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Product Carbon Footprint Report

for Pigment Blue 15:3

Prepared for: [Client Name/Internal Use]

Date: August 21, 2026

Protocol Data (Accounting Standard): GHG Protocol

Disclaimer: This report is generated based on available data and industry standards. While every effort has been made to ensure accuracy, the actual environmental performance may vary due to specific operational details, supply chain complexities, and evolving methodologies. This analysis serves as an illustrative guide for

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Executive Summary

This report provides a detailed Product Carbon Footprint (PCF) analysis for Pigment Blue 15:3, a widely used copper phthalocyanine pigment. The assessment adheres to the GHG Protocol Product Standard, incorporating the latest 2026 updates, including aspects of the Land Sector and Removals (LSR) Standard and enhanced Scope 3 reporting requirements. The analysis focuses on a "factory-gate" system boundary for 1.0 unit (1.0 kg) of pigment produced in India, with a supply chain focus on Asia. The total estimated PCF for 1.0 kg of Pigment Blue 15:3 is **25.783 kg CO2e**, with the majority of emissions stemming from upstream raw material acquisition (Scope 3). Key hotspots include the production of copper-containing raw materials and energy-intensive manufacturing processes. Recommendations for reduction focus on supply chain engagement, renewable energy adoption, and process optimization.

1. Scope Definition

1.1. Functional Unit

The functional unit for this Product Carbon Footprint (PCF) analysis is defined as **1.0 kg of Pigment Blue 15:3**.

1.2. System Boundary

The system boundary for this PCF is **"factory-gate" (Cradle-to-Gate)**. This includes all activities from the extraction and processing of raw materials (upstream) through the manufacturing of the Pigment Blue 15:3 at the production facility, up to the point it leaves the factory gate. It encompasses:

- **Upstream (Scope 3, Category 1 - Purchased goods and services):** Raw material extraction, processing, and transportation to the manufacturing facility.
- **Core Processes (Scope 1 & 2):** Energy consumption (electricity, fuel combustion) and direct process emissions at the pigment manufacturing plant.
- **Waste Management (Scope 3, Category 5 - Waste generated in operations):** Treatment of waste generated during manufacturing.

The "use phase" and "end-of-life" phases of the pigment are excluded from this factory-gate assessment.

1.3. Geographic Scope

The final production country for Pigment Blue 15:3 is **India**. The supply chain focus is **Asia-focused**, meaning emission factors and supply chain assumptions will prioritize data relevant to Asian production and transportation where possible.

1.4. Allocation

Where multi-functional processes occur (e.g., co-production of by-products), allocation of environmental burdens is performed based on physical relationships (e.g., mass, energy content) or economic value, in accordance with GHG Protocol guidance. For this illustrative report, specific allocation details are simplified for clarity.

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2. Lifecycle Mapping (LCI Inventory Stages)

The production of Pigment Blue 15:3 is a complex chemical synthesis and processing endeavor. The main lifecycle stages covered within the "factory-gate" boundary include:

2.1. Key Raw Material Inputs

Pigment Blue 15:3 (Copper Phthalocyanine Blue Beta form) is synthesized from several key precursor chemicals and metals. The primary materials often include:

- **Phthalocyanine Crude:** The basic organic precursor, typically synthesized from phthalic anhydride, urea, and a copper salt. This involves significant chemical processing.
- **Copper Chloride:** A primary source of copper for the phthalocyanine complex. Its production involves copper mining, refining, and chemical conversion.
- **Urea:** A nitrogen source and reactant in the synthesis process. Its production is energy-intensive, often linked to natural gas.
- **Solvents:** Used in various stages of synthesis and particularly in the pigment refining process (e.g., acid pasting, salt milling) to achieve the desired crystal form and particle size.
- **Additives:** Smaller quantities of dispersing agents, crystal modifiers, and other performance-enhancing chemicals.
- **Process Water:** Significant quantities of water are used for washing and purification steps. The energy for water treatment and pumping contributes to the footprint.

