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Product Carbon Footprint Analysis Report

Cotton T-shirt

Protocol Data (Accounting Standard): GHG Protocol

Prepared for: [Client Name]

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Disclaimer: This report is generated based on available data, industry standards, and reasonable approximations. While efforts have been made to ensure accuracy, specific primary

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Executive Summary

This report presents a high-detail Product Carbon Footprint (PCF) analysis for a standard Cotton T-shirt, adhering strictly to the Greenhouse Gas (GHG) Protocol. The analysis covers a cradle-to-factory-gate system boundary for production in India, augmented with downstream sea transport to a global market. The total carbon footprint for one cotton T-shirt, including its production up to the factory gate and its transport via sea for 12,000 km, is estimated at approximately **6.35 kg CO_2e**.

The primary contributors to this footprint are identified within the upstream material processing stages, particularly fabric production (spinning, weaving, dyeing, and finishing), followed by raw cotton cultivation. Purchased electricity and on-site fuel consumption at the final manufacturing facility, along with significant long-distance sea freight, also contribute. This report categorizes emissions into Scope 1, Scope 2, and Scope 3, and incorporates considerations from the forthcoming 2026 Land Sector and Removals (LSR) Standard.

Introduction

As a Senior Sustainability Consultant specializing in the GHG Protocol, this analysis aims to provide a comprehensive understanding of the environmental impact, specifically greenhouse gas (GHG) emissions, associated with the lifecycle of a Cotton T-shirt. The global textile industry faces increasing pressure to

quantify and reduce its environmental footprint. This PCF report serves as a foundational step for identifying emission hotspots and informing strategic sustainability initiatives.

Accounting Standard

This Product Carbon Footprint analysis is conducted in accordance with the **GHG Protocol Product Life Cycle Accounting and Reporting Standard**. This standard provides requirements and guidance for companies to quantify and publicly report GHG emissions and removals associated with individual products. All emissions are reported in kilograms of carbon dioxide equivalent (kg CO_2e).

Methodology

The PCF analysis follows the five key steps outlined by the GHG Protocol:

1. Define Scope
2. Map Lifecycle (LCI inventory stages)
3. Collect Data (Primary/Secondary data points)
4. Calculate Emissions (Activity * Emission Factor = CO2e)
5. Review & Report (Hotspots and reliability)

1. Define Scope

- **Functional Unit:** The functional unit for this analysis is **1.0 unit (one) Cotton T-shirt**.
- **System Boundary:** The system boundary is defined as **cradle-to-factory-gate** for the

manufacturing processes, extended to include **downstream transportation (sea freight)** of the finished product to a global market. This encompasses all stages from raw material extraction (cotton cultivation) and processing, through yarn and fabric production, dyeing, finishing, and final garment assembly in India. The subsequent sea transport of the finished T-shirt from the factory gate is also included.

- **Geographic Scope:**
    - **Final Production Country:** India.
    - **Supply Chain Focus:** Asia for upstream processing (cotton cultivation, spinning, weaving, dyeing), reflecting common global textile supply chains, plus global chain for sea transport.
- **Allocation:** Where co-products or multiple functions exist (e.g., cotton lint and cottonseed from ginning), economic allocation or mass allocation is applied based on industry standards to assign environmental burdens. For this analysis, a direct mass-based approach for the T-shirt\'s primary materials is used.

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

The lifecycle of a Cotton T-shirt involves several stages, each requiring specific material and energy inputs. Given the "factory_gate" system boundary for production, all upstream processes contributing to the finished T-shirt arriving at the factory are considered Scope 3 emissions for the T-shirt manufacturer. The direct operations at the T-shirt manufacturing facility

itself will fall under Scope 1 and Scope 2. The downstream transport is Scope 3.

