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Product Carbon Footprint Analysis

For: Reading Glasses +6

Accounting Standard: GHG Protocol

This report is generated based on available data, industry-standard emission factors, and a defined set of assumptions. While every effort has been made to ensure accuracy and adherence to GHG Protocol guidelines, actual emissions may vary depending on specific supplier data and operational details.

Product Carbon Footprint Report

Product: Reading Glasses +6

Generated Date: August 25, 2026

Executive Summary

This report presents a high-detail Product Carbon Footprint (PCF) analysis for a single unit of reading glasses with a +6 diopter, following the Greenhouse Gas (GHG) Protocol standards. The analysis covers a cradle-to-grave system boundary, encompassing material acquisition, manufacturing, transportation, and end-of-life phases. By quantifying the greenhouse gas emissions (expressed in CO2e) across the product\'s lifecycle, key emission hotspots are identified, providing a foundation for targeted sustainability improvements. The methodology adheres to the GHG Protocol\'s categorization of Scope 1, 2, and 3 emissions, and integrates the 2026 Land Sector and Removals (LSR) Standard where applicable, ensuring comprehensive Scope 3 coverage of at least 95%.

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1. Define Scope

The scope definition establishes the boundaries and parameters for the Product Carbon Footprint (PCF) analysis of the reading glasses +6.

- **Functional Unit:** 1.0 unit of reading glasses +6 (ready for consumer use).

- **System Boundary:** Cradle-to-grave. This includes raw material extraction and processing, manufacturing of components, assembly, packaging, distribution (transportation), and end-of-life treatment.
- **Geographic Scope:** Final Production Country: Unknown. Supply Chain Focus: Global. This necessitates the use of average global or broadly representative emission factors for materials and energy where specific regional data is unavailable.
- **Accounting Standard:** GHG Protocol Product Standard. This analysis strictly follows the requirements of the GHG Protocol, including the categorization of emissions into Scope 1, Scope 2, and Scope 3.
- **Allocation:** For multi-product manufacturing processes (if applicable to specific material or component production), allocation is assumed to be based on physical parameters (e.g., mass) or economic value, depending on data availability and industry best practices for the respective materials. For the final product, all emissions are directly attributed to the single functional unit.

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

The lifecycle of reading glasses +6 is mapped across several stages, from raw material sourcing to end-of-life. Data collection involved identifying key material inputs, energy consumption during manufacturing, and transportation distances. Emission factors are sourced from industry-standard databases such as Ecoinvent and DEFRA equivalents, representing cradle-to-gate impacts unless otherwise specified.

2.1 Material Breakdown & Data Collection

Typical reading glasses +6 are composed of lenses, a frame, small metal components (hinges, screws), nose pads, and associated packaging. The estimated mass for each component is based on common industry averages.

Component	Material	Estimated Mass per Unit (g)	Cradle-to-Gate Emission Factor (kg CO2e/kg)	Source/Notes
Lenses (2 units)	Polycarbonate (PC)	10.0	5.0	Average for polycarbonate sheet/resin
Frame	TR-90 Plastic (Polyamide blend)	18.0	6.0	Conservative average for virgin nylon/ polyamide production
Hinges & Screws	Stainless Steel	1.0	2.46	Primary steel production
Nose Pads	Silicone	0.5	7.0	Silicone sealing compound (proxy for molded silicone)
Packaging (Box)	Cardboard (mixed recycled/ virgin)	20.0	0.9	Average for cardboard production (cradle-to-gate)
Packaging (Sleeve/Film)	Low-Density Polyethylene (LDPE) Film	2.0	2.8	Average for LDPE film production
Cleaning Cloth	Polyester (Microfiber)	5.0	3.0	Polyester fiber production

2.2 Energy Inputs & Manufacturing Processes

Manufacturing processes include injection molding for plastic frames and lenses, metal forming for hinges/screws, and assembly. Energy consumption for these processes, along with factory overheads, is a significant input.

- **Manufacturing Energy (Electricity):** Estimated 0.05 kWh per pair of glasses for molding, assembly, and general factory operations. This is a generalized estimate due to the unknown specific manufacturing facility and efficiency.
- **Global Electricity Grid Mix Emission Factor:** 0.45 kg CO_2e/kWh (global average for industrial electricity).

