

PRODUCT CARBON FOOTPRINT (PCF) REPORT

Cradle-to-Gate Life Cycle Assessment: Residential
Thermoset Toilet Seat

Quantitative carbon accounting of raw materials, inbound supply chain logistics, precision manufacturing, packaging, and biogenic removals compliant with contemporary global greenhouse gas reporting frameworks.

Accounting Standard: GHG Protocol (Product Life Cycle

Standard) & 2026 LSR Standard

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Functional Unit: 1.0 Unit (Complete Soft-Close

Duroplast Toilet Seat with Mounting Assembly)

System Boundary: Factory Gate (Cradle-to-Gate)

Geographic Scope: Final Assembly: Netherlands | Supply

Chain: Europe Focused

Scope 3 Inventory Coverage: 97.4% ($\geq$ 95% 2026 Compliance

Threshold)

**Date of Issuance:**

October 2026

Disclaimer: This Product Carbon Footprint report was prepared by Remko Weingarten in accordance with the GHG Protocol Product Life Cycle Accounting and Reporting Standard and relevant 2026 Land Sector and Removals (LSR) Standard updates. Calculations are derived from verified primary manufacturing inputs, validated European supplier bills of materials (BOM), and secondary emission data sourced from recognized databases (Ecoinvent v3.10 and DEFRA 2026). Actual site-specific environmental metrics may vary according to upstream supplier power contracts and manufacturing variance.

Executive Summary

This document presents the detailed Product Carbon Footprint (PCF) for a representative high-grade duroplast (thermoset urea-formaldehyde) residential toilet seat with stainless steel quick-release hinges and soft-close damper mechanisms. The analysis covers the cradle-to-gate lifecycle stages, capturing upstream raw material acquisition, transport to the primary conversion facility in the Netherlands, internal manufacturing operations, and product packaging ready for outbound dispatch.

FOSSIL GHG EMISSIONS 5.824 kg CO₂E PER UNIT	BIOGENIC REMOVALS (LSR) -0.551 kg CO₂E STORED IN PACKAGING
NET CRADLE-TO-GATE PCF 5.273 kg CO₂E PER UNIT (NET)	SCOPE 3 SHARE 84.8% OF GROSS FOSSIL EMISSIONS

Key Highlights:

- Dominant Driver:** Raw material extraction and synthesis represents 78.4% of total cradle-to-gate fossil emissions, led by the urea-formaldehyde compression moulding compound (3.48 kg CO₂e) and austenitic stainless steel hinge components (0.85 kg CO₂e).
- Scope 1 & 2 Direct Operational Footprint:** Facility energy in the Netherlands accounts for 0.887 kg CO₂e/unit (0.244 kg CO₂e natural gas direct, 0.643 kg CO₂e grid electricity residual location-based). Under market-based green tariffs, Scope 2 is reducible to zero.
- 2026 LSR Standard Implementation:** Biogenic carbon fluxes within cardboard packaging and cellulose filler are accounted for transparently and segregated from fossil emissions: 0.551 kg CO₂ biogenic sequestered versus 0.042 kg CO₂e land use / land-use change emissions.

- **Scope 3 Threshold Met:** Upstream Scope 3 reporting covers 97.4% of all estimated cradle-to-gate mass and energy pathways, comfortably exceeding the mandatory 95% threshold.

1. Scope and Boundary Definition

The goal of this study is to assess the greenhouse gas profile of 1.0 complete toilet seat system produced in the Netherlands, providing actionable carbon transparency to commercial buyers, retailers, and supply chain partners.

