament (from Mechanically Recycled PET from

Bottles with CICLO) Product. Filament production process includes impact for recycled chips/granulates, electricity, masterbatch, spin finishing agent, water, and packaging, transport (raw and packaging material).

Table 4-8 Process-wise results for Recycled Polyester Filament Product (from Mechanically Recycled PET from Bottles with CICLO)

Environmental Quantities	Unit	Total	Filament production	Packaging
ADP elements	kg Sb eq.	4.29E-07	3.64E-07	6.49E-08
ADP fossil	MJ	24.29	22.40	1.89
Acidification Potential	kg SO_2 eq.	0.01	0.01	8.94E-04
Eutrophication Potential	kg Phosphate eq.	9.81E-04	8.75E-04	1.06E-04
GWP (100 years), Incl biogenic carbon	kg CO_2 eq.	2.20	2.16	0.04
GWP (100 years), excl biogenic carbon	kg CO_2 eq.	2.26	2.12	0.14
Ozone Layer Depletion Potential	kg R11 eq.	3.36E-11	3.32E-11	3.93E-13
Photochem. Ozone Creation Potential	kg Ethene eq.	2.33E-04	1.71E-04	6.20E-05
Primary energy demand (net cal. value)	MJ	37.33	32.94	4.39
Ecotoxicity (recommended only)	CTUe	0.01	2.61E-03	0.01
Human toxicity, cancer (recommended only)	CTUh	3.25E-10	3.16E-10	9.05E-12
Human toxicity, non-canc. (recommended only)	CTUh	2.55E-11	2.38E-11	1.72E-12
Blue Water Consumption	kg	22.93	22.30	0.62

Global Warming (100 years), excl. biogenic carbon for 1 kg of filament product is 2.26 kg CO2 eq. with major contribution from the Filament production process (93.83%) followed by the packaging (6.17%).

Table 4-9 Detailed Results from Filament Production Process for Recycled Polyester Filament Product (from Mechanically Recycled PET from Bottles with CICLO)

Environmental Quantities	Unit	Total	rPET chips	Electricity	Spin finish	CiCLO Additive	Transport	Others
ADP elements	kg Sb eq.	3.64E-07	2.65E-08	1.62E-07	6.39E-08	4.09E-09	1.57E-09	1.06E-07
ADP fossil	MJ	22.40	5.86	14.64	0.26	0.15	1.31	0.18
Acidification Potential	kg SO_2 eq.	6.56E-03	1.14E-03	4.30E-03	9.99E-05	3.17E-05	9.39E-04	4.46E-05
Eutrophication Potential	kg Phos-phate eq.	8.75E-04	1.71E-04	4.24E-04	2.36E-05	8.39E-06	2.40E-04	8.56E-06
GWP (100 years), Incl biogenic carbon	kg CO_2 eq.	2.16	0.57	1.46	1.49E-03	0.01	0.10	0.02
GWP (100 years), excl biogenic carbon	kg CO_2 eq.	2.12	0.52	1.46	0.02	0.01	0.09	0.02
Ozone Layer Depletion Potential	kg R11 eq.	3.32E-11	1.45E-12	3.16E-11	1.80E-17	3.95E-14	3.57E-15	6.98E-14
Photochem. Ozone Creation Potential	kg Ethene eq.	1.71E-04	8.56E-05	5.07E-04	5.34E-06	1.97E-06	-4.34E-04	5.19E-06
Primary energy demand (net cal. value)	MJ	32.94	6.83	24.05	0.33	0.20	1.31	0.23
Ecotoxicity (recommended only)	CTUe	2.61E-03	3.47E-04	2.90E-04	3.84E-04	1.07E-03	5.06E-04	1.34E-05
Human toxicity, cancer (recommended only)	CTUh	3.16E-10	6.99E-11	2.41E-10	6.33E-13	1.54E-12	6.64E-13	2.25E-12
Human toxicity, non-canc. (recom-mended only)	CTUh	2.38E-11	3.76E-12	1.94E-11	3.09E-14	2.73E-13	1.74E-13	1.75E-13
Blue Water Consumption	kg	22.30	2.20	11.29	0.10	0.06	6.38E-03	8.65

Global Warming (GWP 100 years), excl. biogenic carbon impact for 1 kg of product from filament production process is 2.12 kg CO2 eq. with major contribution from consumption of Electricity (~68.97%) and Chips/Granulates (~24.38%).