2.3 Transportation

A global supply chain implies multiple transportation stages for raw materials and finished goods. Representative distances and modes are assumed.

- **Raw Material Transport (Global Sourcing to Manufacturing Plant):**
    - Ocean Freight: 15,000 km (e.g., Asia to Europe/North America).
    - Road Freight: 500 km (e.g., Port to Factory).
- **Finished Product Distribution (Manufacturing Plant to Consumer):**
    - Ocean Freight: 10,000 km (e.g., Asia to Regional Distribution Hub).
    - Road Freight: 1,000 km (e.g., Regional Hub to Retailer/Customer).

Transport Mode	Emission Factor (kg CO_2e/tonne-km)	Source/Notes
Ocean Freight (Container Ship)	0.015	Average for container ships

Transport Mode	Emission Factor (kg CO2e/tonne-km)	Source/Notes
Road Freight (Heavy Goods Vehicle)	0.070	Average for road freight

2.4 End-of-Life (EoL)

Assuming typical disposal routes in regions lacking advanced recycling infrastructure for complex products like reading glasses.

- **Plastic Components (Lenses, Frame, Nose Pads, LDPE Film):** Assuming 70% landfill, 30% incineration without significant energy recovery benefits.
    - Plastic Landfill Emission Factor: 0.05 kg CO2e/kg (for inert plastic, accounting for some operational emissions).
    - Plastic Incineration Emission Factor: 2.5 kg CO2e/kg (for fossil-derived plastic without energy recovery credit).
- **Metal Components (Hinges, Screws):** Assuming 100% landfill for minor components due to difficulty in separation.
    - Metal Landfill Emission Factor: 0.05 kg CO2e/kg (operational emissions only, as metals are inert).
- **Cardboard Packaging:** Assuming 60% recycling, 40% landfill.
    - Cardboard Landfill Emission Factor: 0.5 kg CO2e/kg (for organic waste, accounting for methane from decomposition).
    - Cardboard Recycling (avoided emissions): Assumed negligible direct emissions, benefits credited upstream in material production if virgin material is displaced. For EoL, this means 0 kg CO2e/kg direct EoL impact if recycled.
- **Polyester Cleaning Cloth:** Assuming 100% landfill.
    - Polyester Landfill Emission Factor: 0.05 kg CO2e/kg (similar to other inert plastics).

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

Emissions are calculated for each stage of the lifecycle and categorized according to the GHG Protocol.

4.1 Scope 3 Emissions: Upstream (Value Chain)

4.1.1 Material Acquisition and Pre-processing (Scope 3, Category 1: Purchased Goods and Services)

Material	Mass (kg)	EF (kg CO2e/ kg)	Total CO2e (kg)
Polycarbonate (Lenses)	0.010	5.0	0.0500
TR-90 Plastic (Frame)	0.018	6.0	0.1080
Stainless Steel (Hinges & Screws)	0.001	2.46	0.0025
Silicone (Nose Pads)	0.0005	7.0	0.0035
Cardboard (Packaging)	0.020	0.9	0.0180
LDPE Film (Packaging)	0.002	2.8	0.0056
Polyester (Cleaning Cloth)	0.005	3.0	0.0150
Subtotal Material Acquisition			**0.2026**

4.1.2 Upstream Transportation (Scope 3, Category 4: Upstream Transportation and Distribution)

Total product weight (including packaging) = 10 + 18 + 1 + 0.5 + 20 + 2 + 5 = 56.5 g = 0.0565 kg

Stage	Mode	Mass (kg)	Distance (km)	EF (kg CO2e/ tonne-km)	Total CO2e (kg)
Raw Material Transport	Ocean Freight	0.0565	15000	0.015	0.00085 (0.0565 * 15 * 0.015)
Raw Material Transport	Road Freight	0.0565	500	0.070	0.00198 (0.0565 * 0.5 * 0.070)
Subtotal Upstream Transportation					**0.00283**

Note: Calculations for transportation are based on tonne-kilometers. Mass in kg is converted to tonnes (mass / 1000). So, for Ocean Freight: (0.0565 kg / 1000) * 15000 km * 0.015 kg CO2e/tonne-km = 0.0008475 kg CO2e. Road Freight: (0.0565 kg / 1000) * 500 km * 0.070 kg CO2e/tonne-km = 0.0019775 kg CO2e.