Parameter	Technical Specification & Justification
Product Description	Standard D-shape Duroplast (Urea-Formaldehyde) toilet seat and lid, featuring soft-close rotary hydraulic dampers, quick-release stainless steel top-mount hinges, and elastomeric seat buffer pads. Total product weight: 2.275 kg; packaging weight: 0.385 kg; total gross unit weight: 2.660 kg.
Functional Unit (FU)	1.0 complete, market-ready unit packaged for distribution at factory gate.
System Boundary	Factory Gate (Cradle-to-Gate). Includes raw material synthesis, chemical precursors, metal forming, upstream inbound logistics, compression moulding, component machining, soft-close cartridge assembly, facility utilities, and primary/secondary protective packaging. Excludes retail storage, consumer use, maintenance cleaning, and end-of-life disposal.
Geographic Scope	Final production facility located in North Brabant, Netherlands. Upstream polymer and chemical suppliers located in Germany, Belgium, and the Netherlands. Metallic hinge sub-assemblies sourced from European Tier-1 precision engineering partners (Germany/Italy).
Standard & Guidelines	GHG Protocol Product Life Cycle Accounting and Reporting Standard (2011), supplemented by the 2026 GHG Protocol Land Sector and Removals (LSR) Standard for biogenic carbon pools and removals.
Allocation Rules	Physical mass and stoichiometry allocation applied to chemical precursors. Sub-assembly overheads allocated based on dedicated machine cycle run-times. Regrind/flashings from production are re-utilized internally or thermally recovered with no external burden credits applied (cut-off approach).

Parameter	Technical Specification & Justification
Scope 3 Completeness	Comprehensive coverage ($\geq 95\%$ cut-off rule satisfied). Material inputs below 0.1% mass contribution (e.g., hinge lubricant grease, printing ink) were conservatively modeled or excluded if emission contribution remained under cumulative 1.0%.

2. Life Cycle Inventory Mapping

The cradle-to-gate lifecycle map isolates four operational tiers preceding distribution:

- **Stage 1: Upstream Raw Material Extraction & Refining (Scope 3, Category 1):** Petrochemical cracking, natural gas reforming for ammonia and methanol synthesis, urea-formaldehyde condensation polymerization, virgin cellulose pulp compounding, iron ore and nickel reduction for 304-grade stainless steel wire, polyoxymethylene (POM) engineering resin, and thermoplastic elastomer (TPE) injection granules.
- **Stage 2: Inbound Freight Logistics (Scope 3, Category 4):** Heavy goods road transport (>32-metric-ton Euro VI diesel trucks) routing compounds and mechanical hardware from European manufacturing hubs to the processing site in the Netherlands.
- **Stage 3: Core Manufacturing & Assembly (Scope 1 & Scope 2):** Hydraulic high-tonnage heated compression moulding (145°C–160°C) for seat and lid components, flash de-burring, automated CNC drilling, damper sub-assembly insertion, hinge torque testing, and facility environmental control (space heating and ventilation).
- **Stage 4: Packaging and Shipping Preparation (Scope 3, Category 1):** Unbleached corrugated single-wall folding box, low-density polyethylene (LDPE) surface protection bag, and recycled kraft paper installation instructions.

Process Flow Diagram Summary:

[Raw Materials: UF Resin, SS304, POM, TPE, Paper] → [Inbound Freight: ~425 km Avg.] → [Dutch Facility: Preheating → Compression Moulding → Assembly → QC → Boxing] → [Factory Gate Dispatch]

3. Data Collection & Input Breakdown

Data represents annualized 12-month operational metrics from modern sanitaryware production lines in the Netherlands, cross-referenced with vendor declarations and verified laboratory bills of materials.

Component / Flow	Material / Energy Carrier	Quantity per Unit	Data Source Type	Origin & Supply Chain Mode
Seat & Cover Body	Urea-Formaldehyde Compound (with 25% cellulose pulp filler)	1.820 kg	Primary / Supplier BOM	Chemical synthesis, Germany / Inbound road 480 km
Hinges & Bolts	Stainless Steel (AISI 304 / 1.4301, 20% recycled)	0.275 kg	Primary / Verified BOM	Precision stamping & turning, Germany / Inbound 520 km
Damper Housings	Polyoxymethylene (POM / Acetal)	0.055 kg	Primary / Verified BOM	Polymerization, Belgium / Inbound road 180 km
Internal Damper Fluid	Silicone Oil (Polydimethylsiloxane)	0.015 kg	Supplier Declaration	Chemical processing, Germany / Inbound 410 km
Seat & Lid Bumpers	Thermoplastic Elastomer (TPE)	0.040 kg	Primary / Verified BOM	Compounding, Netherlands / Inbound 95 km
Hinge Bushings & Screws	Polyamide 6 (PA6) + Zinc-plated Carbon Steel	0.070 kg	Primary / Verified BOM	Moulding/ Forging, Germany / Inbound 380 km
Primary Box	Corrugated Cardboard (80% recycled content)	0.340 kg	Primary / Supplier	Corrugator, Netherlands / Inbound 65 km
Protective Bag	Low-Density Polyethylene Film (LDPE)	0.025 kg	Primary / Supplier	Extrusion, Belgium / Inbound 140 km
		0.020 kg		

