EcoProfile of recycled PET flakes EU27+3, cradle-to-gate, post-consumer

Jonas Hoffmann, Max Bringmann, Andreas Ciroth
GreenDelta GmbH
May 2025

LCA method overview	
Background database	Ecoinvent v3.10
Dataset type	Cut-off, unit processes
Declared unit	'Production of 1 kg of mechanically recycled PET flakes'
ISO conformity	ISO 14040 and 14044 structure, internal review
LCIA method	Environmental Footprint 3.1
Software	openLCA 2.4
System boundary	Cradle-to-gate

Funded by the European Union's Horizon Europe Programme under Grant Agreement No. 101057067

1 BACKGROUND INFORMATION

- The primary purpose of this document is to present an average life cycle inventory (LCI) and impact assessment (LCIA) for mechanically recycled polyethylene terephthalate (rPET) flakes as result of the Horizon Project PRIMUS. The project seeks to provide a comprehensive understanding of and data for the environmental impacts associated with mechanically recycled plastics.

- rPET is a widespread material known for being a dimensionally stable thermoplastic with excellent machining characteristics, commonly used in beverage bottles, microwavable trays, and clothing fibres. The usage of mechanically recycled PET reduces the use of fossil fuels and energy compared to the production of primary PET.

- Mechanical recycling of PET plastic waste usually involves sorting, granulation, density separation, washing and drying. As most PET waste is sourced from separate collection schemes for drinking bottles, HDPE caps are commonly removed via density separation. Coloured PET mixed into the waste stream may lead to colorisation, and thus, downgrading of the produced recyclate from bottle grade to tray grade.

- The documentation of the method followed in the herein presented EcoProfile follows the main principles of the ISO 14040-14044 standards and was internally reviewed by PlasticRecyclersEurope and experts from the VTT Technical Research Centre of Finland. It is intended for LCA practitioners and sustainability researchers and stakeholders in the field of plastic recyclates.

- Details for the methodology used for this EcoProfile can be found in the accompanying methodology publication. Datasets can be downloaded from openLCA Nexus in JSON-LD and ILCD formats.

2 MODEL DESCRIPTION

- This EcoProfile represents an average of European industry for mechanical rPET production. Data was collected from 6 sites in 2022 in France, Germany, Italy, Spain and Switzerland, represents the recycling of a clean waste stream of clear and coloured bottles from consumer use, and 8.50% of the European installed mechanical recycling capacity of those waste streams. The European coverage has been calculated per waste-stream, as displayed in Table 2 of the accompanying methodology document.

- The herein generated EcoProfile embodies a life cycle inventory in a 'cradle-to-gate' fashion for collection, sorting of waste, and production of PET plastic recyclate flakes. The product under investigation is 1 kg of recycled PET flakes. The main production steps in mechanical recycling are included in the system boundaries of the EcoProfile are visualised in Figure 1.

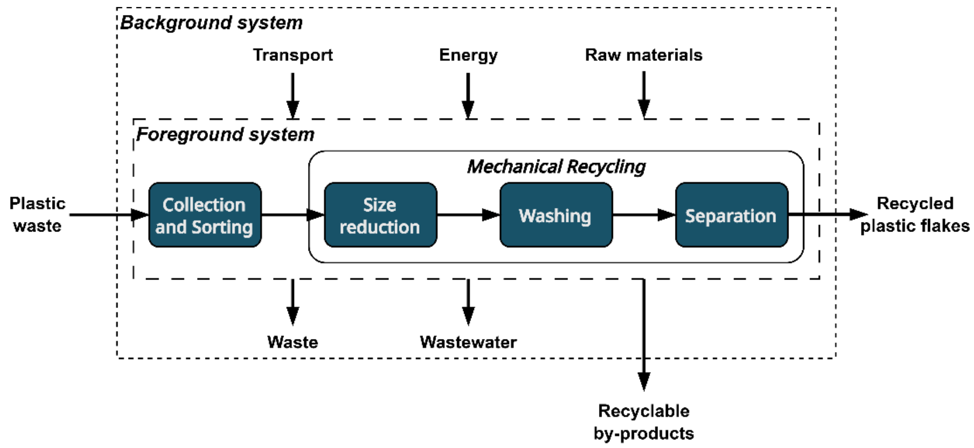

Figure 1: System description and boundaries. Following the PRE recycling scheme.

- The functional unit of the rPET EcoProfile is '**Production of 1 kg of mechanically recycled PET flakes, obtained from clear and coloured bottle waste after collection and sorting, at gate, unpackaged, representing 8.50% of European production**' where the reference flow of the rPET EcoProfile provided is '**1 kg of rPET flakes, unpacked**'.

- Generally, a complete LCI was aimed for, though some neglectable amounts of secondary outputs had to be cut-off. For multi-output processes, physical allocation was used, as described in our methodology.

- The collected primary data was combined with secondary data (for transport, energy, chemicals, and water) from the ecoinvent 3.10 cut-off LCA database. The life cycle inventory and impacts were calculated using the CED and EF 3.1 method.