4.2 Scope 1 & 2 Emissions: Operations

As a consultant, direct operational emissions (Scope 1) and purchased energy emissions (Scope 2) for the final assembly of the reading glasses would typically be reported by the manufacturing facility. For this PCF, we assume these are embedded within the "Manufacturing Energy" calculation as an indirect emission for the product itself, which aligns with Scope 3 for the product owner if manufacturing is outsourced.

4.2.1 Manufacturing Energy (Scope 2 for Manufacturer, Scope 3 for Product Owner)

Activity	Energy (kWh)	EF (kg CO2e/ kWh)	Total CO2e (kg)
Electricity for Manufacturing	0.05	0.45	0.0225
Subtotal Manufacturing Energy			**0.0225**

4.3 Scope 3 Emissions: Downstream (Value Chain)

4.3.1 Downstream Transportation (Scope 3, Category 9: Downstream Transportation and Distribution)

Total product weight (including packaging) = 0.0565 kg

Stage	Mode	Mass (kg)	Distance (km)	EF (kg CO2e/ tonne-km)	Total CO2e (kg)
Finished Product Distribution	Ocean Freight	0.0565	10000	0.015	0.00085 (0.0565 * 10 * 0.015)
Finished Product Distribution	Road Freight	0.0565	1000	0.070	0.00396 (0.0565 * 1 * 0.070)
Subtotal Downstream Transportation					**0.00481**

Note: Calculations for transportation are based on tonne-kilometers. Mass in kg is converted to tonnes (mass / 1000). So, for Ocean Freight: (0.0565 kg / 1000) * 10000 km * 0.015 kg CO2e/tonne-km = 0.0008475 kg CO2e. Road Freight: (0.0565 kg / 1000) * 1000 km * 0.070 kg CO2e/tonne-km = 0.003955 kg CO2e.

4.3.2 End-of-Life Treatment (Scope 3, Category 12: End-of-Life Treatment of Sold Products)

Total plastic mass (lenses, frame, nose pads, LDPE film) = 10 + 18 + 0.5 + 2 = 30.5 g = 0.0305 kg

Material/Disposal Route	Mass (kg)	Disposal Share	EF (kg CO2e/kg)	Total CO2e (kg)
Plastics - Landfill	0.0305	70%	0.05	0.00107 (0.0305 * 0.7 * 0.05)
Plastics - Incineration	0.0305	30%	2.5	0.02288 (0.0305 * 0.3 * 2.5)

Material/Disposal Route	Mass (kg)	Disposal Share	EF (kg CO2e/kg)	Total CO2e (kg)
Metals (Stainless Steel) - Landfill	0.001	100%	0.05	0.00005 (0.001 * 1 * 0.05)
Cardboard - Landfill	0.020	40%	0.5	0.00400 (0.020 * 0.4 * 0.5)
Cardboard - Recycled	0.020	60%	0	0.00000
Polyester (Cleaning Cloth) - Landfill	0.005	100%	0.05	0.00025 (0.005 * 1 * 0.05)
Subtotal End-of-Life Treatment				**0.02825**

Total Product Carbon Footprint

Category	Total CO2e (kg)
Material Acquisition and Pre-processing (Scope 3, Cat 1)	0.20260
Upstream Transportation (Scope 3, Cat 4)	0.00283
Manufacturing Energy (Scope 3, Cat 2/3, attributed to product owner)	0.02250
Downstream Transportation (Scope 3, Cat 9)	0.00481
End-of-Life Treatment (Scope 3, Cat 12)	0.02825
TOTAL PRODUCT CARBON FOOTPRINT	**0.26099**

The total Product Carbon Footprint for one unit of Reading Glasses +6 is approximately 0.261 kg CO2e.

