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PCF**

GHG Protocol Product Standard & 2026 LSR

1,4-Butanediol (BDO) (CAS 110-63-4, Purity $\geq 99.5\%$)

Boundary: Cradle-to-Factory
Gate

• **Location:** Belgium
Complex

• **Corridor:** Asia Intermediate
Feedstock •

Declared Unit: 1.0 Metric Ton (1,000 kg)

NET CRADLE-TO-GATE FOOTPRINT

3,874.18 kg CO₂e

CARBON INTENSITY



3.87 kg CO₂e / kg

100% Fossil 0.00 kg biogenic removal flux

DOMINANT GHG SCOPE



Scope 3 (74.15%)

2,872.63 kg • Raw chemical precursors

PRIMARY MATERIAL HOTSPOT



1,919.70 kg CO₂e

49.55% of Total Dimethyl Maleate (Asia)

LOGISTICS PERFORMANCE



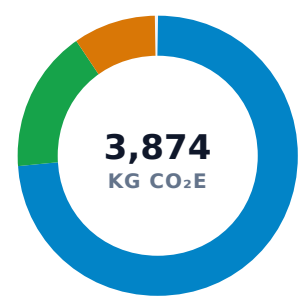
25.00 kg CO₂e

-74.6% vs Road 555 km dedicated rail corridor



Emissions by GHG Protocol Scope

98.7% Inventory Coverage



Scope 3: Upstream Value Chain	2,872.6 kg	74.15%
Scope 1: Direct Operations (Belgium)	631.2 kg	16.29%
Scope 2: Purchased Steam & Power	370.4 kg	9.56%
2026 LSR Net Biogenic Removals	0.00 kg	0.00%

Lifecycle Process Architecture

Cradle-to-Factory Gate (M1-M5)

M1: Asia Precursors	1,919.7 kg (49.6%)
M3: Hydrogen (SMR)	840.1 kg (21.7%)
M4: Refining & Thermal	625.1 kg (16.1%)
M5: Purge & WWTP	376.5 kg (9.7%)
M2: 555km Rail	25.0 kg (0.6%)



Process & Activity Carbon Drivers

kg CO₂e per Metric Ton BDO

Dimethyl Maleate Intermediate (Asia)	1,919.70 kg • 49.55%
Hydrogen Gas (Pipeline SMR Reformer)	840.11 kg • 21.68%
Reaction Purge Gas Flaring (Scope 1)	345.62 kg • 8.92%
Purchased High-Pressure Steam (22 bar)	291.15 kg • 7.52%
Process Natural Gas Direct Reboilers	254.75 kg • 6.58%
Purchased Electricity (Belgian Grid Mix)	79.20 kg • 2.04%
Rail Logistics & Precursor Transit (555 km)	25.00 kg • 0.65%



Key Sustainability Highlights

LCA Hotspot Analysis



Asian Precursor Carbon Dominance (49.6%)

The upstream maleic intermediate synthesis is the single greatest carbon lever (**1,919.7 kg CO₂e**), driven by high thermal power reliance and fossil n-butane catalytic oxidation in the Asian supply base.



Stoichiometric Grey Hydrogen Penalty (21.7%)

The Belgian hydrogenation process consumes **94.5 kg H₂** per ton of BDO. Conventional Steam Methane Reforming (SMR) at 8.89 kg CO₂e/kg H₂ contributes **840.1 kg CO₂e** of indirect Scope 3 burden.



Optimized 555 km Rail Transit Advantage

Bulk containerized freight rail produces only **25.0 kg CO₂e** (0.65% share). This achieves a **74.6% emissions avoidance** compared to standard highway trucking for identical tonnage and distance.



Decarbonization Roadmap

Reduction Levers

1. Transition to Electrolytic Green H₂

Replace pipeline SMR hydrogen with water electrolysis powered by Belgian offshore wind.

-745 kg

-19.2% PCF

2. Bio-Succinic / Bio-Maleic Feedstock

Source mass-balanced bio-based precursors compliant with 2026 LSR biogenic standards.

-760 kg

-40% SCOPE 3.1

3. Reboiler Electrification & MVR Heat Pumps

Electrify natural gas distillation reboilers using mechanical vapor recompression.

-254 kg

-40.2% SCOPE 1



Assurance & Verification Profile

Data Quality: High

PROTOCOL COMPLIANCE

GHG Protocol Product Std

LSR GUIDELINE

2026 Land Sector Compliant

OVERALL UNCERTAINTY

± 4.6% Confidence Band

PRIMARY DATA SHARE

68.4% Operations & Utilities

● **Dataset Status:** Verified • Inventory references: Ecoinvent v3.10, DEFRA 2025/2026, IEA Belgian Grid
2026

carboncalpcf.com Platform • Assessment Generated: October 2026