ISO-Aligned Life Cycle Assessment Report

IE-3505-8P3S-E

Version 1
Date: April 2026
IE-3505-8P3S-E

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Abbreviations

ADP	abiotic depletion potential
ASIC	Application-Specific Integrated Circuit
BOM	bill of materials
BWC	blue water consumption
Cisco	Cisco Systems, Inc.
CO2	carbon dioxide
CO2e	carbon dioxide equivalent
CPU	Central Processing Unit
EOL	end-of-life
GB	gigabyte
GHG	greenhouse gas
GWP	global warming potential
IPCC	Intergovernmental Panel on Climate Change
IC	integrated circuit
ISO	International Organization for Standardization
kg	kilogram
kWh	kilowatt-hour
L	liter
LCA	life cycle assessment
LCI	life cycle inventory
LCIA	life cycle impact assessment
MJ	megajoule
PCB	printed circuit board
PED	primary energy demand
SSD	Solid-State Drive
Sb	antimony
W	watt
WSP	WSP USA Inc.

Version & Date	Developed by	Changes Made	Version of Cisco Scalable LCA Model used
V 1.0 2026-04-03	WSP Team	Initial version created	Version 4.0

Disclaimer on comparability and model updates

As the Scalable LCA Model is continuously updated, both in terms of the foreground model (such as data from Cisco) and the background model (such as electricity grid mixes), it is important to note which version of the model has been used for the specific study. This LCA data is not intended to be compared to LCAs of other Cisco products or any third-party products.

Primary data has been used when possible. Secondary data along with estimates and assumptions has been used for the background system and to fill data gaps. The following LCI databases were used in Version 4.0 of the Scalable LCA Model.

- LCA For Experts service pack 2025001000
  - "Professional 2025" database
  - "XI: electronics 2025" extension database
- ecoinvent version 3.11

Results in this report are estimates and indicative only, based on assumptions and approximations, for particular products and points in time. They are neither predictions, commitments or guarantees of actual outcomes nor intended for purposes other than identifying opportunities to improve the environmental performance of products at various points in their life cycle. Cisco and WSP continue to refine the methodology, modeling, and assumptions. Data and other information are therefore subject to change and uncertainties that are difficult to predict.

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Further information on Cisco's approach to Life Cycle Assessments (LCAs) is available at Cisco's Purpose Reporting Hub at https://www.cisco.com/c/m/en_us/about/purpose/reporting-hub.html

1 Goal of the Study

This report is based on a study performed for Cisco using a Scalable Life Cycle Assessment Model developed by WSP USA Inc. (WSP). It is a parameterized model in the LCA for Experts[1] (formerly GaBi®) software that, when combined with an Excel spreadsheet template called the "Parameterizer," streamlines life cycle assessments (LCAs) of Cisco products. The Parameterizer automatically reads bills of materials (BOMs) to inform parameters for electrical components, which, together with manual data entries and assumptions for data gaps, informs the model's parameters.

Cisco commissioned WSP to develop an LCA using the Scalable LCA Model to calculate the global warming potential (GWP) (excluding biogenic carbon), non-renewable primary energy demand (PED), and blue water consumption (BWC) of Cisco's IE-3505-8P3S-E (from here on referred to as "the product"). GWP is also referred to as greenhouse gas (GHG) emissions and the GWP results (excluding biogenic carbon) of the product life cycle are as characterized by the Intergovernmental Panel on Climate Change (IPCC) AR6 characterization factors for GWP100. The PED from non-renewable resources impact category represents the amount of fossil energy demanded from the ecosystem. BWC is the volume of surface and groundwater consumed (or otherwise made unavailable by evaporation or fouling) as a result of production of a good or service. In addition, abiotic depletion potential (ADP) was also considered. ADP assesses the depletion of non-living resources, such as metals and minerals, and evaluates the potential for resource scarcity.

This LCA covers the life cycle of the product from cradle-to-grave. The IE-3505-8P3S-E switch is an industrial-grade managed Ethernet switch from Cisco's IE3500 Rugged Series, designed for harsh industrial environments, and supports advanced security and reliable edge connectivity for operational technology networks. Therefore, the goal of this study is to determine the GHG emissions, PED, BWC and ADP impacts of Cisco's IE-3505-8P3S-E switch from cradle-to-grave.

1.1 Reasons for Carrying Out the Study

This study is meant to inform product development and internal decision making by identifying the environmental impact of the IE-3505-8P3S-E switch. Cisco recognizes that the environmental impacts depend greatly on the specifics of the inputs, production method, location, transportation, and disposal of the product.

This study was conducted to determine the GHG emissions, PED, BWC, and ADP impacts associated with the production, transport, use phase, and end-of-life (EOL) of the product according to International Organization for Standardization (ISO) Standards 14040 and 14044 on LCA (ISO, 2006). The GHG emissions, PED, BWC, and ADP impacts were selected based on potential business value, data availability, requests from stakeholders, and commonly included metrics for electronic products. While the results of the Scalable LCA model are in alignment with ISO Standards 14040 and 14044 for LCA, there currently is no ISO standard that applies to LCA models or tools. The ISO standards only apply to reports and their contents. Therefore, the Scalable LCA model itself cannot be considered "ISO-conformant" and the Scalable LCA model's results can only be considered ISO-conformant if documented in an ISO-conformant LCA report that undergoes critical review. In summary, instead of performing critical review of each individual LCA report, the Scalable LCA Model itself has been reviewed.

[1] Modeling for all systems in this study was conducted in the LCA software LCA for Experts (formerly GaBi), developed by thinkstep, now Sphera (https://sphera.com/product-sustainability-software/).

1.2 Intended Applications

The study is intended to provide actionable environmental impact information about the GHG, PED, BWC, and ADP impacts from all cradle-to-grave life cycle phases of the Cisco product.

1.3 Target Audience

The study results are prepared for Cisco's internal use and external reference in alignment with ISO Standards 14040 and 14044. Specific audiences may include the company's employees (e.g., leadership, product designers and engineers, communications, and sustainability professionals).

1.4 Critical Review

This report is intended to be aligned with the requirements of ISO Standards 14040 and 14044, which set forth the requirements for public disclosures and documentation for LCAs. This report has not been critically reviewed and is therefore not ISO-conformant.

2 Scope of the Study

The study is a cradle-to-grave LCA of a Cisco electronic product. This section outlines the function of the product, its declared unit, system boundary, and other scope specific information.

2.1 Product and Function

The IE-3505-8P3S-E switch (Figure 1) is a rugged, industrial-grade managed ethernet switch from Cisco's IE3500 Rugged Series, featuring 8 Gigabit Ethernet Power over Ethernet (PoE)+ ports and 3 Gigabit Small Form-factor Pluggable (SFP) uplinks. It is designed for harsh industrial environments and supports Layer 2/Layer 3 switching, high-availability industrial protocols, advanced security, and reliable edge connectivity for operational technology networks. A brief overview of the technical specifications of the product is provided in Table 1.

