carboncalcpcf.com

Product Carbon Footprint Analysis Report

Acetic Acid

Accounting Standard: GHG Protocol

Prepared for: Internal Stakeholders

Prepared by: Senior Sustainability Consultant (GHG Protocol Specialist)

Product Carbon Footprint Analysis: Acetic Acid

Generated Date: September 2, 2026

Executive Summary

This report presents a high-detail Product Carbon Footprint (PCF) analysis for 1.0 kg of Acetic Acid, adhering to the GHG Protocol. The analysis covers a "factory_gate" system boundary, with final production occurring in China and a supply chain focus on Europe for certain inputs/processes. Key parameters such as sea transport over 6000 km and direct-to-consumer last-mile delivery are integrated into the assessment. The primary objective is to quantify Greenhouse Gas (GHG) emissions across the product\'s lifecycle, categorize them into Scope 1, 2, and 3, and identify emission hotspots to inform decarbonization strategies. The report also incorporates the 2026 Land Sector and Removals (LSR) Standard update and ensures at least 95% coverage for Scope 3 reporting, reflecting the latest requirements in climate accounting.

---

1. Define Scope

1.1 Functional Unit

The functional unit for this Product Carbon Footprint (PCF) analysis is **1.0 kilogram (kg) of Acetic Acid**. This unit serves as the reference basis for quantifying all associated environmental impacts.

1.2 System Boundary

The system boundary for this PCF is defined as **"factory_gate"**. This encompasses all greenhouse gas (GHG) emissions from the raw material

acquisition phase (cradle) through to the manufacturing of the acetic acid and its departure from the final production facility (gate). This includes:

- Extraction and processing of raw materials.
- Upstream transportation of raw materials to the manufacturing facility.
- Energy consumption (electricity, heat) at the manufacturing facility.
- Direct process emissions from chemical reactions within the factory.

Emissions from the use phase and end-of-life treatment of the product are outside this "factory_gate" boundary but downstream transportation is specifically requested and included as a critical Scope 3 component.

1.3 Geographic Scope

The geographic scope for this analysis is defined by:

- **Final Production Country: China.** This implies that the manufacturing processes and associated direct energy consumption primarily utilize the Chinese energy grid mix and local infrastructure.
- **Supply Chain Focus: Europe Focused.** This consideration is primarily for aspects like potential sourcing of specific catalysts or technology, and for the downstream distribution channels, specifically for the primary transport leg (sea freight) and last-mile delivery.

1.4 Allocation

Allocation methods are crucial for distributing environmental impacts when a process yields multiple co-products or involves shared infrastructure. For this PCF, due to the focus on a single product (acetic acid), direct attribution of emissions is prioritized where possible. In cases where upstream processes in the supply chain produce co-products, **mass-based allocation** is the default method applied. This method attributes impacts proportionally to the mass of the output products. This approach is widely accepted and commonly used due to its simplicity and direct correlation with physical material flows.

---

2. Map Lifecycle (LCI Inventory Stages) & 3. Collect Data (Primary/Secondary Data Points)

The lifecycle mapping and data collection focus on the dominant production method for acetic acid and its associated supply chain elements.

2.1 Acetic Acid Production Process: Methanol Carbonylation

The vast majority of industrial acetic acid is produced via the methanol carbonylation process. This energy-intensive process involves reacting methanol and carbon monoxide over a catalyst, typically a metal complex like rhodium or iridium (e.g., Cativa process).

2.2 Detailed Breakdown of Materials and Energy Inputs (Cradle-to-Gate)

For 1.0 kg of Acetic Acid (Cradle-to-Gate):

2.2.1 Primary Raw Materials

- **Methanol:** The primary feedstock, reacting with carbon monoxide. Upstream methanol production is a significant contributor to the overall carbon footprint, often accounting for over 60% of total lifecycle emissions, especially when derived from fossil-based natural gas or coal, which is prevalent in China.
- **Carbon Monoxide (CO):** Another key reactant.
- **Catalyst:** Metal complexes (e.g., rhodium or iridium compounds) facilitate the reaction.
- **Water:** Used in various stages, including for cooling and potential purification steps.

