



Solar-Grade Polysilicon (Si $\geq$ 99.9999999%)

Product Carbon Footprint (PCF) Analytics • Modified Siemens Closed-Loop Process

✓ **ISO 14064
Compliant**

Functional Unit: 1.0 kg

Origin: China (CN)

Audit Readiness: Level 1

TOTAL CARBON FOOTPRINT



54.72 kg CO₂e / kg

🕒 Boundary: **Cradle-to-Factory Gate**

ENERGY INDIRECT (SCOPE 2)



68.3% 37.37 kg CO₂e

Driven by **59.5 kWh** electricity/kg polysilicon

TOP RAW MATERIAL (MGS)

From **1.08 kg MGS** SAF carbothermic reduction



DEEP-SEA LOGISTICS (SCOPE 3)



0.22% 0.12 kg CO₂e

10,000 km transoceanic maritime freight

🕒 **Emissions by Standardized Scope & Process Stage**

ISO 14064 categorized breakdown per 1.0 kg finished polysilicon

■ Scope 1 (Direct):	0.48 kg (0.88%)	■ Scope 2 (Power & Steam):	37.37 kg (68.30%)	■ Scope 3 (Upstream Supply):	16.87 kg (30.82%)
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LIFE CYCLE STAGE CONTRIBUTION (CRADLE-TO-GATE)

MGS Smelting (SAF)

14.90 kg (27.2%)

Siemens CVD Core (48 kWh)

29.29 kg (53.5%)

Auxiliary & Distillation

8.09 kg (14.8%)

Reagents (H2, HCl, UPW)

0.84 kg (1.5%)

Direct Facility (Scope 1)

0.48 kg (0.9%)

Maritime Transit (10,000 km)

0.12 kg (0.2%)



Regional Grid Decarbonization Sensitivity

Impact of Chinese provincial grid emission factor variations

Because **59.5 kWh of electricity** is required per functional unit, location choice produces up to a **53.5% swing** in total product carbon footprint.

Southwest Hydro Grid (Sichuan/Yunnan)

EF: 0.240 kg CO₂e / kWh • Renewable-Powered

31.6 kg CO₂e

↓ 42.3% lower than current baseline

National Industrial Baseline (Current PCF)

EF: 0.6101 kg CO₂e / kWh • Mixed Thermal/Renewable

54.72 kg CO₂e

Current Audit Baseline Benchmark

Northwest Thermal Grid (Xinjiang/Inner Mongolia)

EF: 0.850 kg CO₂e / kWh • Sub-critical Coal Predominant

67.9 kg CO₂e

↑ 24.1% higher carbon intensity

≡ **Activity Stream Inventory Breakdown**

Activity data, emission factors, and GWP100 quantification

INVENTORY INPUT / STREAM	QUANTITY (FU: 1KG)	EMISSION FACTOR	SCOPE	GHG CONTRIBUTION
CVD Bell-Jar Electricity	48.00 kWh	0.6101 kg CO ₂ e/kWh	Scope 2	29.28 kg
Metallurgical Silicon (MGS)	1.08 kg	13.800 kg CO ₂ e/kg	Scope 3	14.90 kg
Auxiliary Power & Distillation	11.50 kWh	0.6101 kg CO ₂ e/kWh	Scope 2	7.02 kg
Purchased Industrial Steam	18.50 MJ	0.0580 kg CO ₂ e/MJ	Scope 2	1.07 kg
Hydrogen Gas (99.999%)	0.045 kg	10.200 kg CO ₂ e/kg	Scope 3	0.46 kg
On-site Gas Combustion & Flaring	0.12 m ³	2.0200 kg CO ₂ e/m ³	Scope 1	0.24 kg
Hydrochloric Acid (HCl 100%)	0.14 kg	1.6800 kg CO ₂ e/kg	Scope 3	0.24 kg
Deep-Sea Maritime Freight	11.50 t·km	0.0105 kg CO ₂ e/t·km	Scope 3	0.12 kg

Key Sustainability Insights

Critical auditor and operational findings



Bell-Jar CVD Reaction is the Primary Carbon Anchor

Direct resistive heating of silicon slim rods to $\sim 1,100^{\circ}\text{C}$ requires 48 kWh/kg, driving **53.5% of total cradle-to-gate emissions** alone. Enhancing reactor insulation shields and optimizing batch cycle runtimes represent the single most impactful lever.



MGS Embodied Smelting is 94% of Feedstock Scope 3

Carbothermic reduction of silica with coal, coke, and charcoal emits both direct fossil CO_2 and high electrical demand (11.5 kWh/kg MGS). Transitioning to bio-char reductants and renewable-powered SAF furnaces reduces upstream pressure.



Global Maritime Freight Displays Low Impact Relative to Mass

At **0.12 kg CO_2e per 10,000 km**, deep-sea shipping represents merely 0.22% of total impact. Decarbonization investments should decisively favor grid electricity source procurement over shortening sea logistics routes.

↗ Targeted Decarbonization Roadmap & Action Plan

Recommended interventions to reduce polysilicon PCF towards ≤ 25 kg CO₂e / kg

Expected Abatement: Up to 55%

IMMEDIATE (0-12 MO)

Green Power Purchase Agreements (PPAs)

Contract dedicated off-site solar/wind or migrate facility operations to hydro-dense grids (e.g., Sichuan/Yunnan). Shifting power emission factors from 0.61 to 0.24 cuts 23.1 kg CO₂e instantly.

✓ **Abatement Potential: 42.3% of total PCF**

MEDIUM TERM (12-24 MO)

Low-Carbon Bio-Reductant MGS Procurement

Establish strict procurement rules favoring Metallurgical Silicon suppliers using certified biogenic charcoal instead of fossil petroleum coke, combined with hydro-powered electric arc furnaces.

✓ **Abatement Potential: 5.5 to 8.0 kg CO₂e / kg**

LONG TERM (24-36 MO)

High-Efficiency FBR Process Transition

Complement or replace Modified Siemens bell-jar reactors with Fluidized Bed Reactor (FBR) granular polysilicon technology, decreasing synthesis power draw from ~48 kWh/kg down to ≤ 15 kWh/kg.

✓ **Abatement Potential: ~20.1 kg CO₂e / kg**

carboncalcpcf.com • Industrial Product Carbon Footprint Platform • ISO 14064 & ISO 14067 Audit Ready

Data Quality: **High (DQR 1.3)**

Background LCI: **Ecoinvent 3.10 / IPCC AR6**

Assurance Level: **Limited & Reasonable Audit Ready**