Table 1: Technical Specifications of the Product

Technical Data	IE-3505-8P3S-E
Product weight	3.1 kg
Modeled power consumption[2]	64 W
Dimensions (H * W * D)	6.0x4.0x5.3 inches
Market release date	2025
Technical Data	**IEM-3500-16P=**
Product weight	1.13 kg
Dimensions (H * W * D)	3.26 x 6.00 x 5.29 inches
Market release date	2025
Product Configuration	**Quantity**
PID - IE-3505-8P3S-E	1
PSU - PWR-IE480W-PCAC-L	1
Expansion Module - IEM-3500-16P	1

[2] Modeled power consumption is estimated based on product function and assumed product use.

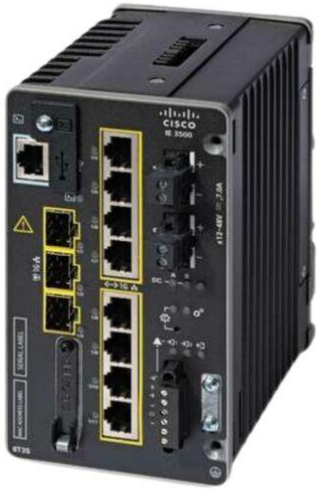

Figure 1: Image of the product – IE-3505-8P3S-E

Source: Cisco

2.2 Functional Unit

The Scalable LCA Model does not generate results per a functional unit, which is typically done in LCA to allow for comparison. A functional unit is a quantified description of the function of the product or process and is used as the reference quantity throughout analysis. This uniform functional unit allows for comparisons across different products. Instead, this study presents results per a declared unit of one device across its life cycle from cradle-to-grave, including the use phase. This is in alignment with PCR 2024:06 on electronic and electrical equipment from The International EPD System (2024) and the International Electrotechnical Commission standard 63366 for LCA of electrical and electronic products and systems (IEC, 2024).

2.3 System Boundary

The Scalable LCA model's system boundary (Figure 2) is from cradle-to-grave for the life cycle inventory (LCI) and impact assessment and includes raw material extraction and refinement, material transport, component manufacturing, assembly, testing, delivery, use phase, and EOL. Infrastructure and capital goods (e.g., buildings and machines used for production) are not included due to their assumed small contribution to the overall impact of the electronics products balanced with the challenges of collecting granular and specific data on the depreciable capital involved in electronics production. Production of infrastructure has been excluded also for background generic processes in order to ensure consistency between the foreground and background datasets.

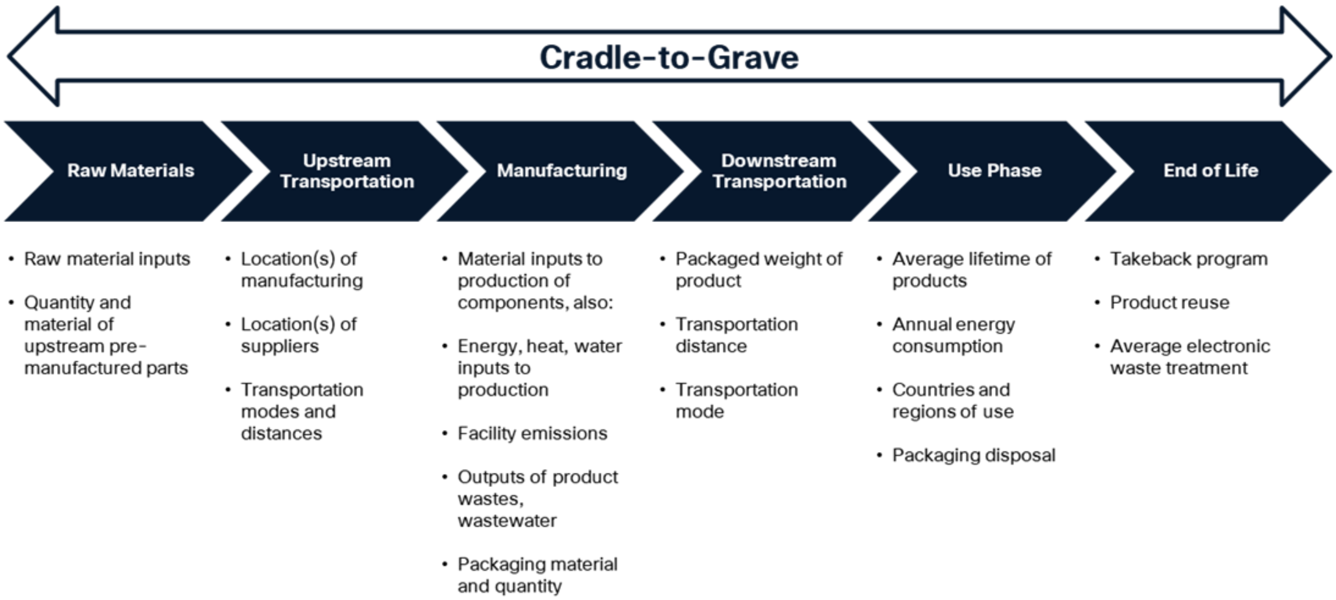

Figure 2: The system boundaries of the Cisco Scalable LCA model

Manufacturing boundaries will vary depending on the product and the selected source of secondary data for production burdens. The system boundaries are set by the secondary data sources used. The tool categorizes manufacturing into two steps: assembly and testing. Assembly entails producing the final product through combining components and materials. Testing is done to ensure the functionality and reliability of the product through hardware and software testing. Excluded are the peak conditions tests, which involve extreme temperatures and altitude testing, as this is not performed on every single product produced. Rather, testing in this context is the nominal testing that is performed on all products produced to ensure functionality before shipping.

Packaging materials for the raw materials and semi-finished goods are also excluded for the same reason as infrastructure and capital goods. However, the weights of packaging can be added to the transportation burdens through simple assumptions. Recovery in EOL is excluded from the system boundaries due to recycled waste stream methodology, the “cut-off” approach (also called the recycled content approach), applied in this tool. The recovery includes the material flows intended for reuse, recycling, and energy recovery, and includes waste processing for recycling and energy recovery (e.g., shredding).

2.4 Temporal and Geographical Boundary

All material, transportation, manufacturing, and use data inputs are from 2025 and 2026. The data that are matched to the material inputs are valid for 2026, with some valid through 2026 and 2027. The product is disposed of at its EOL, modeled as five years after production. All the datasets used to model EOL are for 2022.