2.2.2 Energy Inputs at Production Facility (China)

Acetic acid production is energy-intensive, requiring specific temperature and pressure conditions in the reactor, as well as energy for separation and purification processes like distillation. The main energy inputs are:

- **Electricity:** Sourced from the Chinese national grid.
- **Heat/Steam:** Often generated from natural gas combustion or co-generation units.

Typical industrial data indicates energy consumption of 30-40 GJ per ton of product, which translates to 30-40 MJ/kg of acetic acid.

2.3 Transportation (Downstream)

2.3.1 Primary Transport Mode: Sea Freight

- **Mode:** Sea (Container Ship)
- **Distance:** 6,000 km
- **Route:** Assumed from a major port in China (e.g., Shanghai) to a major port in Europe (e.g., Rotterdam or Hamburg).

2.3.2 Last-Mile Delivery Channel: Direct-to-Consumer

- **Mode:** Light Commercial Vehicle / Van
- **Channel:** Direct shipments from a regional distribution hub to individual consumers in Europe. This channel is characterized by potentially lower load factors and more frequent stops compared to business-to-business deliveries, leading to higher emissions per unit of product.

2.4 GHG Protocol Scope 3 Categories

Scope 3 emissions are all indirect GHG emissions not included in Scope 1 or Scope 2, occurring in the value chain of the reporting company. This analysis ensures at least 95% coverage for Scope 3 reporting. The relevant categories for this PCF include:

- **Category 1: Purchased Goods and Services:** This category is highly significant and covers the embedded emissions in all raw materials (methanol, carbon monoxide, catalysts) and the emissions

associated with their manufacturing processes up to the factory gate in China. For this report, the "cradle-to-gate" factor for acetic acid production (excluding downstream transport) will primarily fall into this category.

- **Category 3: Fuel- and Energy-Related Activities (not included in Scope 1 or 2):** Covers upstream emissions associated with the production and extraction of fuels and purchased electricity used at the manufacturing facility. These are typically integrated into the emission factors used for electricity and natural gas.
- **Category 4: Upstream Transportation and Distribution:** This covers the transportation of raw materials to the acetic acid manufacturing plant in China. (These are implicitly covered within the cradle-to-gate factor for purchased goods and services).
- **Category 9: Downstream Transportation and Distribution:** This crucial category includes emissions from the sea freight of the finished acetic acid from China to Europe and the subsequent direct-to-consumer last-mile delivery.

2.5 2026 Land Sector and Removals (LSR) Standard Update

The GHG Protocol\'s Land Sector and Removals (LSR) Standard, released in January 2026, provides accounting requirements and guidance for land emissions and CO_2 removals. While the standard takes effect on January 1, 2027, companies are expected to use 2026 data for their first compliant inventory. It\'s essential for companies with land sector activities, including producing, processing, buying, or selling agricultural products.

For synthetic acetic acid production via methanol carbonylation, direct land-use change is less prominent. However, the LSR Standard is relevant for:

- **Feedstock Origin:** If methanol or other raw materials were sourced from bio-based routes, any land-use change (e.g., deforestation for biomass) associated with their production would fall under the LSR Standard.
- **Energy Mix:** If the electricity or heat used in the supply chain incorporates significant biomass or hydropower, the land-use implications (e.g., reservoir creation) would need to be considered under the LSR Standard.

In this PCF, given the fossil-based nature of typical methanol production in China and grid electricity, direct application of LSR accounting for this specific product is limited. However, it\'s acknowledged as a critical emerging standard for comprehensive Scope 3 reporting, especially as supply chains transition towards bio-based feedstocks and renewable energy sources.

---

4. Calculate Emissions (Activity * Emission Factor = CO2e)

This section quantifies the GHG emissions for the functional unit (1.0 kg of Acetic Acid) by multiplying activity data by representative industry-standard emission factors.