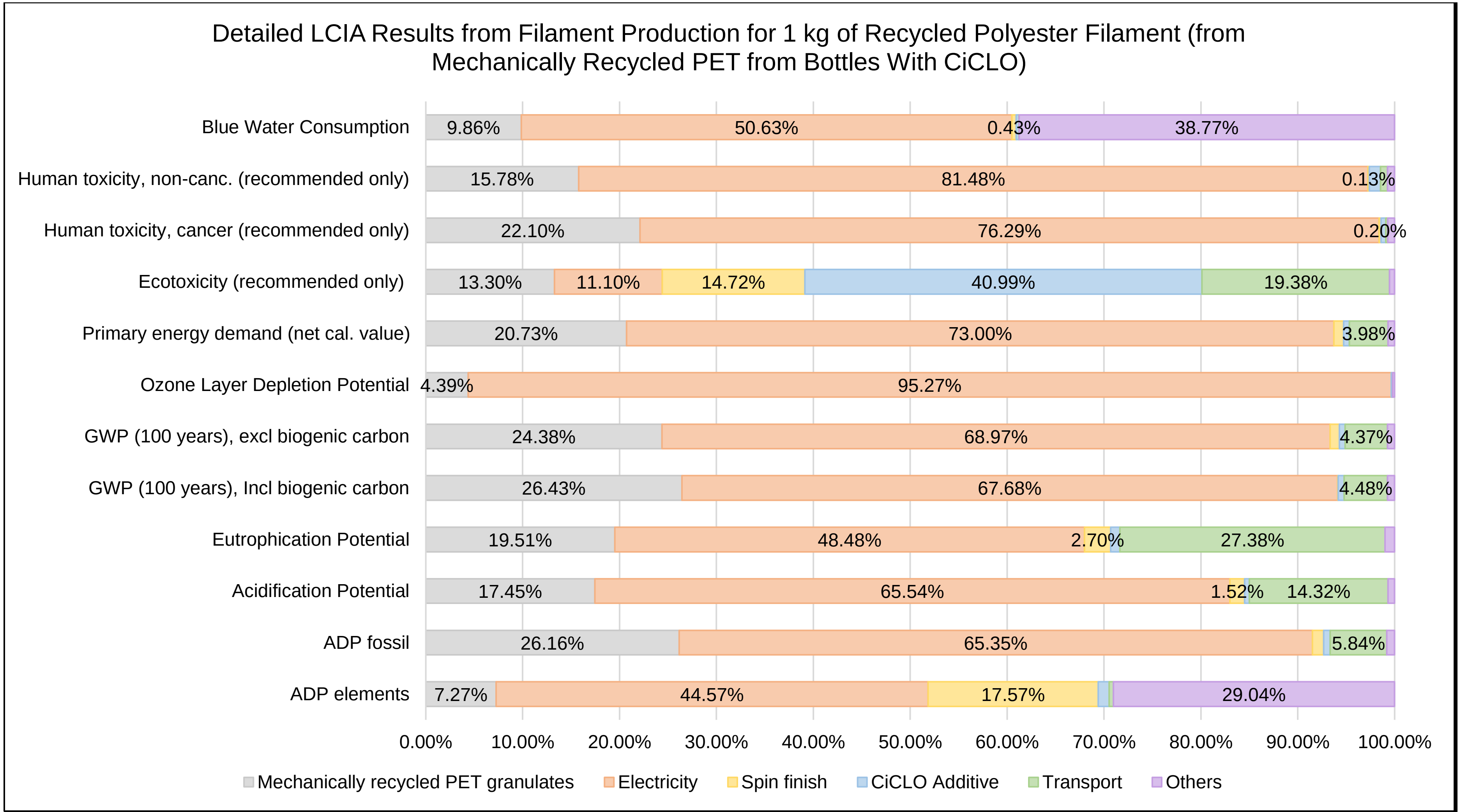

Figure 4-3 Detailed LCIA Results from Filament Production Process for Recycled Polyester Filament Product (from Mechanically Recycled PET from Bottle with CiCLO)

Hotspots Identification:

The hotspots in the Cradle to Gate life cycle environmental impacts of 1 kg of Recycled Polyester Filament (from Mechanically Recycled PET from PET Bottles with CiCLO additives) Product from filament manufacturing process, are summarised below:

- Abiotic Depletion (elements) is 3.64E-07 kg Sb eq. with major contribution from Electricity (~44.57%) followed by Others (~29.04%), Spin finish (~17.57%) and Mechanically recycled PET granulates (~7.27%)
- Abiotic Depletion (fossil) is 22.40 MJ with major contribution from Electricity (~65.35%) followed by Mechanically recycled PET granulates (~26.16%), Transport (~5.84%) and Spin finish (~1.17%)
- Acidification Potential is 6.56E-03 kg SO2 eq. with major contribution from Electricity (~65.54%) followed by Mechanically recycled PET granulates (~17.45%), Transport (~14.32%) and Spin finish (~1.52%)
- Eutrophication Potential is 8.75E-04 kg Phosphate eq. with major contribution from Electricity (~48.48%) followed by Transport (~27.38%), Mechanically recycled PET granulates (~19.51%) and Spin finish (~2.7%)
- Global Warming Potential (100 years) is 2.16 kg CO2 eq. with major contribution from Electricity (~67.68%) followed by Mechanically recycled PET granulates (~26.43%), Transport (~4.48%) and Others (~0.74%)
- Global Warming Potential (100 years) excluding biogenic carbon is 2.12 kg CO2 eq. with major contribution from Electricity (~68.97%) followed by Mechanically recycled PET granulates (~24.38%), Transport (~4.37%) and Spin finish (~0.95%)
- Ozone Layer Depletion (steady state) is 3.32E-11 kg R11 eq. with major contribution from Electricity (~95.27%) followed by Mechanically recycled PET granulates (~4.39%), Others (~0.21%) and CiCLO Additive (~0.12%)
- Photochem. Ozone Creation Potential (POCP) is 1.71E-04 kg Ethene eq. with major contribution from Electricity (~296.23%) followed by Mechanically recycled PET granulates (~49.97%), Spin finish (~3.12%) and Others (~3.03%)
- Primary Energy Demand is 32.94 MJ with major contribution from Electricity (~73%) followed by Mechanically recycled PET granulates (~20.73%), Transport (~3.98%) and Spin finish (~0.99%)
- Ecotoxicity (recommended only) is 2.61E-03 CTUe with major contribution from CiCLO Additive (~40.99%) followed by Transport (~19.38%), Spin finish (~14.72%) and Mechanically recycled PET granulates (~13.3%)
- Human toxicity, cancer (recommended only) is 3.16E-10 CTUh with major contribution from Electricity (~76.29%) followed by Mechanically recycled PET granulates (~22.1%), Others (~0.71%) and CiCLO Additive (~0.49%)
- Human toxicity, non-canc. (recommended only) is 2.38E-11 CTUh with major contribution from Electricity (~81.48%) followed by Mechanically recycled PET granulates (~15.78%), CiCLO Additive (~1.15%) and Others (~0.74%)
- Blue Water Consumption is 22.30 kg with major contribution from Electricity (~50.63%) followed by Others (~38.77%), Mechanically recycled PET granulates (~9.86%) and Spin finish (~0.43%)

5. Interpretation

This section aims to satisfy the interpretation phase of an LCA in accordance with ISO 14040/14044 by identifying any significant issues based on the LCI (section 3) and LCIA (Section 4) phases, evaluate the study via completeness, sensitivity, and consistency checks, and capturing conclusions, recommendations, and limitations.

5.1. Identification of Relevant Findings

Recycled Polyester Filament Product (from Mechanically Recycled PET from PET Bottles)

Cradle to Gate impacts has the highest contribution from the filament production process across all impact categories except ecotoxicity which is contributed mostly by the packaging process.

- Cradle to Gate Global Warming Potential (GWP 100 years) is 2.14 kg CO_2 eq. with major contribution from filament production (~98.25%) followed by packaging (~1.75%). In filament production the major impact is contributed by the consumption of electricity (~70.95%) followed by rPET granulate (~27.40%).
- Cradle to Gate Global Warming Potential (GWP 100 years) excluding biogenic carbon is 2.21 kg CO_2 eq. with major contribution from filament production (~93.67%) followed by packaging (~15.08%). In filament production the major impact is contributed by the consumption of electricity (~72.20%) followed by rPET granulate (~25.24%).
- Cradle to Gate Abiotic Depletion (ADP elements) is 4.31E-07 kg Sb eq. with major contribution from filament production (~84.92%) followed by packaging (~15.08%). In filament production the major impact is contributed by the consumption of electricity (~45.23%) followed by water (~29.17%).
- Cradle to Gate Acidification Potential (AP) is 0.01 kg SO_2 eq. with major contribution from filament production (~86.68%) followed by packaging (~13.32%). In filament production the major impact is contributed by the consumption of electricity (~75.24%) followed by rPET granulate (~19.82%).
- Cradle to Gate Blue Water Consumption (BWC) is 23.21 kg with major contribution from filament production (~97.32%) followed by packaging (~2.68%). In filament production the major impact is contributed by the consumption of electricity (~70.95%) followed by rPET granulate (~27.40%).
- Cradle to Gate Primary Energy demand (PED) is 36.60 MJ with major contribution from filament production (~88.01%) followed by packaging (~11.99%). In filament production the major impact is contributed by the consumption of electricity (~50.96%) followed by water (~38.65%).