The study assumes most electronics production occurs in Asia. All material inputs are matched to datasets that are either global averages or an Asian country’s datasets. Manufacturing is modeled specifically for a country in Asia as the manufacturing country in terms of energy consumption. The use phase is assumed to take place in the United States. EOL is assumed as a global average.

2.5 Cut-off Criteria and Limitations

LCA for Experts (formerly GaBi) databases were used, including the LCA for Experts implementation of the ecoinvent v3.11 database. Any cut-off criteria implemented in the ecoinvent or LCA for Experts databases are included in this assessment according to the LCA for Experts Modeling Principles (Sphera, 2023). Where applicable, cut-off criteria would only be applied for components that contribute to 1 percent or less of total mass or energy of the system and 5 percent or less of the total environmental impacts. Cut-off criteria were applied within the electronic components.

In addition, no mass was excluded within non-electricals, plastic, or product packaging. One exclusion was made in packaging materials for raw materials and semi-finished components. No other primary data or mass and energy flows were knowingly excluded. However, there are several limitations.

The primary limitations of the Scalable LCA Model are the assumptions related to electronic and electrical components and the use of secondary data for these as well as for the manufacturing burdens. In terms of materials burdens, a special focus was placed on key electronic components that are known to have a disproportionately high environmental impact compared to other components such as housing or packaging. Several proxies needed to be made using scaling factors, as direct dataset matches were not available.

Manufacturing burdens for both assembly and testing were proxied using secondary datasets from ecoinvent, which represent different levels of complexity in the assembly and testing processes. This is a significant limitation that should be addressed in future iterations of the Scalable LCA model through additional data collection (e.g., representative Cisco manufacturing sites).

2.6 Allocation

No co-products during manufacturing were identified for the studied product. Therefore, this study did not perform allocation. Allocation of environmental burdens to material and energy co-products throughout the upstream supply chain is embedded in the LCI data used in this study and described in the documentation of these datasets.

3 Life Cycle Inventory Analysis

3.1 IE-3505-8P3S-E Life Cycle Inventory

This section outlines the inventory compiled to assess the life cycle impacts of the IE-3505-8P3S-E switch. The switch is a ruggedized industrial Ethernet switch composed primarily of a metal enclosure. The product includes a steel or aluminum chassis, multiple printed circuit board assemblies (PCBAs) populated with integrated circuits and passive components, copper Ethernet ports, SFP optical interfaces, internal power regulation components to support PoE/PoE+, and external connectors and cabling interfaces. The components are assembled into a finished product before undergoing testing and being distributed to customers. The product then consumes electricity throughout the use phase as it delivers industrial-grade Ethernet connectivity, power, and network management for operational technology environments. Finally, the products reach EOL and are recycled, landfilled, or returned to Cisco for recycling.

3.1.1 Component Manufacturing

The components utilized in manufacturing Cisco products fall into four main categories: key electronic, electrical, electro-mechanical, and mechanical components. The key electronics category is defined as printed circuit boards (PCBs) and integrated circuits (ICs). Electrical components are capacitors, inductors, resistors, diodes, and transistors. Electro-mechanical components include cables, fans, connectors, batteries, disks, video equipment, power supplies, etc. The mechanicals category is defined as all other materials, such as housing materials (plastics, metals), heatsinks, nuts, spacers, screws, solder paste, and the like. Based on WSP's experience on similar projects and readily available literature, electronic electrical components (through manufacturing, but potentially also at EOL incineration) and the use phase typically are the most significant contributors to environmental impacts for IT products (Gonzalez, et al., 2012). Therefore, emphasis has been placed on the modeling of electronic and electrical components specifically, as outlined in the following subsection.

It is important to acknowledge that there will be manufacturing waste generated during processes such as grinding and sawing. Therefore, a 2 percent waste rate has been incorporated to represent the percentage of material that is discarded or lost in the manufacturing process, a common assumption when the waste flows are unknown.

Modeling of Electronic and Electrical Components

The list of electrical components includes ICs, PCBs, capacitors, resistors, transistors, and inductors. Furthermore, ICs and PCBs are considered key electronic components. For each category, key variables were identified based on environmental impacts and internal categorization at Cisco. The most commonly used parts by Cisco were identified and categorized around the key variables. For example, for PCBs, the number of layers were identified as a key driver of environmental impacts from PCBs, and as such the number of layers were identified by Cisco.

As part of the Parameterizer, WSP integrated the functionality to read the BOM for the electrical components based on the part descriptions in the BOM. Compared to the non-electricals, for which the user must enter values manually, this enables an automatic extraction of electrical components into the desired format of the model. In essence, this means that the electricals of the BOM were easily summarized into the inputs specified in the confidential appendix. If the BOM reading failed to identify the specific type of electrical component (such as a specific IC), it defaulted to the highest impact option as a conservative assumption. Due to the sensitive nature of the data, it is placed in a confidential appendix not included in the public version of this report.

In some of the passive component dataset descriptions, there is a distinction between base metals and precious metals. Base metals typically include commonly used metals such as copper, zinc, and nickel, while precious metals typically include more rare and expensive metals such as gold, silver, and platinum. This is a critical distinction in some datasets because impacts associated with the extraction and refinement of base and precious metals can vary drastically due to differences in their mining and processing practices. Free online documentation of the LCA for Experts Extension database “XI: electronics” 2025, as well as all other databases, can be found here.

Electronic and Electrical Components Modeling Assumptions

A central aspect of the BOM read is the connection between the components that are being read and what dataset they are matched to. As previously mentioned, the most common electrical components that Cisco used were identified in collaboration with an internal Cisco team and were included in the BOM read. However, several of these components do not have direct dataset matches. As such, several proxies needed to be made. For those components that do not have a direct match, scaling factors were applied to the most suitable match. For example, linear ICs of the TSSOP packaging type are matched to a dataset for the SSOP packaging type (based on IC type and dimensions) with a scaling factor of 0.69.

As the BOM read did not cover all of the components that Cisco uses, there was a need for a solution for “unidentified components.” The BOM read summarizes all unidentified components for each component type and conservatively assumes that they are the dataset with the highest environmental impact. For ICs, this solution has more proxy options than the other components. IC unidentified proxies are made based on IC type and packaging type to the degree possible. The other components have a singular assumption each, as presented in Table 2.