4.1 Emission Factors Used

Activity/Material	Emission Factor (EF)	Unit	Source/Comment
Acetic Acid Production (Cradle-to-Gate, excluding downstream transport)	1.66	kg CO_2e/ kg product	Verified by CarbonCloud, for E260 (Acetic Acid) at factories worldwide. This covers raw material acquisition and manufacturing processes.
Electricity Grid Mix (China, 2025 average)	0.525	kg CO_2e/ kWh	Ember estimate for China\'s power sector carbon intensity in 2025.
Natural Gas (Europe, incl. upstream & combustion)	0.244	kg CO_2e/ kWh	Representative factor for natural gas in Europe, including combustion and upstream activities.
Sea Freight (Container Ship, average)	0.01598	kg CO_2e/ tonne-km	Derived from UK DEFRA 2019/ GHG Protocol data via Climatiq.
Last-Mile Delivery (Direct-to-consumer Van)	0.24934	kg CO_2e/ km (van)	UK BEIS/Defra 2024 factor for average van (up to 3.5 tonnes). Specific calculation for product is derived below.

4.2 Emissions Calculation for 1.0 kg Acetic Acid

4.2.1 Acetic Acid Production (Cradle-to-Gate)

This includes raw material extraction, processing, upstream transport of raw materials, and manufacturing at the factory in China.

- Activity: 1.0 kg Acetic Acid produced
- Emission Factor: 1.66 kg CO_2e/kg product
- **Emissions: 1.0 kg * 1.66 kg CO_2e/kg = 1.66 kg CO_2e**
- **GHG Scope Allocation:** Primarily Scope 3, Category 1 (Purchased Goods and Services), as it represents the embedded emissions from the upstream value chain of acquiring and transforming materials into the final product at the factory gate.

4.2.2 Downstream Transportation: Sea Freight

Transport of 1.0 kg of Acetic Acid over 6,000 km by container ship from China to Europe.

- Activity: 1.0 kg * 6,000 km = 6,000 kg-km (or 6 tonne-km)
- Emission Factor: 0.01598 kg CO_2e/tonne-km
- **Emissions: 6 tonne-km * 0.01598 kg CO_2e/tonne-km = 0.09588 kg CO_2e**
- **GHG Scope Allocation:** Scope 3, Category 9 (Downstream Transportation and Distribution).

4.2.3 Downstream Transportation: Last-Mile Delivery (Direct-to-Consumer)

This is for delivering 1.0 kg of Acetic Acid from a European distribution hub to the end consumer. Given the direct-to-consumer model, vehicle utilization is often lower. We assume an average last-mile distance of 10 km covered by a van specifically for the delivery of this product (or the portion of the route associated with it) and an average load factor for the van of 50 kg for our product category.

- Van Emission Factor: 0.24934 kg CO_2e/km (average van)
- Assumed Last-Mile Distance per delivery item: 10 km

- Assumed Average Load for product category in van: 50 kg
- Emissions per kg of product per km: 0.24934 kg CO_2e/km / 50 kg = 0.0049868 kg CO_2e/kg-km
- **Emissions for 1.0 kg product over 10 km: 1.0 kg * 10 km * 0.0049868 kg CO_2e/kg-km = 0.049868 kg CO_2e**
- **GHG Scope Allocation:** Scope 3, Category 9 (Downstream Transportation and Distribution).

4.3 Total Product Carbon Footprint (PCF)

The aggregated PCF for 1.0 kg of Acetic Acid from Cradle-to-Gate (plus specified downstream transport):

Lifecycle Stage	Emissions (kg CO_2e)	GHG Scope	GHG Category
Acetic Acid Production (Cradle-to-Gate)	1.66000	Scope 3	Category 1: Purchased Goods and Services
Downstream Transport: Sea Freight (6,000 km)	0.09588	Scope 3	Category 9: Downstream Transportation and Distribution
Downstream Transport: Last-Mile Delivery (Direct-to-Consumer)	0.04987	Scope 3	Category 9: Downstream Transportation and Distribution
Total PCF (for 1.0 kg Acetic Acid)	**1.80575**		

Total Product Carbon Footprint: 1.81 kg CO_2e per 1.0 kg of Acetic Acid.

4.4 Scope 1, 2, and 3 Summary

Based on the calculated emissions and typical allocation for "factory_gate" plus downstream transport:

- **Scope 1 Emissions:** In this simplified PCF with a "cradle-to-gate" aggregate for production, direct process emissions and on-site fuel combustion for energy generation are considered embedded within the 1.66 kg CO_2e/kg for purchased goods and services. If separate, these would be direct emissions from owned or controlled sources at

the production facility (e.g., combustion of natural gas for process heat not covered by purchased energy scope 2). For a high-detail plant-level analysis, specific onsite fuel consumption would be measured. For this analysis, we assume minimal direct Scope 1 not covered by the aggregate Scope 3 Category 1.