2.2. Energy Inputs

The manufacturing process of Pigment Blue 15:3 is energy-intensive, requiring substantial inputs for:

- **Electricity:** For mixing, grinding (e.g., ball milling), pumping, filtration, drying, and general plant operations. Given the production in India, the regional grid mix is a significant factor.
- **Thermal Energy (Heat/Steam):** Generated often from natural gas, coal, or other fuels, used for heating reactors, distillation of solvents, and drying the final pigment.

2.3. Manufacturing Process Overview

The typical production process for Pigment Blue 15:3 involves two main phases: crude pigment synthesis and pigment refining.

1. **Crude Copper Phthalocyanine Synthesis:** Phthalic anhydride, urea, and a copper source (like copper chloride) react at high temperatures, often in the presence of a catalyst and solvent, to form crude copper phthalocyanine. This is a complex organic synthesis.
2. **Pigment Refining (Crystal Modification):** The crude pigment is then processed to achieve the desired beta crystal form (Pigment Blue 15:3) with specific particle size and morphology. This critical step often involves:
    - **Dry Grinding/Ball Milling:** Mechanical energy to break down crude particles.
    - **Acid Pasting/Acid Slurry Process:** Dissolving the crude pigment in concentrated sulfuric acid, followed by reprecipitation with water. This requires acid production and waste acid treatment.
    - **Salt Milling/Kneading:** Grinding the pigment with inorganic salts and organic solvents.
    - **Solvent Treatment:** Heating the pigment in a solvent to promote crystal growth and stabilization.

3. **Washing, Filtration, Drying, and Pulverization:** After refining, the pigment is thoroughly washed to remove impurities, filtered, dried (energy-intensive), and then pulverized to achieve the final powder form.

Table 1: Illustrative Key Lifecycle Inventory Inputs for 1.0 kg of Pigment Blue 15:3 (Factory-Gate)

Input Category	Specific Input	Illustrative Quantity per 1.0 kg Pigment	Unit	GHG Scope Relevance
Raw Materials (Upstream)	Phthalocyanine Crude	0.8	kg	Scope 3 (Category 1)
Raw Materials (Upstream)	Copper Chloride	0.2	kg	Scope 3 (Category 1)
Raw Materials (Upstream)	Urea	0.1	kg	Scope 3 (Category 1)
Raw Materials (Upstream)	Solvents (e.g., NMP, Chlorobenzene)	0.5	kg (net loss/ makeup)	Scope 3 (Category 1)
Raw Materials (Upstream)	Sulfuric Acid (conc.)	0.3	kg	Scope 3 (Category 1)
Energy (Direct)	Electricity (Indian Grid)	5.0	kWh	Scope 2
Energy (Direct)	Natural Gas (for thermal energy)	10.0	kWh (thermal)	Scope 1
Water (Process & Utility)	Process Water (purified)	5.0	kg	Scope 3 (Category 1)
Waste		0.1	kg	

Input Category	Specific Input	Illustrative Quantity per 1.0 kg Pigment	Unit	GHG Scope Relevance
in Operations)	Solid Waste (e.g., filter cake, packaging)			Scope 3 (Category 5)
Waste (Generated in Operations)	Wastewater Treatment (energy/ chemicals)	Implicit in Scope 1/2	-	Scope 1/2/3 (Category 5)

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3. Data Collection (Primary/Secondary Data Points)

Data collection involves a combination of primary and secondary data sources to ensure comprehensive coverage and adherence to GHG Protocol requirements, including the 2026 Scope 3 completeness rule (at least 95% coverage).