Table 2: Assumptions for Unidentified Electrical Components

Component	Unidentified Component Assignment
Resistors	Resistor flat chip 1206 (9.2mg)
Capacitors	Capacitor ceramic MLCC 0603
Inductors	Coil multilayer chip 1812 (108mg) 4.5x3.2x1.5
Transistors	Transistor signal SOT223 8 leads (180mg) 3.8x7.65x3
Diodes	Diode power DO214/219 (93mg) 4.3×3.6×2.3
Linear IC	IC SSOP 24 (123mg) 8.2x5.3 mm
Logic IC	IC SSOP 24 (123mg) 8.2x5.3 mm
Communication IC	IC BGA 48 (72mg) 8x6 mm
Microprocessor IC	IC BGA 256 (4g) 27x27 mm
Memory IC	IC TSOP 32 (373mg) 8x20 nm flash
Other IC	IC BGA 144 (360mg) 13X13mm

Modeling of Electro-Mechanical Components

The electro-mechanical components category consists of audio and video equipment (e.g., microphones and displays), cables, switches, connectors, batteries, power supplies, and fans. As Cisco BOMs do not always contain information necessary to convert into the unit of measure used by the LCA datasets, assumptions were also needed for electro-mechanical components (regardless of whether being read from the BOM or entered manually). The assumptions made for those components that do not have quantities as a unit of measure in the LCA datasets are presented in the confidential appendix. The assumptions are made based on the weights of the components in the dataset.

Modeling of Mechanical Parts and Packaging

The mechanical components category consists of plastic and metals, commonly used as housing material and for smaller components such as screws, gaskets, spacers, and heatsinks. The complete list of inputs, values, and data sources is provided in the confidential appendix.

3.1.2 Transportation of Materials and Components to Factory

The packaging for raw materials and components was not included in this study. Upstream transportation between supplier and manufacturing facility assumes a mix of truck, sea freight, and air freight (**Error! Not a valid bookmark self-reference.**). Distances were assumed based on regional sourcing with an average transportation distance of 3,000 miles, distributed as 39 percent truck transport, 60 percent sea freight, and 1 percent air freight. Exact distances between supplier and manufacturing facility were not calculated. A simplified approach to transportation was taken in the Scalable LCA Model because early iterations showed that transport was not a significant contributor to environmental impacts and generic distance options for different kinds of geographical sourcing was deemed sufficient. For example, 3,000 miles is approximately equivalent to transportation between in-land locations in a country in Asia.

Table 3: Generic Data Used for Upstream Transportation

Dataset	Value (tkm)	Data Source	Last Update Date	Geographical Coverage
transport, freight, lorry 16-32 metric ton, EURO6	7.4	ecoinvent 3.11	2025	Rest of the World
transport, freight, sea, container ship	11.3	ecoinvent 3.11	2025	Global
transport, freight, aircraft, dedicated freight, long haul	0.19	ecoinvent 3.11	2025	Global

3.1.3 Assembly

As primary data was not available on assembly burdens, a proxy was used. As the product under study is an industrial switch, it was deemed that the smartphone dataset from ecoinvent was a suitable proxy for assembly burdens (details in **Error! Not a valid bookmark self-reference.**). Both smartphones and industrial switches involve intricate technological systems, requiring the assembly of various electronic components to create a functional end product. The complexity and diversity of components in a smartphone make it a representative model for understanding the assembly burdens of the industrial switch.

Table 4: Proxy Data for Assembly Burdens

ecoinvent process	consumer electronics production, mobile device, smartphone
Literature source the ecoinvent process is based on[1]	Güvendik (2014)
Water use (liter) per kilogram of product	513
Electricity (kilowatt-hour) per kg of product	2.78
Wastewater output (cubic meter) per kilogram of product	0.48

Note: [1] As identified by WSP as the underlying data informing the ecoinvent process.

Electricity consumption, water use, and wastewater output were extracted from the proxy and included in the modeling of assembly by scaling based on the weight of the studied product. Activity values and datasets used are provided in Table 5. Manufacturing was assumed to take place in Asia. Water use and electricity consumption were modeled using a country-specific dataset, while wastewater uses a regional average dataset.

Table 5: Assumptions for Assembly

Activity	Value	Dataset	Data Source	Geographical Coverage
Electricity (kWh)	8.6	Sphera	Electricity grid mix	Country in Asia
Water use (liter)	1590.3	Sphera	Tap water from ground water	Asia
Wastewater output (cubic meter)	1.5	ecoinvent	Market for wastewater, unpolluted	Rest of World

3.1.4 Testing

For testing, an approach similar to assembly was used, as no primary data were available. The power consumption of the device, in combination with an assumption on testing extent, was used to calculate energy consumption inputs for testing. For example, some testing requires both heat and electricity, while some testing is more manual and uses lower amounts of electricity. The maximum power consumption was used as a conservative assumption since this is the most amount of energy the device can use (Table 6). The approach is meant to represent average nominal testing before shipping, not peak testing in extreme conditions.

Table 6: Assumptions for Testing

Activity	Value (kWh)	Dataset	Data Source	Geographical Coverage
Electricity	15.5	Electricity grid mix	Sphera	Country in Asia
Heat	6.2	Market for heat, district or industrial, other than natural gas	ecoinvent 3.10	Rest of World

Note: Testing was assumed to take place in a country in Asia.

3.1.5 Distribution

Distribution entails transportation from the manufacturing location to the consumer. Burdens from storage in warehouses were not considered. Downstream transportation between the manufacturing facility and the customer assumes a mix of truck, sea freight, and air freight (**Error! Not a valid bookmark self-reference.**). Distances were assumed based on international distribution with an average transportation distance of 7,000 miles, distributed as 98 percent air freight and 2 percent truck transport. Exact distances between manufacturing facility and consumer were not calculated for the reasons provided in Section **Error! Reference source not found.** on upstream transportation. The distance of 7,000 miles is approximately equivalent to transportation between the manufacturing country in Asia and the United States.

Table 7: Generic Data Used for Downstream Transportation

Dataset	Value (tkm)	Data Source	Last Update Date	Geographical Coverage
transport, freight, lorry 16-32 metric ton, EURO6	0.86	ecoinvent 3.11	2025	Rest of the world
transport, freight, aircraft, dedicated freight, long haul	42.4	ecoinvent 3.11	2025	Global

3.1.6 Use

The use phase comprises the electricity needed during the device's lifetime operation, including the electricity needed for the sharing of information across network devices thus ensuring continuous and efficient communication between various interconnected devices. The product was modeled as being used in the United States. The use phase has been modeled around energy consumption with the following parameters:

- Country of use: United States
- Modeled power consumption: 64 Watts
- Modeled annual energy consumption: 560.6 kWh
- Lifespan of product: 5 years

The modeled power and energy consumption and lifespan of the product were provided by Cisco. The annual energy consumption is multiplied by the lifespan of the product for the complete use phase electricity consumption, which is provided in Table 8 alongside the dataset used for the grid mix.