Detailed Breakdown of Materials and Energy Inputs (for one 0.18 kg Cotton T-shirt):

Lifecycle Stage	Primary Inputs/ Activities	Estimated Activity Data (per T-shirt)	Scope Classification
Raw Material Cultivation (Cotton)	Cotton farming (fertilizers, pesticides, water, machinery fuel for irrigation/ harvest)	0.2 kg cotton lint (approx.)	Scope 3, Category 1 (Purchased Goods and Services)
Material Processing (Ginning, Spinning, Weaving, Dyeing & Finishing)	Energy for mechanical processes, water, dyes, chemicals, heat for wet processing	2.7 kWh electricity, 0.9 kg thermal energy (e.g., natural gas) per 0.18 kg fabric (approx.)	Scope 3, Category 1 (Purchased Goods and Services)
T-shirt Manufacturing (Cutting, Sewing, Packaging)	Purchased electricity for machinery, on-site fuel for minor heating/ steam, packaging materials (polybag, hangtag)	2 kWh electricity, 0.1 kg on-site fuel (e.g., diesel), 0.02 kg packaging	Scope 1 (On-site Fuel), Scope 2 (Purchased Electricity), Scope 3 (Packaging)

Lifecycle Stage	Primary Inputs/ Activities	Estimated Activity Data (per T-shirt)	Scope Classification
Transport of Finished Goods (Sea Freight)	Fuel consumption for cargo ship over long distance	0.2 kg product weight (T-shirt + packaging) over 12,000 km	Scope 3, Category 9 (Downstream Transportation and Distribution)

Note on Data Collection: Activity data are estimated based on typical industry averages and ratios for cotton textile production, and specific parameters provided (e.g., transport distance). Primary data from specific suppliers would provide greater accuracy.

4. Calculate Emissions (Activity * Emission Factor = CO_2e)

Emissions are calculated by multiplying the activity data by relevant industry-standard emission factors (EFs). These EFs are derived from reputable sources such as Ecoinvent or DEFRA, or their commonly cited averages.

Emission Factors Used:

- **Cotton Cultivation:** 2.0 kg CO_2e / kg cotton lint (based on average Indian cotton EFs).
- **Electricity Grid (India):** 0.710 kg CO_2e / kWh (average for FY 2024-25).
- **Thermal Energy (Natural Gas Equivalent):** 2.5 kg CO_2e / kg fuel (approximation).
- **On-site Fuel (Diesel Equivalent):** 3.15 kg CO_2e / kg fuel (approximation).

- **Sea Freight:** 0.019 kg CO_2e / tonne-km (19 g CO_2e / tonne-km).

Emission Calculation Breakdown (for 1 Cotton T-shirt):

Lifecycle Stage & Input	Activity Data	Emission Factor	CO_2e Emissions (kg)	GHG Scope
Upstream Emissions (Scope 3, Category 1: Purchased Goods and Services)				
Raw Material Cultivation (Cotton Lint)	0.2 kg	2.0 kg CO_2e/kg	0.400	Scope 3
Fabric Production (Electricity)	2.7 kWh	0.710 kg CO_2e/kWh	1.917	Scope 3
Fabric Production (Thermal Energy)	0.9 kg	2.5 kg CO_2e/kg	2.250	Scope 3
Direct & Energy Indirect Emissions (T-shirt Manufacturer\'s Operations in India)				
T-shirt Mfg. (On-site Fuel)	0.1 kg	3.15 kg CO_2e/kg	0.315	Scope 1
T-shirt Mfg. (Purchased Electricity)	2 kWh	0.710 kg CO_2e/kWh	1.420	Scope 2
Downstream Emissions (Scope 3, Category 9: Downstream Transportation and Distribution)				
Transport of Finished Goods (Sea Freight)	0.2 kg product over 12,000 km	0.000019 kg CO_2e/ kg-km	0.046	Scope 3
Total Product			**6.348**	

Lifecycle Stage & Input	Activity Data	Emission Factor	CO_2e Emissions (kg)	GHG Scope
Carbon Footprint				

GHG Scope Summary:

For the T-shirt manufacturer, the breakdown of emissions is as follows:

- **Scope 1 (Direct Emissions):** 0.315 kg CO_2e (On-site fuel combustion).
- **Scope 2 (Indirect Emissions from Purchased Energy):** 1.420 kg CO_2e (Purchased electricity for manufacturing).
- **Scope 3 (Other Indirect Emissions - Value Chain):** 4.613 kg CO_2e (Comprising Raw Material Cultivation, Fabric Production, and Downstream Sea Transport).