3.1. Primary Data

Primary data points are collected directly from the manufacturing facility in India and include:

- Actual consumption of electricity (kWh) from utility bills.
- Actual consumption of fuels (e.g., natural gas in kWh or m^3) for boilers, dryers, or direct process heat.
- Quantities of major raw materials purchased (Phthalocyanine Crude, Copper Chloride, Urea, Solvents, Acids, Additives).
- Quantities and types of waste generated and sent for treatment/disposal.
- On-site transportation fuel consumption (e.g., forklifts, if applicable to factory gate)

- Direct process emissions from any chemical reactions or leaks (e.g., fugitive emissions), if measurable.

3.2. Secondary Data

Secondary data, primarily in the form of emission factors, is sourced from reputable Life Cycle Inventory (LCI) databases and government publications. Given the "Asia-focused" supply chain and India as the production country, regional data is prioritized.

- **Emission Factors for Purchased Raw Materials (Scope 3, Category 1):** Generic emission factors for the production of copper metal, various organic chemicals (phthalic anhydride, urea, solvents), and sulfuric acid are obtained from databases like Ecoinvent and DEFRA-equivalent sources (where specific regional data is unavailable, globally representative averages are used). These factors cover "cradle-to-gate" of the raw material itself.
- **Electricity Grid Emission Factors (Scope 2):** Country-specific average grid emission factors for India are used. The Central Electricity Authority (CEA), Ministry of Power, provides such data. For instance, the 2020 average electricity grid emission factor for India was approximately 0.653 kg CO2e/ kWh.
- **Fuel Combustion Emission Factors (Scope 1):** Standard emission factors for natural gas combustion (CO2, CH4, N2O) are applied.
- **Transportation Emission Factors (Scope 3, Category 4 & 9):** Emission factors for various transport modes (road, rail, sea) relevant to the Asian supply chain (e.g., for inbound raw materials) are used, often from sources like Ecoinvent or DEFRA.
- **Waste Treatment Emission Factors (Scope 3, Category 5):** Factors for common waste disposal methods (e.g., landfill, incineration, recycling) relevant to India.

Table 2: Illustrative Primary/Secondary Data Points and

Data Point	Illustrative Quantity	Unit	Source Type	Reference Source/ Basis
Phthalocyanine Crude Consumption	0.8	kg	Primary	Plant Production Records
Copper Chloride Consumption	0.2	kg	Primary	Plant Production Records
Urea Consumption	0.1	kg	Primary	Plant Production Records
Electricity Consumption	5.0	kWh	Primary	Utility Bills
Natural Gas Consumption	10.0	kWh (thermal)	Primary	Energy Meters
Electricity Grid Emission Factor (India)	0.653	kg CO2e/ kWh	Secondary	Central Electricity Authority (CEA) India (2020 average)
Natural Gas Combustion Emission Factor	0.20	kg CO2e/ kWh (thermal)	Secondary	Illustrative (based on common IPCC/DEFRA averages)
Copper Production Emission Factor	4.0	kg CO2e/kg Copper	Secondary	Illustrative (mid-range from Ecoinvent/ industry data for primary copper)
Organic Production Ef	10.0	kg CO2e/kg	Secondary	Illustrative complex

Data Point	Illustrative Quantity	Unit	Source Type	Reference Source/ Basis
(Phthalocyanine Crude proxy)				organic synthesis in Ecoinvent)
Urea Production Emission Factor	1.5	kg CO2e/kg	Secondary	Illustrative (based on Ecoinvent/ industry data)
Solvent Production Emission Factor	3.0	kg CO2e/kg	Secondary	Illustrative (based on Ecoinvent/ industry data)
Sulfuric Acid Production Emission Factor	0.15	kg CO2e/kg	Secondary	Illustrative (based on Ecoinvent/ industry data)
Truck Transport (inbound materials)	100	tkm (illustrative average)	Primary/ Secondary	Fuel logs (primary) & DEFRA/ Ecoinvent for EF (secondary)
Waste to Landfill (non-hazardous)	0.05	kg	Primary	Waste Manifests

Note: All emission factors and quantities in this table are illustrative for demonstration purposes and would require specific data collection and database lookups in a real-world assessment.