Table 8: Generic Data Used for Use Phase

Dataset	Value (kwh)	Data Source	Last Update Date	Geographical Coverage
Electricity grid mix	2803.2	Sphera	2025	United States

Note: Information on the grid mix composition can be found in the dataset documentation: https://lcadatabase.sphera.com/2026/xml-data/processes/6b6fc994-8476-44a3-81cc-9829f2dfe992.xml

3.1.7 End-Of-Life

The EOL stage was modeled as a split between the United States national average treatment of electronic products and the Cisco takeback program. The United States average treatment of electronics waste is assumed to be 75 percent landfill and 25 percent recycling, in line with previous work conducted by WSP and readily available statistics (EPA, 2022), although the range of recycling of electronics varies between 15 to 30 percent depending on the source. Basing the EOL on data specific to the United States assumes the most responsible and burdensome waste management, a conservative approach in which all products are properly disposed. Adding regional options for the average waste treatment of electronics could be considered in future improvements of the Scalable LCA model.

Electronics that are sent to landfill or recycling facilities are typically first shredded. For recycling, default processes for metal recycling and plastic recycling are used. Metal recycling is used for electronics, including key electronics, while plastic recycling is used for non-electricals.

Besides recycling and landfill, Cisco also has a takeback program. The specifics of how this influences the EOL flows are detailed in the confidential appendix, along with a table summary of all EOL flows. In the takeback flow, all of the product is assumed to go to recycling. The confidential appendix presents the complete statistics for EOL as outlined in this subsection.

In summary, the EOL phase consists of transportation, landfill, recycling, and takeback. The confidential appendix contains the complete list of activities and values applied in the EOL stage of this study.

3.2 Limitations

There are a few key data limitations associated with electrical components and the use of secondary data for assembly and testing. Within the BOM, electrical components were matched to the components available in the LCA for Experts (formerly GaBi) and ecoinvent databases, which were not always an exact match. The matching was done using packaging type and dimensions to match the electrical parts in the product to that of electricals components available in the databases. Proxied components were scaled by length and width or mass to reflect the number and type of components in the product under study.

Manufacturing burdens of the assembly and testing of the product were proxied using secondary datasets from ecoinvent, as these operations involve energy consumption and water use and the proxies include all these flows. A limitation of the proxies is that they do not track operations improvements or changes over time.

3.3 Cut-Off Criteria

All secondary data are considered to be internally consistent as they have been modeled according to the LCA for Experts Modeling Principles and guidelines. According to these principles, cut-off rules for each unit process require coverage of at least 95 percent mass and energy of the input and output flows and 98 percent of their environmental relevance (according to expert judgement). Where applicable, cut-off criteria would only be applied for components that contribute to 1 percent or less of total mass or energy of the system and 5 percent or less of the total environmental impacts. The cut-off criteria were applied to packaging of upstream materials and components as well as warehouse burdens due to data availability.

3.4 Allocation Procedures

There are no co-products associated with the studied product. Therefore, this study did not perform allocation. Allocation of environmental burdens to material and energy co-products throughout the upstream supply chain is embedded in the LCI data used in this study and described in the documentation of these datasets.

4 Life Cycle Impact Assessment

4.1 Life Cycle Impact Assessment Procedures and Calculation

LCA for Experts can generate results for many impact categories. Below is a list of impact categories that were assessed as part of the development of the Scalable LCA model and were assessed in this study. These impact categories were identified as being of key interest to Cisco and its stakeholders while also being common categories for assessment of electronics. Attached to each impact category is the method implemented in LCA for Experts to generate results for the stated impact category.

- GHG emission (GWP 100, excluding biogenic carbon dioxide [CO_2]) (kg CO_2 equivalent [CO_2e]) - IPCC AR6 (excluding biogenic)
    - Assesses the emission of GHGs into the atmosphere and evaluates the contribution to GWP over a 100-year period and excludes emissions from biological sources.
    - The impact is expressed in terms of carbon dioxide equivalents. As each greenhouse gas has a different warming effect depending on the chosen timeframe, this unit represents all greenhouse gases converted into equivalents of carbon dioxide over a 100-year period.
- PED (from non-renewable energy sources) (megajoules [MJ]) – LCA for Experts Energy Indicators, non-renewable energy
    - The low heating value (or net calorific value) approach was used to determine the primary energy from non-renewable resources and is measured in MJ.
- BWC (kg) – LCA for Experts Water Indicators, BWC
    - Assesses the consumption of freshwater resources from surface and groundwater bodies.
    - The BWC results are presented in kilograms in LCA for Experts; however, since 1 kg of water is equal to 1 liter of water in the metric system, results are presented in liters.
- Abiotic Depletion (ADP Elements) (kilogram [kg] antimony [Sb] equivalent) - CML 2001 (Aug. 2016)
    - Assesses the depletion of non-living resources, such as metals and minerals, and evaluates the potential for resource scarcity.
    - The impact is expressed in terms of the environmental damage equivalent to the depletion of a certain amount of Sb.

The results of the abiotic depletion environmental impact indicators are not intended for comparison due to high uncertainty associated with the indicators. For the toxicity impact categories, a difference of 1,000 percent is not significant.[3] For abiotic resource depletion, the results shall be used with care as the uncertainties of the results are high due to high variability depending on calculation approach and uncertainties in the material reserves data.

[3] The USEtox documentation provides further insights on uncertainty in toxicity impact metrics: https://usetox.org/model/documentation

4.2 Life Cycle Impact Assessment Results

The LCA for Experts software calculates life cycle impact assessment (LCIA) results in its balance function and computes the environmental impact results according to predefined characterization methods in the selected LCIA methodology.

4.2.1 Global Warming Potential

The GHG emissions (excluding biogenic carbon) per IE-3505-8P3S switch were 1,573 kg CO2e. As shown in Figure 3, the GHG emissions were categorized into different life cycle stages covering manufacturing, transport, use phase, and disposal.

The use phase is the highest contributor, accounting for 86 percent of total emissions, followed by manufacturing at 12 percent and transport at 2 percent. End-of-life contributed less than 0.1 percent of total emissions. The primary contribution from the use phase is attributed to electricity consumption during the product's operational lifetime. The electricity grid mix has a carbon intensity that results in substantial cumulative emissions from continuous operation, with the use phase generating 1,349 kg CO_2eq compared to only 187 kg CO_2eq from manufacturing.

As stated above, the product was modeled as being used in the United States. The United States electric grid is heavily dependent on fossil fuels, with 34 percent of electricity from natural gas and 29 percent of electricity from coal (Sphera, 2023a). The dependence on fossil fuels such as coal and natural gas is known to be a large contributor to GHG emissions from the United States electric grid.