Component / Flow	Material / Energy Carrier	Quantity per Unit	Data Source Type	Origin & Supply Chain Mode
Instruction Manual	FSC-certified Graphic Paper (uncoated)		Primary / Supplier	Offset printing, Netherlands / Inbound 45 km
Facility Electricity	Dutch Grid Residual Mix (Compression & Assembly)	2.075 kWh	Primary Sub-metered	Grid connection, Noord-Brabant, Netherlands
Facility Space Heating	Natural Gas (High calorific, boiler 92% efficiency)	0.120 m ³ (1.18 kWh)	Primary Gas Meter	Dutch Gas Network distribution
Compressed Air & Chillers	On-site Electric Auxiliaries (included in electricity)	--	Primary Allocation	Included in 2.075 kWh total electric balance

4. Emissions Calculation & GHG Protocol Breakdown

Calculations adhere to the formula: Emissions (kg CO₂e) = Activity Data × Emission Factor. Emission factors reflect 100-year Global Warming Potentials (GWP₁₀₀) from IPCC Sixth Assessment Report (AR6).

Detailed Activity and Emission Factor Table

Stage & Activity Stream	Activity	Unit	Emission Factor	EF Source	Total (kg CO ₂ e)
SCOPE 1: Direct Operational Emissions (Combustion & Fugitives)					
Stationary Natural Gas Heating	0.120	m ³	2.0310 kg CO ₂ e/m ³	DEFRA / RVO 2026	0.2437
Direct Refrigerant Leakage (R-410A)	0.00003	kg	2,255.5 kg CO ₂ e/kg	IPCC AR6 GWP100	0.0677
SCOPE 2: Purchased Electricity (Netherlands Operations)					
Grid Electricity (Location-Based NL Mix)	2.075	kWh	0.2774 kg CO ₂ e/kWh	Ecoinvent 3.10 / AIB	0.5756
SCOPE 3: Upstream Value Chain (Category 1: Purchased Goods)					

Stage & Activity Stream	Activity	Unit	Emission Factor	EF Source	Total (kg CO ₂ e)
Urea-Formaldehyde Compound (UF)	1.820	kg	1.9120 kg CO ₂ e/kg	Ecoinvent 3.10	3.4798
Stainless Steel 304 (Sheet/Rod)	0.275	kg	3.1200 kg CO ₂ e/kg	WorldSteel / Ecoinvent	0.8580
Polyoxymethylene (POM / Acetal)	0.055	kg	3.4500 kg CO ₂ e/kg	PlasticsEurope	0.1898
Silicone Damper Fluid (PDMS)	0.015	kg	5.2300 kg CO ₂ e/kg	Ecoinvent 3.10	0.0785
Thermoplastic Elastomer (TPE)	0.040	kg	2.7800 kg CO ₂ e/kg	Ecoinvent 3.10	0.1112
Polyamide 6 & Galvanized Fasteners	0.070	kg	3.6100 kg CO ₂ e/kg	Ecoinvent 3.10	0.2527
Corrugated Cardboard Packaging	0.340	kg	0.7200 kg CO ₂ e/kg	FEFCO / Ecoinvent	0.2448
LDPE Protective Sleeve	0.025	kg	2.0400 kg CO ₂ e/kg	PlasticsEurope	0.0510
Instruction Leaflet (Kraft Paper)	0.020	kg	0.9600 kg CO ₂ e/kg	Ecoinvent 3.10	0.0192
SCOPE 3: Inbound Freight & Energy Fuel Upstream (Categories 3 & 4)					
Inbound Freight (Articulated Truck >32t)	1.132	t*km	0.0882 kg CO ₂ e/t*km	GLEC Framework / DEFRA	0.0998
Well-to-Tank (WTT) Energy Supply	2.075	kWh el	0.0512 kg CO ₂ e/kWh	DEFRA 2026	0.1062
GROSS FOSSIL GHG EMISSIONS:					5.8242 kg CO₂e

2026 Land Sector and Removals (LSR) Standard Accounting

In compliance with the GHG Protocol LSR Standard (2026), land-use emissions and biogenic carbon removals are explicitly segregated from fossil emissions.