Recycled Polyester Filament Product (from Chemically Recycled PET from textiles waste)

Cradle to Gate impacts has the highest contribution from the filament production process across all impact categories.

- Cradle to Gate Global Warming Potential (GWP 100 years) is 4.08 kg CO_2 eq. with major contribution from filament production (~99.08%) followed by packaging (~0.92%). In filament production the major impact is contributed by rPET granulate (~62.77%) followed by the consumption of electricity (~36.15%).
- Cradle to Gate Global Warming Potential (GWP 100 years) excluding biogenic carbon is 4.20 kg CO_2 eq. with major contribution from filament production (~96.68%) followed by packaging (~3.32%). In filament production the major impact is contributed by rPET granulate (~62.48%) followed by the consumption of electricity (~36.01%).
- Cradle to Gate Abiotic Depletion (ADP elements) is 2.73E-05 kg Sb eq. with major contribution from filament production (~99.76%) followed by packaging (~0.24%). In filament production the major impact is contributed by the rPET granulate (~98.74%) followed by the consumption of electricity (~0.60%).
- Cradle to Gate Acidification Potential (AP) is 0.01 kg SO_2 eq. with major contribution from filament production (~92.53%) followed by packaging (~7.47%). In filament production the major impact is contributed by the rPET granulate (~58.04%) followed by the consumption of electricity (~38.76%).
- Cradle to Gate Blue Water Consumption (BWC) is 23.07 kg with major contribution from filament production (~97.30%) followed by packaging (~2.70%). In filament production the major impact is contributed by the consumption of electricity (~50.27%) followed by Blue water consumption (~38.28%).
- Cradle to Gate Primary Energy demand (PED) is 59.72 MJ with major contribution from filament production (~92.65%) followed by packaging (~7.35%). In filament production the major impact is contributed by the rPET granulate (~55.03%) followed by the consumption of electricity (~43.43%).

Recycled Polyester Filament (from Mechanically Recycled PET from Bottles With CiCLO)

Cradle to Gate impacts has the highest contribution from the filament production process across all impact categories except ecotoxicity which is contributed mostly by the packaging process.

- Cradle to Gate Global Warming Potential (GWP 100 years) is 2.20 kg CO_2 eq. with major contribution from filament production (~98.30%) followed by packaging (~1.70%). In filament production the major impact is contributed by the consumption of electricity (~67.68%) followed by rPET granulate (~26.43%).
- Cradle to Gate Global Warming Potential (GWP 100 years) excluding biogenic carbon is 2.26 kg CO_2 eq. with major contribution from filament production (~93.83%) followed by packaging (~6.17%). In filament production the major impact is contributed by the consumption of electricity (~68.97%) followed by rPET granulate (~24.38%).
- Cradle to Gate Abiotic Depletion (ADP elements) is 4.29E-07 kg Sb eq. with major contribution from filament production (~84.86%) followed by packaging (~15.14%). In filament production the major impact is contributed by the consumption of electricity (~44.57%) followed by Others (~29.04%).
- Cradle to Gate Acidification Potential (AP) is 0.01 kg SO_2 eq. with major contribution from filament production (~88%) followed by packaging (~12%). In filament production the major impact is contributed by the consumption of electricity (~65.54%) followed by rPET granulate (~17.45%).
- Cradle to Gate Blue Water Consumption (BWC) is 22.93 kg with major contribution from filament production (~97.28%) followed by packaging (~2.72%). In filament production the major impact is contributed by the consumption of electricity (~50.63%) followed by Others (~38.77%).
- Cradle to Gate Primary Energy demand (PED) is 37.33 MJ with major contribution from filament production (~88.24%) followed by packaging (~11.76%). In filament production the major impact is contributed by the rPET granulate (~73.0%) followed by the consumption of electricity (~20.73%).

5.2. Assumptions and Limitations

The data provided by Changshu Polyester Co. Ltd, is for the time period June 2023 to June 2024. Below are the assumptions and limitations made during the evaluation of life cycle information for the product.

- Transport of materials through truck, rail and ship are analysed by using LCA FE datasets.
- There were very few cases where proxy data (see section 3.3) had to be used in the LCA models. This occurred when no LCI data was available for an intermediate chemical/material.
- Likewise, there were few cases where data had to be used from a different region or technology. These instances were uncommon and noted in the Data Quality section of the LCA Report.