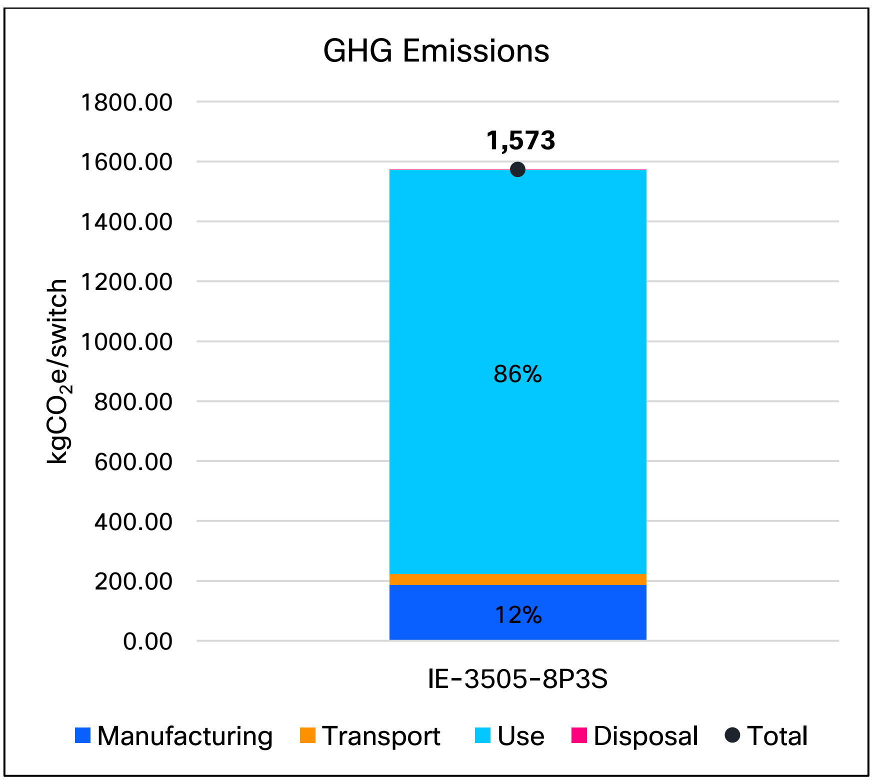

Figure 3: Global Warming Potential per IE-3505-8P3S switch by Life Cycle Stage

The manufacturing phase was the second-largest contributor to GHG emissions, accounting for 12 percent of total GHG emissions per switch. As shown in Figure 3, excluding the energy consumed during assembly and testing, as well as the treatment of manufacturing waste and packaging, and focusing solely on the components processed within the upstream supply chain, key electronic components, such as ICs and PCBs, contributed 49 percent of the manufacturing impacts. Following key electronic components, mechanical components and electro-mechanical components comprised 25 percent and 17 percent of impacts, respectively, with electrical components accounting for the remaining 9 percent. Key electronic components such as PCBs and ICs are known to be energy intensive processes, accounting for 50 and 37 percent of key electronic impacts. This high contribution is likely driven by the energy- and emissions-intensive semiconductor fabrication processes required for IC production, including cleanroom environmental controls and the use of process gases with high global warming potential.

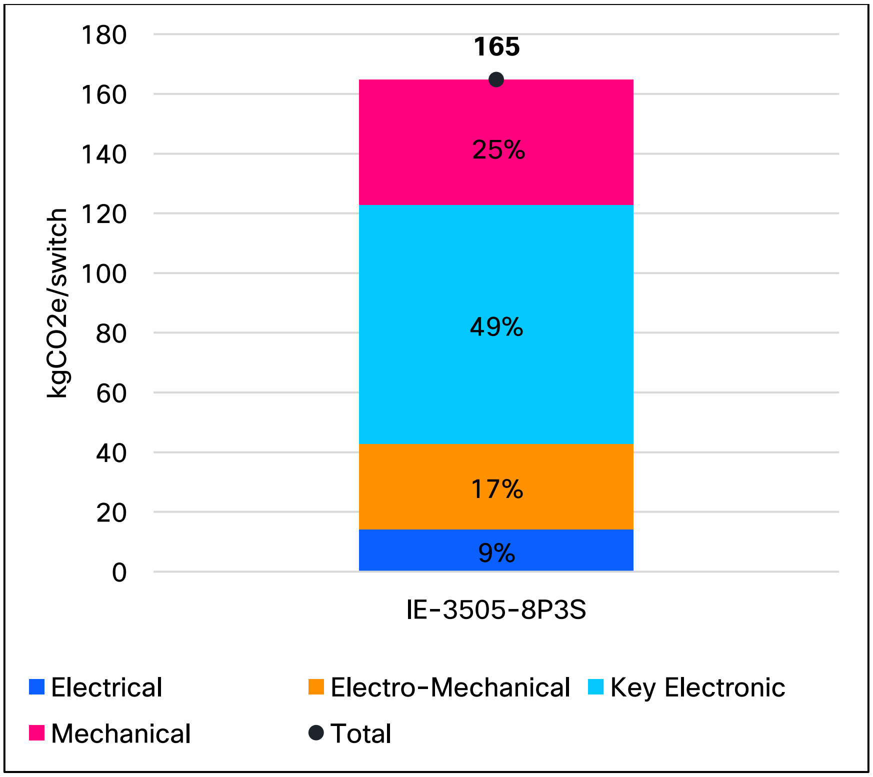

Figure 4: Global Warming Potential per IE-3505-8P3S from Manufacturing Components Across the Upstream Supply Chain

4.2.2 Primary Energy Demand

The PED from non-renewable sources reflects the amount of energy demanded from the ecosystem. As shown in Figure 5, the total PED, characterized by fossil-based energy demand, was 26,328 MJ per switch. The use phase dominates the overall impact, contributing 89 percent to the total non-renewable energy consumption, due to the annual energy consumption of 560 kWh over a 5-year lifetime, driven by direct and indirect energy. Direct energy is the operation of electricity itself, while indirect energy is the energy required to produce electricity. Indirect electricity includes the mining, transportation, and processing of resources required to produce electricity. Manufacturing is the second-largest contributor to PED at 9 percent. These impacts are due to the electricity required to produce electronic components within the switch. The primary contributor within the manufacturing stage is key electronics, accounting for 46 percent of total energy consumption within this phase. ICs and PCBs are the most significant contributors among these key electronic components, which must be manufactured through energy-intensive processes due to their complex internal structures.