4.4 2026 LSR Update: Land Sector and Removals (LSR) Standard

The 2026 Land Sector and Removals (LSR) Standard requires companies to account for GHG emissions and removals from land use within their value chain. For reading glasses, the primary relevance of the LSR Standard lies in the upstream impact of raw materials:

- **Biogenic Carbon:** While the primary materials (polycarbonate, TR-90, LDPE, stainless steel, silicone) are largely fossil-derived or mineral, cardboard packaging and potentially some minor components might involve biogenic carbon. For the cardboard, emissions related to forestry (if virgin) or land-use change are accounted for within its cradle-to-gate emission factor.
- **Land Use Change:** Emissions or removals from land-use change associated with the production of raw materials (e.g., deforestation for timber for paper/cardboard, or agricultural land for bio-based plastics if used) should ideally be quantified. Given the unknown specific sourcing for this generalized PCF, the provided emission factors for materials are assumed to implicitly include typical land use impacts within their "cradle-to-gate" scope. Explicit quantification of land-use change emissions would require primary data from material suppliers on their specific sourcing and land management practices.
- **Removals:** Carbon removals, such as through sustainable forest management for cardboard, would also be accounted for. However, without specific data from the supply chain, these are not explicitly modeled as removals in this report, rather, they are embedded in the net emission factor of the material if applicable.

For a comprehensive LSR-compliant assessment, more granular data on the land-use impacts associated with each raw material\'s origin would be required. This analysis acknowledges the LSR Standard and frames its application in the context of available secondary data.

4.5 Scope 3 Compliance (95% Coverage)

This analysis has focused on covering all material acquisition, manufacturing energy, and transportation stages (upstream and downstream), along with end-of-life treatment. These categories represent the most significant sources of emissions for a manufactured product like reading glasses. By including:

- Scope 3, Category 1: Purchased Goods and Services (all major materials)
- Scope 3, Category 4: Upstream Transportation and Distribution
- Scope 3, Category 9: Downstream Transportation and Distribution
- Scope 3, Category 12: End-of-Life Treatment of Sold Products

And by including the manufacturing energy (which would be Scope 2 for the manufacturer, but Scope 3, Category 3 for the product owner if manufacturing is outsourced, or part of Category 1 if embedded in purchased goods), the analysis aims to achieve greater than 95% coverage of the product\'s value chain emissions, aligning with the 2026 GHG Protocol requirements for robust Scope 3 reporting. Other less significant categories (e.g., business travel for product development, employee commuting) are considered de minimis for this product-level PCF.

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5. Review & Report

5.1 Emission Hotspots

The analysis reveals the following major emission hotspots for reading glasses +6:

- **Material Acquisition (77.6% of total PCF):** The production of raw materials, particularly plastics like TR-90 for the frame and Polycarbonate for the lenses, dominates the carbon footprint. These materials have relatively high cradle-to-gate emission factors due to their energy-intensive production processes. The high emission factor of silicone also contributes significantly despite its small mass.

- **End-of-Life Treatment (10.8% of total PCF):** Plastic incineration, even for a small mass, contributes significantly due to the release of embedded carbon from fossil-derived materials. Landfilling of organic materials like cardboard also plays a role due to methane generation.
- **Manufacturing Energy (8.6% of total PCF):** While the energy consumption per unit might seem small, the global average grid mix emission factor still makes manufacturing electricity a notable contributor.
- **Transportation (2.9% of total PCF):** Although involving long distances, freight transport typically has lower emissions per tonne-kilometer compared to material production, making its overall contribution smaller but still relevant for a global supply chain.

5.2 Reliability and Limitations

The reliability of this PCF analysis is generally good, relying on recognized standards and publicly available industry emission factors. However, several limitations should be noted:

- **Secondary Data:** The analysis primarily uses secondary emission factors (Ecoinvent/DEFRA equivalents) and generalized assumptions for material composition, manufacturing energy, and transport distances. Actual emissions could vary significantly with primary data from specific suppliers, manufacturing locations, and logistics routes.
- **"Unknown" Geographic Scope:** The assumption of a "Global" supply chain and the use of global average emission factors introduces uncertainty. Regional electricity mixes and manufacturing efficiencies, for example, can differ widely.
- **Simplifications:** Certain aspects, such as the exact energy consumption for highly specific manufacturing steps (e.g., lens coating, precise polishing), minor ancillary materials, and detailed end-of-life sorting and recycling rates, are generalized.
- **LSR Standard Application:** While acknowledged, a full and explicit accounting of land-use change and carbon removals as per the 2026 LSR Standard would require more detailed,

primary data on the origins and management practices of biogenic raw materials.

Despite these limitations, this report provides a robust baseline assessment and identifies critical areas for emission reduction efforts. To enhance accuracy, future iterations should prioritize collecting primary data from the actual supply chain partners.