- LCA FE datasets provide a completely aggregated, cradle-to-gate process inventory. The use of this type of datasets had two main consequences, on the modelling exercise: (i): predefined methodological choices had to be used (e.g. regarding multifunctionality), making it difficult to ensure consistency within the same product life cycle and across the different analysed scenarios; and (ii) the level of granularity of the contribution analysis was bound to the level of aggregation of the used datasets, which is particularly high for processes in the upstream part of the supply chain.

5.3. Data Quality Assessment

Inventory data quality is judged by its precision (measured, calculated or estimated), completeness (e.g., unreported emissions), consistency (degree of uniformity of the methodology applied) and representativeness (geographical, temporal, and technological).

To cover these requirements and to ensure reliable results, first-hand industry data in combination with consistent background LCA information from the Sphera's MLC 2024.2 database were used wherever applicable. The LCI datasets from the Sphera's MLC 2024.2 database are widely distributed and used with the LCA FE 10.9 Software. The datasets have been used in LCA models worldwide in industrial and scientific applications in internal as well as in many critically reviewed and published studies. In the process of providing these datasets they are cross-checked with other databases and values from industry and science.

5.3.1. Precision and Completeness

- ✓ **Precision:** As the majority of the relevant foreground data are measured data or calculated based on primary information sources of the owner of the technology, precision is considered to be high. All background data are sourced from LCA FE databases with the documented precision.
- ✓ **Completeness:** Each foreground process was checked for mass balance and completeness of the emission inventory. No data were knowingly omitted except that of described in Section 3.3. Completeness of foreground unit process data is considered to be high. All background data are sourced from LCA FE databases with the documented completeness.

5.3.2. Consistency and Reproducibility

- ✓ **Consistency:** To ensure data consistency, all primary data were collected with the same level of detail, while all background data were sourced from the LCA FE databases.

  Data Source: All primary data were collected with same level of detail from the manufacturing unit, while all background data were sourced from LCA FE database. The data is found to be consistent along the product's life cycle.

  Data Accuracy: All the primary and background data are good based on their accuracy and thus found to consistent along the product's life cycle.

  Data Age: All the primary data were collected for the time period June 2023 to June 2024, while the background data come from Sphera's MLC 2024.2, reference year is shown in the section 3.3. The data age is found to be consistent along the product's life cycle.

Technology coverage: Technological representativeness is high for both primary and secondary data, thus they are consistent throughout the product's life cycle.

Time related coverage: Based on section 2.2.3, time related coverage is consistent throughout the product's life cycle.

Geographical coverage: Based on section 2.2.2, geography coverage is consistent throughout the product's life cycle.

- ✓ **Reproducibility:** Reproducibility is supported as much as possible through the disclosure of input-output data, dataset choices, and modelling approaches in this report. Based on this information, any third party should be able to approximate the results of this study using the same data and modelling approaches.

5.3.3. Representativeness

- ✓ **Temporal:** All primary data were collected for the time period June 2023 to June 2024. All secondary data come from the Sphera's MLC 2024.2.
- ✓ **Geographical:** All primary and secondary data were collected specific to the countries or regions under study. Where country-specific or region-specific data were unavailable, proxy data were used. Geographical representativeness is considered to be high.
- ✓ **Technological:** All primary and secondary data were modelled to be specific to the technologies or technology mixes under study. Where technology-specific data were unavailable, proxy data were used. Technological representativeness is considered to be high.

5.4. Model Completeness and Consistency

5.4.1. Completeness

All relevant process steps for each product system were considered and modelled to represent each specific situation. The process chain is considered sufficiently complete and detailed with regards to the goal and scope of this study.

5.4.2. Consistency

All assumptions, methods and data are consistent with each other and with the study's goal and scope. Differences in background data quality were minimized by using LCI data from the LCA FE databases. System boundaries, allocation rules, and impact assessment methods have been applied consistently throughout the study.

5.5. Recommendations

Based on the observations of the study, a few directional recommendations can be summarised as follows:

- In order to further reduce the Global Warming impacts contributed from manufacturing operations due to electricity consumption, it is suggested to Changshu Polyester Co. Ltd. to source electricity from renewables such as solar, wind etc or purchase green energy certificates.
- Improvement in energy efficiency of filament production processes can lead to reduction in various environmental impacts.
- Optimization of resource consumptions may lead to reduce wastes, which might lead to higher yield of the product resulting in lowering the various environmental impacts.