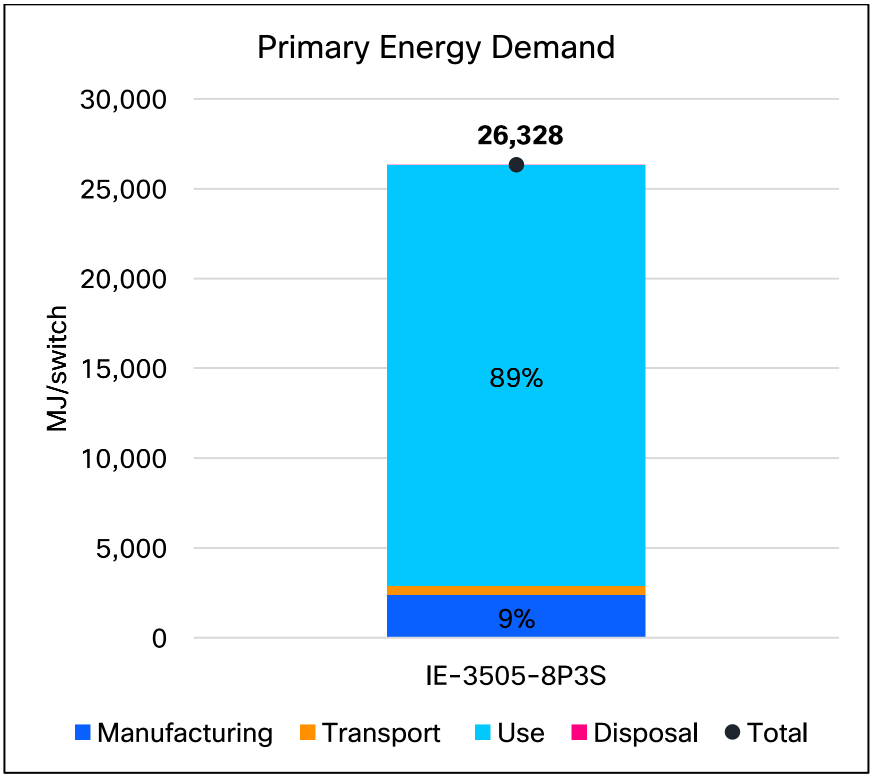

Figure 5: Primary Energy Demand per IE-3505-8P3S by Life Cycle Stage

4.2.3 Blue Water Consumption

BWC represents the net difference between water extracted from the ecosystem and water returned to the ecosystem in a usable form. As shown in Figure 6, the BWC results are 11,384 liters per IE-3505-8P3S switch. The use phase is the largest contributor, accounting for 74 percent of total water consumption, while manufacturing is the second-largest contributor with 25 percent. Transport and end-of-life combined contributed less than 1 percent. As previously mentioned, the United States electric grid mix is primarily dependent on fossil fuels such as coal and natural gas. Both of these sources require water for their extraction and electricity generation, where water is converted to steam post-resource combustion (Union of Concerned Scientists, 2010; WRI, 2020).

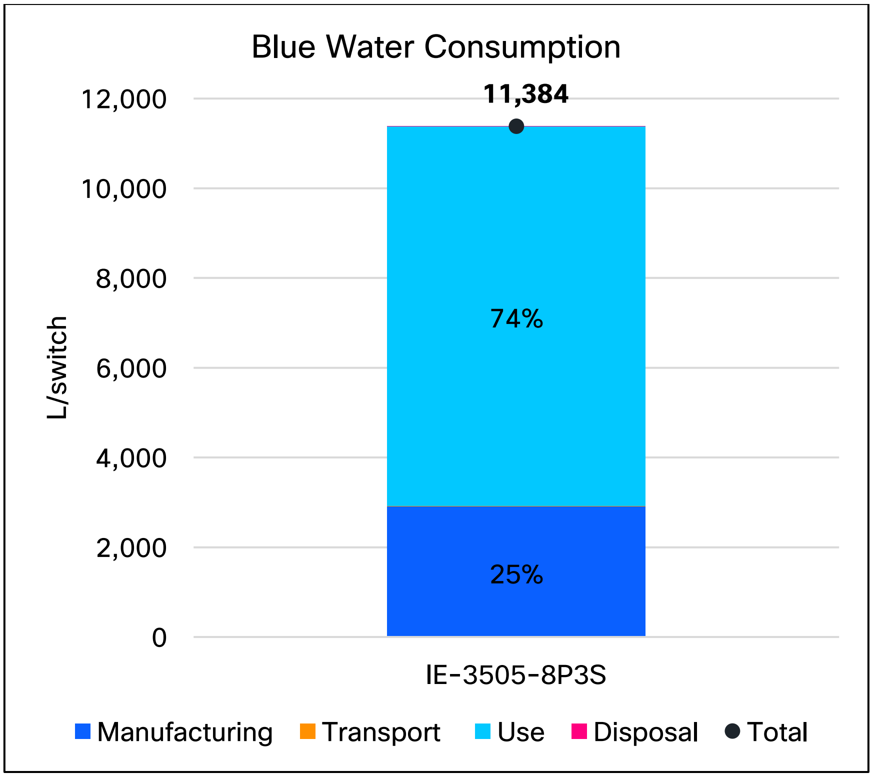

Figure 6: Blue Water Consumption per IE-3505-8P3S by Life Cycle Stage

4.2.4 Abiotic Depletion Potential

ADP assesses the depletion of non-living resources, such as metals and minerals (not energy), and evaluates the potential for resource scarcity. The impact is expressed in terms of the environmental damage equivalent to the depletion of a certain amount of antimony (Sb). As shown in Figure 7, the ADP result is characterized as 0.019 kg Sb-equivalent per IE-3505-8P3S switch. Manufacturing is the largest contributor, accounting for approximately 99 percent of the total impacts. The use phase contributed only 1 percent, with transport and end-of-life contributing less than 0.1 percent each.

This pattern contrasts sharply with energy-related categories, reflecting the material-intensive nature of electronic component production. Manufacturing contributed 0.019 kg Sb-eq compared to only 0.0002 kg Sb-eq from the use phase. Within manufacturing, electro-mechanical components contributed 42 percent of the manufacturing total, contributing 0.008 kg Sb-eq. This contribution reflects the rare earth elements and precious metals required for semiconductor fabrication. Key electronic components contribute an additional 39 percent of manufacturing impacts, reflecting the material intensity of power supply components and metal housings.