3 LCI RESULTS

Table 1. Summary of material and energy in- and outputs of an exemplary secondary material production process for recycled PET flakes with a cradle-to-gate boundary

Incoming Material	**Flow Quantities per 1 kg**
Mixed plastic waste including impurities[1]	1.78 kg
Material inputs	
calcium carbonate, precipitated	3.83E-04 kg
calcium nitrate	3.20E-04 kg
chemical, inorganic	7.39E-06 kg
Cleaning consumables, with water	9.00E-04 kg
containerboard, linerboard	7.80E-04 kg
diesel, low-sulfur	2.30E-04 kg
fleece, polyethylene	8.90E-09 kg
hydrochloric acid, without water, in 30% solution state	5.33E-05 kg
iron sulfate	7.24E-03 kg
iron(III) chloride, without water, in 40% solution state	5.65E-05 kg
phosphoric acid, industrial grade, without water, in 85% solution state	6.20E-04 kg
polyacrylamide	2.03E-03 kg
polyaluminium chloride	3.07E-03 kg
Polyamine	9.00E-04 kg
polydimethylsiloxane	1.44E-03 kg
polyethylene, high density, granulate	6.90E-04 kg
polyethylene, low density, granulate	2.97E-02 kg
polypropylene, granulate	9.70E-04 kg
silicone product	7.04E-06 kg
sodium chloride, brine solution	2.90E-04 kg
sodium chloride, powder	2.95E-05 kg
sodium hydroxide, without water, in 50% solution state	9.43E-03 kg
steel, low-alloyed	1.00E-02 kg
tin plated chromium steel sheet, 2 mm	8.59E-05 m²
urea	2.22E-05 kg
Service inputs	
drawing of pipe, steel	7.65E-05 kg
extrusion, plastic film	3.03E-02 kg
injection moulding	6.90E-04 kg
wire drawing, steel	9.96E-03 kg
Water consumption	
tap water	2.98 kg
water, completely softened	5.46E-03 kg
ground water	1.71E-03 m³
Energy	
diesel, burned in building machine	0.203 MJ
electricity, high voltage	0.210 MJ
electricity, low voltage	1.20 MJ
electricity, medium voltage	1.54E-02 MJ
heat, central or small-scale, other than natural gas	4.31E-02 MJ
heat, district or industrial, natural gas	1.20 MJ
Infrastructure	
waste preparation facility	5.56E-09 Item(s)
Transportation	
Transport, forklift, diesel-driven	3.30E-04 t*km
transport, freight train	1.50E-04 t*km
transport, freight, lorry 16-32 metric ton, EURO3	2.40E-02 t*km
transport, freight, lorry 16-32 metric ton, EURO4	0.108 t*km
transport, freight, lorry 16-32 metric ton, EURO5	0.164 t*km
transport, freight, lorry 16-32 metric ton, EURO6	2.83E-02 t*km

[1] This value expresses an aggregation of all polymer waste streams contributing to the EcoProfile inputs. Please find the disaggregated input values per-waste stream in the disaggregated datasets.

transport, freight, lorry 3.5-7.5 metric ton, EURO4	4.17E-03 t*km
transport, freight, lorry 7.5-16 metric ton, EURO4	2.50E-06 t*km
transport, freight, lorry, unspecified	6.52E-02 t*km
transport, freight, sea, container ship	3.35E-03 t*km
transport, passenger car	170.8 m
Solid Waste	
hazardous waste, for incineration	6.40E-07 kg
municipal solid waste	0.470 kg
raw sludge	4.63E-02 kg
waste plastic, mixture	0.138 kg
waste polyethylene	2.53E-02 kg
waste polyethylene terephthalate	3.74E-02 kg
waste yarn and waste textile	3.77E-07 kg
Secondary material outputs	
Waste fraction - diverse - recycling cut-off	1.97E-02 kg
Waste fraction - metal - recycling cut-off	3.20E-03 kg
Waste fraction - wood - recycling cut-off	3.73E-05 kg
Wastewater treatment	
wastewater, average	4.90E-04 m³
Water	1.16E-02 m³
Probability to litter plastic	
plastic litter	1.47E-03 kg

Table 2. Primary energy demand by carrier using CED method for an exemplary secondary material production process for recycled PET flakes with a cradle-to-gate boundary

Energy carrier	**Total energy input for 1kg of rPET flakes**
Oil, crude	3.84 MJ-Eq
Gas, natural	3.74 MJ-Eq
Uranium	1.80 MJ-Eq
Coal, hard	1.52 MJ-Eq
Coal, brown	0.54 MJ-Eq
Energy resources: non-renewable	11.49 MJ-Eq
Energy resources: renewable	1.19 MJ-Eq
Total	12.68 MJ-Eq

4 LCIA RESULTS

Table 3. Life cycle impacts of the cradle-to-gate rPET model related to 1 kg of flakes

Impact Category	**Impact assessment[2]**	**Unit**
Acidification	2.85E-03 ± 5.04E-04	mol H+-Eq
Climate change	1.27 ± 0.14	kg CO2-Eq
Ecotoxicity: freshwater	7.97 ± 1.15	CTUe
Energy resources: non-renewable	10.8 ± 2.6	MJ, net calorific value
Eutrophication: freshwater	2.40E-04 ± 3.25E-05	kg P-Eq
Eutrophication: marine	1.13E-03 ± 1.20E-04	kg N-Eq
Eutrophication: terrestrial	7.37E-03 ± 1.18E-03	mol N-Eq
Human toxicity: carcinogenic	5.94E-09 ± 2.22E-09	CTUh
Human toxicity: non-carcinogenic	1.12E-08 ± 1.81E-09	CTUh
Ionising radiation: human health	0.103 ± 0.011	kBq U235-Eq
Land use	5.22 ± 3.22	dimensionless
Material resources: metals/minerals	5.62E-06 ± 1.78E-06	kg Sb-Eq
Ozone depletion	1.67E-06 ± 1.30E-07	kg CFC-11-Eq
Particulate matter formation	4.00E-08 ± 6.74E-09	disease incidence
Photochemical oxidant formation: human health	2.84E-03 ± 6.08E-04	kg NMVOC-Eq
Plastic litter	8.93E-02 ± 5.82E-03	kg
Water use	0.238 ± 0.044	m3 world Eq deprived

[2] The uncertainty value presented here has been calculated on the foreground data. Details are described in the methodology.