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Annex A: Life Cycle Inventory (Confidential Data)

1. Recycled Polyester Filament Production (from Mechanically Recycled PET from PET Bottles)来自PET瓶子做成的再生PET长丝					
Melting, BCF Extrusion, Spinning, Winding etc.熔融，BCF挤压，纺丝，缠绕					
Process - Input投料	**Unit**	**Total for JUN 2023 TO JUN 2024**	**Transportation Distance (km)运输距离**		
			Truck卡车	**Ship 船运**	**Origin (Country) 原产地**
Recycled Polyester (Chips/Granules/Pel-lets)再生涤纶	Tonnes	4050	136KM		CHINA
Spin Finish/Antistatic agent纺丝油剂	Tonnes	33	226KM	1736	JAPAN
Masterbatch母料	Tonnes	3	60KM		CHINA
Water水	m³	33267.6	2KM		CHINA
Electricity电	kWh	8043300	2KM		CHINA
Diesel柴油	Tonnes	0.55	2KM		CHINA
Other chemicals其他化学品	Tonnes	0.148	10KM		CHINA
Process - Output产出	**Unit**	**Total for JUN 2023 TO JUN 2024**	**Transportation Distance (km)运输距离**		
			Truck卡车	**Ship 船运**	**Origin (Country) 原产地**
Recycled Polyester Filament再生涤纶长丝	Tonnes	3821	1005KM	4500 NMI/920NMI	CHINA/INDIA/VN
Yarn waste废丝	Tonnes	107	60KM		CHINA
Other solid waste其他固体废物	Tonnes	2.35	380KM		CHINA
Wastewater废水	m³	0			
2. Recycled Polyester Filament Production (from Chemically Recycled PET from textiles waste)来自化学法PET做成的再生长丝					
Melting, BCF Extrusion, Spinning, Winding etc.熔融，BCF挤压，纺丝，缠绕					
Process - Input投料	**Unit**	**Total for JUN 2023 TO JUN 2024**	**Transportation Distance (km)运输距离**		
			Truck卡车	**Ship 船运**	**Origin (Country) 原产地**
Recycled Polyester (Chips/Granules/Pel-lets)再生涤纶	Tonnes	9	203KM		CHINA
Spin Finish/Antistatic agent纺丝油剂	Tonnes	0.072	226KG		CHINA
Masterbatch母料	Tonnes	NONE			
Water水	m³	73	2KM		CHINA
Electricity电	kWh	17577	2KM		CHINA

Diesel柴油	Tonnes	0.001	2KM		CHINA
Other chemicals其他化学品	Tonnes	0.0003	10KM		CHINA
Process - Output产出	**Unit**	**Total for JUN 2023 TO JUN 2024**	**Transportation Distance (km)运输距离**		
			Truck卡车	**Ship 船运**	**Origin (Country) 原产地**
Recycled Polyester Filament再生涤纶长丝	Tonnes	8.5	1005km	4500 NMI	CHINA/INDIA
Yarn waste废丝	Tonnes	0.4	50KM		CHINA
Other solid waste其他固体废物	Tonnes	0.1	20KM		CHINA
Wastewater废水	m^3	0			
3. Recycled Polyester Filament Production (from Mechanically Recycled PET from PET Bottles With CiCLO Additives)可降解再生涤纶长丝					
Melting, BCF Extrusion, Spinning, Winding etc.熔融，BCF挤压，纺丝，缠绕					
Process - Input投料	**Unit**	**Total for JUN 2023 TO JUN 2024**	**Transportation Distance (km)运输距离**		
			Truck卡车	**Ship 船运**	**Origin (Country) 原产地**
Recycled Polyester (Chips/Granules/Pellets)再生涤纶	Tonnes	1	1005KM		CHINA
Spin Finish/Antistatic agent纺丝油剂	Tonnes	0.008	226KM		CHINA
CiCLO Additive CICLO添加剂	Tonnes	0.02	80KM	11500	USA
Masterbatch母料	Tonnes	NONE			
Water水	m^3	8.2	2KM		CHINA
Electricity电	kWh	1964	2KM		CHINA
Diesel柴油	Tonnes	0.0001	2KM		CHINA
Other chemicals其他化学品	Tonnes	NONE			
Process - Output产出	**Unit**	**Total for JUN 2023 TO JUN 2024**	**Transportation Distance (km)运输距离**		
			Truck卡车	**Ship 船运**	**Origin (Country) 原产地**
Recycled Polyester Filament再生涤纶长丝	Tonnes	0.95	1005KM		CHINA
Yarn waste废丝	Tonnes	0.05	60KM		CHINA
Other solid waste其他固体废物	Tonnes	0			
Wastewater废水	m^3	0			