Total PCF: 6.348 kg CO_2e per Cotton T-shirt.

2026 LSR Update Application:

The GHG Protocol\'s new Land Sector and Removals (LSR) Standard, released in January 2026 and effective January 1, 2027, provides crucial guidance for accounting for land sector emissions (e.g., land use change, land management) and CO_2 removals. For a Cotton T-shirt, this standard is particularly relevant for the Raw Material Cultivation stage (cotton farming). The emissions associated with cotton cultivation in this report (e.g., N_2O from fertilizers, energy for irrigation) fall under the purview of this standard. Future, more granular data collection should align with LSR requirements to quantify potential biogenic carbon sequestration in agricultural lands and precisely report

emissions from land use and land-use change, which can significantly refine the footprint of natural fibers.

Scope 3 Compliance:

As per 2026 requirements, this analysis aims for at least 95% coverage for Scope 3 reporting. Given that Scope 3 typically accounts for 70-90% of a company\'s total footprint, comprehensive data collection across all relevant categories is critical. This report covers major upstream (materials, processing) and downstream (transport) categories for the product. While this analysis focuses on the T-shirt\'s primary lifecycle, a full corporate Scope 3 inventory would also include categories like capital goods, business travel, employee commuting, waste generated in operations, etc. Ongoing engagement with suppliers and the implementation of robust data collection systems will be essential to ensure compliance and achieve the 95% coverage target for a complete corporate Scope 3 inventory.

5. Review & Report

Emission Hotspots:

The analysis identifies the following key emission hotspots:

- **Fabric Production (Spinning, Weaving, Dyeing, Finishing):** This stage, largely due to energy consumption for mechanical processes and significant thermal energy for wet processing, accounts for the largest portion of emissions in the product\'s upstream value chain (4.167 kg CO_2e).
- **T-shirt Manufacturing (Purchased Electricity):** The energy consumed at the final assembly factory, primarily electricity from

India\'s grid, is a significant contributor (1.420 kg CO_2e).

- **Raw Material Cultivation (Cotton):** Emissions from farming practices contribute substantially to the upstream footprint (0.400 kg CO_2e).
- **Sea Transport:** While efficient per tonne-km, the very long distance (12,000 km) makes it a notable contributor to the downstream footprint (0.046 kg CO_2e).

Data Reliability and Limitations:

This PCF report relies on a combination of specific activity data (e.g., transport distance) and secondary emission factors/activity estimations based on industry averages. While these approximations provide a robust initial assessment, enhanced accuracy would require:

- **Primary Data Collection:** Direct data from each supplier in the value chain (e.g., energy consumption per kg of yarn from spinners, specific dye chemical inputs).
- **Geographic Specificity:** More precise emission factors for electricity grids and agricultural practices in the exact regions of cultivation and processing beyond general country averages for India and Asia.
- **Dynamic EFs:** Regular updates to emission factors to reflect technological advancements and changes in energy mixes.

Recommendations for Emission Reduction:

To mitigate the identified hotspots, the following actions are recommended:

- **Optimize Fabric Production:** Invest in energy-efficient machinery and processes for spinning,

weaving, dyeing, and finishing. Explore technologies like waterless dyeing or cold-pad-batch dyeing to reduce thermal energy demand. Engage with suppliers to promote renewable energy adoption at their facilities.

- **Decarbonize Manufacturing Operations:** Transition to renewable energy sources (e.g., solar, wind) for the T-shirt manufacturing facility in India. Improve energy efficiency of sewing and cutting operations.
- **Sustainable Cotton Sourcing:** Prioritize sourcing cotton from farms employing regenerative agricultural practices to reduce fertilizer-related emissions and enhance soil carbon sequestration, aligning with the LSR Standard.
- **Logistics Optimization:** While sea transport is chosen for its lower emissions compared to air freight, further optimization could include optimizing container loading and exploring alternative low-carbon marine fuels where available.