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4. Emission Calculation

Emissions are calculated by multiplying activity data (e.g., quantity of material consumed, energy used) by the corresponding emission factor (Activity Data * Emission Factor = CO2e). The results are categorized according to GHG Protocol Scopes 1, 2, and 3.

4.1. Scope 1 Emissions (Direct Emissions)

These are direct GHG emissions from sources owned or controlled by the reporting company. For a pigment manufacturing plant, this primarily includes on-site combustion of fuels for heat, steam generation, and potentially company-owned vehicles.

- Natural Gas Combustion (for thermal energy): 10.0 kWh * 0.20 kg CO2e/kWh = 2.00 kg CO2e

Total Illustrative Scope 1 Emissions: 2.00 kg CO2e

4.2. Scope 2 Emissions (Energy Indirect Emissions)

These are GHG emissions from the generation of purchased electricity, heating, cooling, and steam consumed by the reporting company.

- Purchased Electricity (Indian Grid): 5.0 kWh * 0.653 kg CO2e/kWh = 3.27 kg CO2e

Total Illustrative Scope 2 Emissions: 3.27 kg CO2e

4.3. Scope 3 Emissions (Other Indirect Emissions)

These are all other indirect emissions that occur in the value chain of the reporting company, both upstream and downstream. Given the "factory-gate" boundary, the primary focus is on upstream Scope 3 categories.

Scope 3, Category 1: Purchased goods and services (Upstream Raw Materials)

CO2e

- Copper Chloride: 0.2 kg * 4.0 kg CO2e/kg (Copper as primary component) = 0.80 kg CO2e
- Urea: 0.1 kg * 1.5 kg CO2e/kg = 0.15 kg CO2e
- Solvents (net loss/makeup): 0.5 kg * 3.0 kg CO2e/kg = 1.50 kg CO2e
- Sulfuric Acid: 0.3 kg * 0.15 kg CO2e/kg = 0.05 kg CO2e
- Process Water (upstream treatment/supply energy): 5.0 kg * 0.0005 kg CO2e/kg (illustrative EF) = 0.003 kg CO2e

Scope 3, Category 4: Upstream transportation and distribution (Inbound logistics)

- Truck Transport for raw materials (illustrative): 100 tkm * 0.1 kg CO2e/tkm (illustrative EF) = 10.00 kg CO2e

Scope 3, Category 5: Waste generated in operations (End-of-life treatment of operational waste)

- Solid Waste to Landfill (non-hazardous): 0.05 kg * 0.2 kg CO2e/kg (illustrative EF) = 0.01 kg CO2e

Total Illustrative Scope 3 Emissions: 8.00 + 0.80 + 0.15 + 1.50 + 0.05 + 0.003 + 10.00 + 0.01 = 20.513 kg CO2e

Note: Illustrative emission factors are used here for demonstration. A robust PCF would use specific, regionalized factors from databases like Ecoinvent or government programs (e.g., CEA for India electricity, DEFRA for UK-specifics) and reflect the specific global warming potentials (GWP100) from the latest IPCC assessment reports.

4.4. Overall Product Carbon Footprint

Table 3: Detailed Illustrative Emission Calculation for 1.0 kg of Pigment Blue 15:3

Emission Source Category	Activity Data	Unit	Emission Factor	Unit	CO2e Emissions	GHG Scope
	10.0	kWh	0.20		2.00	Scope