Packaging包装					
Process - Input投料	**Unit**	**Total for JUN 2023 TO JUN 2024**	**Transportation Distance (km)运输距离**		
			Truck卡车	**Ship船运**	**Origin (Country) 原产地**
Wooden Pallets实木托盘	Tonnes	722.99	20KM~60KM		
Paper Tubes纸管	Tonnes	1213.86	20KM~60KM		
Carton Divider Plates纸箱隔板	Tonnes	115.11	20KM~60KM		
Stretch Foil弹性箔片	Tonnes	61.1	20KM~60KM		
Other Input (If any…)其他投入					
Process - Output产出	**Unit**	**Total for JUN 2023 TO JUN 2024**	**Transportation Distance (km)运输距离**		
			Truck卡车	**Ship船运**	**Origin (Country) 原产地**
Packaged Filament Product长丝包装产品	Tonnes	NONE			
Plastic Scrap废弃塑料	Tonnes	NONE			
Wooden Scrap木屑	Tonnes	NONE			
Cardboard waste纸板废料	Tonnes	NONE			
Other waste其他废弃物	Tonnes	80.5	5KM~20KM		
Other Output (If any…)其他产出					

Annex B: Description of Selected Inventories and Impact Categories

- ***Abiotic Depletion Potential***

The abiotic depletion potential (ADP) covers all natural resources as metal containing ores, crude oil and mineral raw materials. Abiotic resources include all raw materials from non-living resources that are non-renewable. This impact category describes the reduction of the global amount of non-renewable raw materials. Non-renewable means a time frame of at least 500 years. The abiotic depletion potential is split into two sub-categories.

Abiotic depletion potential (elements) covers an evaluation of the availability of natural elements like minerals and ores, incl. uranium ore. The reference substance for the characterisation factors is antimony.

The second sub-category abiotic depletion potential (fossil) includes the fossil energy carriers (crude oil, natural gas, coal resources). The respective unit is the Megajoule.

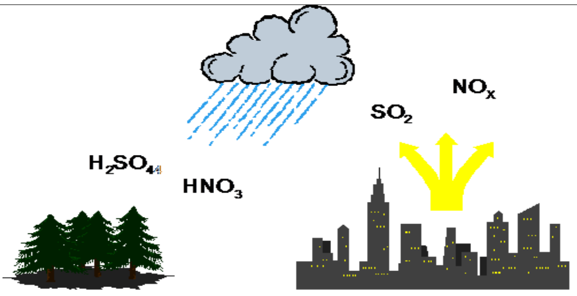
- ***Acidification Potential***

The acidification of soils and waters occurs predominantly through the transformation of air pollutants into acids. This leads to a decrease in the pH-value of rainwater and fog from 5.6 to 4 and below. Sulphur dioxide and nitrogen oxide and their respective acids (H_2SO_4 und HNO_3) produce relevant contributions. This damages ecosystems, whereby forest dieback is the most well-known impact.

Acidification has direct and indirect damaging effects (such as nutrients being washed out of soils or an increased solubility of metals into soils). But even buildings and building materials can be damaged. Examples include metals and natural stones which are corroded or disintegrated at an increased rate.

When analysing acidification, it should be considered that although it is a global problem, the regional effects of acidification can vary.

The acidification potential is given in sulphur dioxide equivalents (SO_2-Eq.). The acidification potential is described as the ability of certain substances to build and release H+ - ions. Certain emissions can also be considered to have an acidification potential, if the given S-, N- and halogen atoms are set in proportion to the molecular mass of the emission. The reference substance is sulphur dioxide.

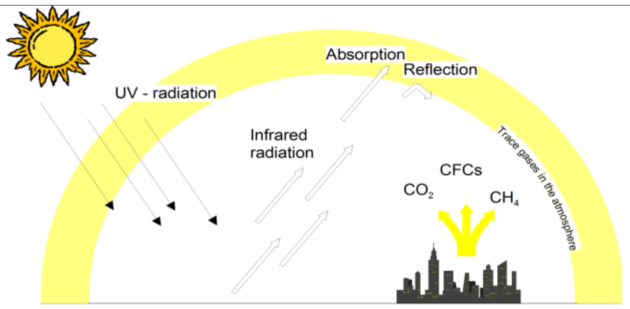


Acidification potential

- ***Global Warming Potential***

The mechanism of the greenhouse effect can be observed on a small scale, as the name suggests, in a greenhouse. These effects are also occurring on a global scale. The occurring short-wave radiation from the sun encounters the earth's surface and is partly absorbed (leading to direct warming) and partly reflected as infrared radiation. The reflected part is absorbed by so-called greenhouse gases in the troposphere and is re-radiated in all directions, including back to earth. This results in a warming effect at the earth's surface.