- **Scope 2 Emissions:** Similarly, purchased electricity and heat at the Chinese production facility would fall under Scope 2. However, these are often included in the cradle-to-gate factor for purchased goods (Scope 3, Category 1) when applying a product-level EF. For direct reporting by the manufacturer, this would be crucial. For this PCF, it\'s considered embedded within the 1.66 kg CO_2e/kg as part of the upstream value chain emissions of the manufactured product.
- **Scope 3 Emissions: 1.80575 kg CO_2e.** This constitutes approximately 100% of the calculated PCF, comprising Category 1 (Purchased Goods and Services - 1.66 kg CO_2e), and Category 9 (Downstream Transportation and Distribution - 0.09588 kg CO_2e + 0.04987 kg CO_2e). This comfortably meets the 95% coverage requirement for Scope 3 reporting.

---

5. Review & Report

5.1 Emission Hotspots and Reliability

The analysis clearly indicates that the predominant emission hotspot for acetic acid is the **production phase (Cradle-to-Gate, Scope 3 Category 1)**, accounting for approximately 91.9% of the total PCF.

- **Raw Material Production:** Upstream methanol production is a critical area, especially given the reliance on coal-based feedstocks in China, which significantly elevates its carbon intensity. Shifting to green methanol (from renewable sources like biomass or green hydrogen) would drastically reduce this impact.
- **Manufacturing Energy:** The energy-intensive nature of acetic acid synthesis and purification contributes to the overall footprint, with the Chinese electricity grid mix (largely coal-dependent) being a key factor. Decarbonization of the power sector in China is crucial for reducing this aspect of the footprint.

- **Downstream Transportation:** While significant in absolute terms, the contribution of sea freight and last-mile delivery is smaller compared to the production phase, at about 5.3% and 2.8% respectively. Nevertheless, these areas offer opportunities for optimization through mode shifts, route optimization, and cleaner fuels/vehicles.

5.2 Data Quality and Limitations

This report relies on a combination of secondary data and representative industry-average emission factors due to the hypothetical nature of the specific facility and supply chain data.

- **Secondary Data:** Emission factors from CarbonCloud, Ember, Climatiq (referencing BEIS/Defra, IEA), and other academic sources provide robust estimates based on established methodologies (e.g., LCA databases like Ecoinvent/DEFRA equivalents).
- **Assumptions:** Specific assumptions were made for last-mile delivery distance and vehicle load factor due to the lack of specific primary data for a hypothetical direct-to-consumer channel. These assumptions, while reasonable, introduce a degree of uncertainty.
- **Geographic Specificity:** While China\'s electricity grid mix is specific, and European factors are used where appropriate, detailed country-specific data for every raw material input at every tier of the supply chain was not available and would require extensive primary data collection.
- **Dynamic Nature of Emissions:** Emission factors, especially for electricity grids, are continually evolving due to decarbonization efforts. The factors used are current estimates for 2025/2026.

5.3 Recommendations for Decarbonization

To significantly reduce the PCF of Acetic Acid, key actions should focus on:

- **Supplier Engagement:** Collaborate with methanol and CO suppliers to encourage a shift to lower-carbon production methods (e.g., green methanol, CCUS-enabled CO production).
- **Renewable Energy Procurement:** Explore options for procuring renewable electricity at the Chinese production facility, either directly or via renewable energy certificates (RECs).

- **Process Optimization:** Invest in energy efficiency measures within the manufacturing plant to reduce overall energy consumption.
- **Logistics Optimization:** Further optimize sea freight routes and consider alternative, even lower-carbon shipping technologies. For last-mile, explore fleet electrification, route optimization software, and consolidated delivery models.
- **LSR Standard Integration:** As the LSR Standard becomes effective, proactively assess the land-use impacts of any agricultural or bio-based feedstocks in the broader value chain to ensure compliance and identify additional reduction opportunities.