Emission Source Category	Activity Data	Unit	Emission Factor	Unit	CO2e Emissions	GHG Scope
Natural Gas Combustion (On-site)				kg CO2e/ kWh		
Purchased Electricity (Indian Grid)	5.0	kWh	0.653	kg CO2e/ kWh	3.27	Scope 2
Phthalocyanine Crude (Upstream)	0.8	kg	10.0	kg CO2e/ kg	8.00	Scope 3 (Cat 1)
Copper Chloride (Upstream)	0.2	kg	4.0	kg CO2e/ kg	0.80	Scope 3 (Cat 1)
Urea (Upstream)	0.1	kg	1.5	kg CO2e/ kg	0.15	Scope 3 (Cat 1)
Solvents (Upstream)	0.5	kg	3.0	kg CO2e/ kg	1.50	Scope 3 (Cat 1)
Sulfuric Acid (Upstream)	0.3	kg	0.15	kg CO2e/ kg	0.05	Scope 3 (Cat 1)
Process Water (Upstream Supply/ Treatment)	5.0	kg	0.0005	kg CO2e/ kg	0.003	Scope 3 (Cat 1)
Inbound Raw Material Transport (Truck)	100	tkm	0.10	kg CO2e/ tkm	10.00	Scope 3 (Cat 4)
Operational Waste to	0.05	kg	0.20	kg CO2e/	0.01	Scope 3 (Cat

Table 4: Summary of Product Carbon Footprint by GHG Scope for 1.0 kg of Pigment Blue 15:3

GHG Scope	Illustrative CO2e Emissions (kg CO2e)	Percentage (%)
Scope 1 (Direct Emissions)	2.00	7.8%
Scope 2 (Purchased Energy)	3.27	12.7%
Scope 3 (Value Chain Emissions)	20.513	79.5%
Total PCF	**25.783**	**100.0%**

Note: Percentages may not sum to 100% due to rounding.

4.5. 2026 LSR Standard Application (Land Sector and Removals)

The GHG Protocol\'s Land Sector and Removals (LSR) Standard, effective January 1, 2027, provides requirements for quantifying and reporting land-related emissions and CO2 removals. For Pigment Blue 15:3, which is a synthetic chemical pigment, direct land use change emissions at the manufacturing facility are typically negligible. However, the principles of the LSR Standard are critically important for its upstream supply chain.

- **Upstream Raw Materials:** Emissions associated with the extraction of copper (mining operations can involve land disturbance) or the agricultural production of biomass for certain chemicals (e.g., bio-solvents, though not explicitly detailed here) would fall under the purview of LSR. The emission factors used for these raw materials (Scope 3, Category 1) are assumed to implicitly or explicitly account for relevant land-use change and land management emissions based on the LCI database\'s methodologies.
- **Biogenic Carbon:** For this specific synthetic product, there

CO2). Any biogenic carbon associated with upstream materials (e.g., if using bio-based solvents) would be tracked and reported separately from gross fossil emissions, as per LSR guidelines.

- **Removals:** No significant CO2 removals directly associated with the Pigment Blue 15:3 manufacturing process have been identified within the factory-gate boundary. If any technological carbon capture were implemented, it would be reported distinctly as removals.

The intent is to ensure that even for an inorganic/synthetic product like Pigment Blue 15:3, upstream land impacts are considered within the Scope 3 calculations by using comprehensive emission factors.

4.6. Scope 3 Compliance (2026 Requirements)

The 2026 GHG Protocol Scope 3 updates emphasize enhanced reporting quality, including a mandatory **95% completeness rule** for total relevant Scope 3 emissions to claim conformance. Our illustrative assessment ensures that all major upstream categories, including purchased goods and services (raw materials) and upstream transportation, are included. Based on the illustrative calculation:

- Total emissions: 25.783 kg CO2e
- Scope 3 emissions: 20.513 kg CO2e
- Scope 3 contribution: (20.513 / 25.783) * 100% = 79.5% (approx.)

While this illustrative example highlights the dominance of Scope 3, a real-world calculation would need to rigorously identify and quantify all relevant Scope 3 categories to achieve the 95% threshold. This would involve a more detailed breakdown of all purchased goods and services, capital goods, fuel- and energy-related activities not included in Scope 1 or 2, and potentially business travel, employee commuting, and waste-related emissions in greater detail. The move towards mandatory data disaggregation (primary vs. secondary data) will also require significant supplier

engagement to gather primary data for key upstream materials, especially those with high carbon footprints.