In addition to the natural mechanism, the greenhouse effect is enhanced by human activities. Greenhouse gases that are considered to be caused, or increased, anthropogenically are, for example, carbon dioxide, methane and CFCs. An analysis of the greenhouse effect should consider the possible long term global effects.

The global warming potential is calculated in carbon dioxide equivalents (CO_2-Eq.). This means that the greenhouse potential of an emission is given in relation to CO_2. Since the residence time of the gases in the atmosphere is incorporated into the calculation, a time range for the assessment must also be specified. A period of 100 years is customary.	 **Global Warming Potential**

- ***Primary energy demand***

Primary energy demand is often difficult to determine due to the various types of energy source. Primary energy demand is the quantity of energy directly withdrawn from the hydrosphere, atmosphere or geosphere or energy source without any anthropogenic change. For fossil fuels and uranium, this would be the amount of resource withdrawn expressed in its energy equivalent (i.e., the energy content of the raw material). For renewable resources, the energy-characterised amount of biomass consumed would be described. For hydropower, it would be based on the amount of energy that is gained from the change in the potential energy of the water (i.e., from the height difference). As aggregated values, the following primary energies are designated:

The total **"Primary energy from non-renewable resources"**, given in MJ, essentially characterises the gain from the energy sources natural gas, crude oil, lignite, coal, and uranium. Natural gas and crude oil were used both for energy production and as material constituents e.g., in plastics. Coal was primarily used for energy production. Uranium was only used for electricity production in nuclear power stations.

The total **"Primary energy from renewable resources"**, given in MJ, is generally accounted separately and comprises hydropower, wind power, solar energy, and biomass.

It is important that the end energy (e.g., 1 kWh of electricity) and the primary energy used are not miscalculated with each other; otherwise, the efficiency for production or supply of the end energy will not be accounted for.

The energy content of the manufactured products was considered as feedstock energy content. It was characterized by the net calorific value of the product. It represents the still usable energy content.

- ***Aquatic Eutrophication***

Aquatic Eutrophication occurs when excessive amounts of nutrients reach freshwater systems or oceans. Algae bloom may result, and fish may disappear. Whereas phosphorous is mainly responsible for eutrophication in freshwater systems, nitrogen is mainly responsible for eutrophication in ocean water bodies.

The Aquatic Eutrophication indicator based on the potential impact relative to the reference substance phosphorous, i.e. [kg P eq / FU] is recommended for freshwater eutrophication and mass of nitrogen equivalents [kg N eq) / FU] is recommended for marine eutrophication.

- ***Photochemical Ozone Creation Potential (POCP)***

Photochemical Ozone Creation Potential (POCP) is the potential of ozone creation at ground level (i.e., tropospheric ozone) through photochemical transformation of ozone precursor emissions. The main ozone precursor compounds are nitrogen oxides (NOx) and non-methane volatile organic compounds.

(NMVOC). Mass of non-methane volatile organic compound equivalents, e.g. [kg NMVOC eq / FU] calculated using the "photochemical oxidant formation potential" indicator at a midpoint level, as described in the ReCiPe impact assessment methodology.

- ***Freshwater Consumption***

Methodologies for the measurement and assessment of life cycle impacts related to water resources are currently under development within the scientific community as well as in international initiatives, such as the UNEP/SETAC Life Cycle Initiative (http://lcinitiative.unep.fr), and standardization bodies such as ISO which is currently working on the international standard ISO/WD 14046 Water footprint—Requirements and guidelines. Due to the ongoing development, it is premature to recommend life cycle impact assessment methods for freshwater use. We therefore recommend measuring net water consumption (also called "consumptive use") on an inventory level. Aggregating different measures of water, such as in-stream water use (e.g., turbined river water for hydro power generation), off-stream use (e.g., cooling water that is returned to the same watershed) or degradative use (e.g., water pollution) at an inventory level would not generate useful decision support and they are therefore excluded from this indicator awaiting the acceptance of a relevant impact assessment method.

- ***Blue water***

Fresh surface and groundwater, in other words, the water in freshwater lakes, rivers and aquifers.

- ***Human Toxicity Potential (HTP)***

The human toxicity potential (HTP), a calculated index that reflects the potential harm of a unit of chemical released into the environment, is based on both the inherent toxicity of a compound and its potential dose. It is used to weight emissions inventoried as part of a life-cycle assessment (LCA) or in the toxics release inventory (TRI) and to aggregate emissions in terms of a reference compound. Total emissions can be evaluated in terms of benzene equivalence (carcinogens) and toluene equivalents (non-carcinogens).