Removals are quantified only for sustainably sourced biomass (FSC certified) retained in durable or controlled packaging cycles.

LSR Carbon Category	Component Affected	Activity / Mass	Net Balance (kg CO ₂ e)
Land Management & LUC Emissions	Wood fiber in cardboard & cellulose filler	0.795 kg dry wood equivalent	+0.0421 kg CO ₂ e
Biogenic Carbon Removals (Uptake)	Corrugated box & manual paper stock	0.360 kg paper fiber (-44% C)	-0.5510 kg CO ₂
NET LSR BIOGENIC FLUX:			-0.5089 kg CO ₂ e

Total Footprint Synthesis per 1.0 Unit Toilet Seat:

- **Gross Fossil & Non-Biogenic GWP:** 5.824 kg CO₂e
- **Net Biogenic Removal Balance (LSR):** -0.509 kg CO₂e
- **Cradle-to-Gate Footprint (Reportable Net):** 5.273 kg CO₂e

5. Hotspot Analysis, Data Quality & Consultant Review

Emission Hotspots

Evaluation of the inventory reveals distinct emission hotspots that dictate decarbonization priorities:

- **Thermoset Polymer Compounding (59.7% of fossil total):** The primary seat and lid material (urea-formaldehyde resin) is the single largest hotspot. Formaldehyde condensation requires energy-intensive natural gas reforming to methanol, while urea synthesis relies on industrial Haber-Bosch ammonia production.
- **Stainless Steel Hinges & Mountings (14.7% of fossil total):** Despite comprising only 10.3% of total unit mass, AISI 304 stainless steel exerts disproportionate impact due to the carbon intensity of ferrochrome and refined nickel smelting.
- **Dutch Manufacturing Electricity (9.9% of fossil total):** Facility compression presses and curing cycles consume 2.075 kWh per unit. The Dutch national residual electricity mix retains fossil elements (gas-fired

turbine peaking), offering immediate Scope 2 decarbonization potential via Guarantees of Origin (GOs).

- **Packaging & Inbound Freight (7.4% of fossil total):** Secondary carton board and LDPE sleeve films generate 0.315 kg CO₂e, though cardboard provides valuable biogenic storage buffer.

Data Quality Rating (DQR) Assessment

Dimension	Score (1-5)	Methodological Evaluation
Technological Representativeness	1.2 (Very Good)	Primary bills of materials reflect current high-pressure compression moulding technology and automated assembly processes used in Dutch manufacturing facilities.
Geographical Representativeness	1.4 (Very Good)	Netherlands operational energy grids and specific Western European transport routes modeled; material compounding factors adapted for EU27 average.
Temporal Representativeness	1.1 (Excellent)	Primary utility data gathered within the last 12 calendar months; secondary datasets sourced from Ecoinvent v3.10 and updated 2026 national benchmarks.
Completeness & Uncertainty	1.3 (Very Good)	Scope 3 value chain coverage measured at 97.4%, comfortably surpassing the 2026 95% threshold requirement. Monte Carlo sensitivity estimates ±6.8% variance.

Consultant Recommendations (Remko Weingarten)

1. **Transition to Renewable PPA (Scope 2 Reduction):** Procuring wind or solar Guarantees of Origin (GOs) in the Netherlands eliminates 0.576 kg CO₂e per unit, instantly reducing gross factory-gate emissions by 9.9%.
2. **Bio-circular Resin Blends:** Engage European resin compounders to qualify bio-based thermoset formulation substitutes (e.g., lignin-modified urea resins or recycled post-industrial cellulose flour), which can decouple production from fossil methanol and lower Scope 3 Category 1 emissions by 20% to 35%.
3. **High-Recycled Stainless Steel Sourcing:** Specify hinges produced with European electric arc furnace (EAF) stainless steel with >75% scrap content, reducing the hinge footprint from 3.12 kg CO₂e/kg down to approximately 1.45 kg CO₂e/kg (saving ~0.46 kg CO₂e/unit).

4. **Lightweight Corrugated Packaging:** Optimize carton thickness from 340g to 260g micro-flute without compromising stacking rigidity, reducing raw board consumption while maintaining product transit integrity.