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5. Review & Report

5.1. Hotspot Analysis

Based on the illustrative PCF, the primary emission hotspots for Pigment Blue 15:3 are:

- **Upstream Raw Materials (Scope 3, Category 1):** This category accounts for the largest share of emissions (over 70% of total PCF in this illustration). Specifically, the production of Phthalocyanine Crude (complex organic synthesis) and Copper Chloride (copper mining and refining) are significant contributors.
- **Upstream Transportation (Scope 3, Category 4):** Inbound logistics for raw materials contribute significantly, especially if long distances or inefficient modes of transport are used.
- **Purchased Electricity (Scope 2):** Given India\'s grid mix, electricity consumption for manufacturing operations is a substantial contributor (over 10% of total PCF).
- **On-site Thermal Energy (Scope 1):** Direct combustion of natural gas for process heat and drying also represents a notable hotspot.

These hotspots align with general trends in chemical manufacturing, where raw material sourcing and energy consumption often dominate the carbon footprint.

5.2. Reliability Assessment

The reliability of this PCF assessment is influenced by the data sources and assumptions made:

- **Primary Data Quality:** Assumed high for direct facility operations (electricity, fuel, major material inputs).
- **Secondary Data Quality:** Illustrative emission factors are used here. In a real assessment, the use of up-to-date, regionalized, and process-specific emission factors from robust LCI databases (e.g., Ecoinvent) or national inventories (e.g., CEA for India electricity, DEFRA for UK-specifics) would enhance reliability.
- **System Boundary:** "Factory-gate" provides a clear, actionable boundary for the manufacturer\'s direct influence, but excludes important downstream impacts.
- **Scope 3 Coverage:** Efforts were made to include significant upstream Scope 3 categories, aiming for the 95% completeness rule, which requires diligent data collection and estimation.
- **LSR Standard:** Acknowledgment of LSR principles for upstream impacts and separate reporting of removals (if any) contributes to compliance with the upcoming 2026 requirements.

To improve reliability, direct engagement with key suppliers for primary data on their production emissions (especially for high-impact raw materials) is crucial.

5.3. Recommendations for Reduction

1. **Supplier Engagement for Scope 3 Reduction:** Collaborate with suppliers of Phthalocyanine Crude, Copper Chloride, and other major chemical precursors to identify and implement emissions reduction strategies in their production processes. Encourage them to provide product-specific PCF data.

2. **Transition to Renewable Energy:** Invest in on-site renewable energy generation (e.g., solar PV) or procure renewable electricity through power purchase agreements (PPAs) or renewable energy certificates to significantly reduce Scope 2 emissions.
3. **Energy Efficiency Improvements:** Optimize manufacturing processes (e.g., drying, grinding, heating) to reduce electricity and fuel consumption. Implement waste heat recovery systems.
4. **Process Optimization:** Explore alternative synthesis routes or refining techniques that require less energy or fewer high-impact raw materials. Optimize solvent recovery and reuse to reduce fresh solvent demand.
5. **Waste Reduction and Management:** Implement strategies to minimize process waste, and explore recycling or valorization options for by-products and wastewater.
6. **Logistics Optimization:** Optimize inbound raw material transportation through route planning, consolidation, and shifting to lower-emission transport modes (e.g., rail or sea over long distances where feasible).

Conclusion

This Product Carbon Footprint analysis for Pigment Blue 15:3, conducted under the GHG Protocol and anticipating 2026 updates, reveals that the majority of emissions originate from upstream raw material production and purchased energy. By focusing on supplier collaboration, renewable energy adoption, and process efficiency, significant reductions in the PCF can be achieved. Continuous monitoring, data refinement (especially for Scope 3), and adherence to evolving GHG Protocol standards, including the LSR Standard and the 95% Scope 3 completeness rule, are essential for robust and credible sustainability reporting.