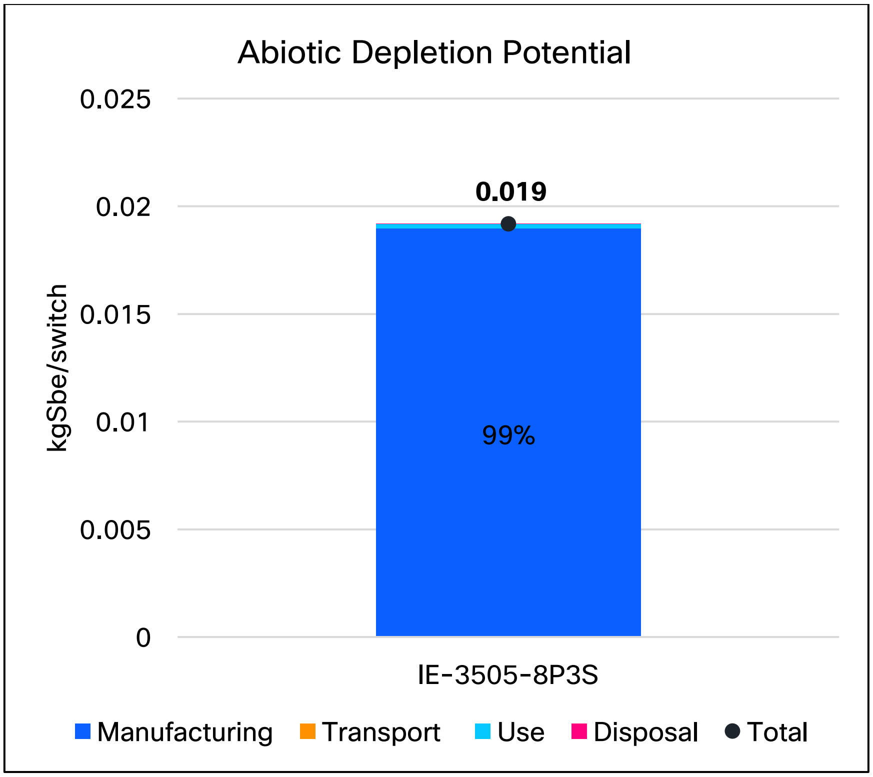

Figure 7: Abiotic Depletion Potential per IE-3505-8P3S by Life Cycle Stage

4.3 Limitations

The primary limitations of the Scalable LCA Model are the assumptions related to electrical components and the use of secondary data for manufacturing burdens. In terms of materials burdens, a special focus was placed on electrical components that (as outlined in Section 3) are known to have a disproportionately high environmental impact compared to other components such as housing or packaging. The initial intention was to cover the top 10 most-used component types in each component category (ICs, PCBs, etc.), which leads to a limitation for Cisco products that mainly use components not represented in this version of the model. However, throughout the iterations of the Scalable LCA model, additional components have been added, and today over 90 electronic components and their dimensions are included in the BOM reader. Furthermore, several proxies needed to be made using scaling factors, as direct dataset matches were not available. The dataset proxies were made based on component attributes such as electrical packaging type or dimensions, but there remains a limitation in the scaling factors being based on linear relationships based on area or volume. Based on the area or volume of the component under study, the proxy dataset was scaled to the equivalent area or volume. It is a known limitation of this approach that environmental impact does not scale linearly in this way.

Manufacturing burdens for both assembly and testing were proxied using secondary datasets from ecoinvent. Other than the circular activities of Cisco, the EOL disposal and manufacturing waste use average datasets that could benefit from higher resolution, especially in terms of manufacturing waste, which currently only has a metals waste flow and a plastics waste flow.

The Scalable LCA Model applies the recycled content approach to modeling materials reuse and recycling (also called the cut-off approach), which in this context means that the burdens from processing wastes into recycled materials are included as part of the materials burdens for manufacturing Cisco products, while any emissions or credits of reused materials are “cut off” at transport to recycling facilities. As such, no credit is given, and no system expansion is conducted to align with the system boundaries of the approach.

Beyond the limitations and assumptions associated with the modeling and tool, there are further considerations that need to be made for the underlying data. As identified by the data quality assessment, the data have an average representative score of 2 to 3, with large variations between the life cycle stages and several instances of low representativeness. Identifying these limitations will help inform stakeholders on how the Scalable LCA model can be improved to be more representative in future iterations.

4.4 Description of Practitioner Value Choices

The practitioner value choices have been limited to the selected LCIA and the allocations procedures described in the relevant sections of this report. All results are presented on a midpoint basis using the methods noted in Section 4.1; normalization and weighting are not used. Other impact categories have been excluded from the results because they do not answer the questions defined as the goal and scope for the intended audience in Section 1 of this report.

4.5 Statement of Relativity

LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins, or risks. No grouping of impact categories has been performed; all impacts are presented at the midpoint level. LCIA impacts presented in this report are based on midpoint characterization factors (e.g., kg CO2e for GWP), and this study does not refer to the ultimate damage to human health and the environment. For example, GWP and water consumption may be a negative or a positive environmental impact depending on the conditions in locations where emissions or resource consumption occur. Since this study does not present end-point results, it does not draw any conclusions about the relative impact (positive or negative) for the categories considered by the study.

5 Life Cycle Interpretation

5.1 Identification of Relevant Findings

The use phase is the dominant contributor across most selected environmental impact categories, including GHG emissions, PED, and BWC, accounting for approximately 74–89% of total impacts, depending on the category. These impacts are largely driven by electricity generation and consumption during use, as a substantial portion of electricity in the grid is derived from coal and natural gas sources. For ADP, the manufacturing phase was the primary driver of impacts, accounting for 99 percent of impacts.

5.2 Sensitivity Analysis

To evaluate the ways in which inputs to the modeling in this study influence results, a sensitivity analysis was conducted by changing input parameters and assumptions. The analysis involved increasing the total amount of recycled metal content by 50 percent. This scenario modeled an increase in recycled metal content of up to 50 percent to evaluate the sensitivity of embodied impacts to material circularity assumptions. Incremental increases in recycled content (approximately 10–30 percent) are commonly achievable through supplier selection and recycled alloy specification, while maintaining equivalent material performance and manufacturing requirements. These changes typically do not require redesign and can be implemented within existing production constraints. Higher recycled content levels (40–50 percent) generally reflect more ambitious sourcing strategies that may require alternative alloy formulations, expanded supplier qualification efforts, or changes in recycled feedstock availability. As such, the upper-bound recycled content modeled here represents a technically plausible but more aspirational scenario intended to illustrate potential impact reduction rather than a guaranteed near-term outcome.

For this study, GWP and BWC have been selected as the impact categories evaluated because they represent critical environmental indicators that are highly relevant to sustainability assessments and can significantly influence overall life-cycle assessment.

Increasing the amount of recycled metal content by 50 percent results in a slight decrease in overall GWP from 1,573 kg CO2eq to 1,554 kg CO2eq, which is a reduction of about 1 percent. As shown in Figure 8, when focusing on the manufacturing phases and excluding the energy consumed during assembly and testing, as well as the treatment of manufacturing waste and packaging, and focusing solely on the components processed within the upstream supply chain, the GWP decreases from 165 kg CO2eq to 146 kg CO2eq, which is a reduction of about 11 percent with most of the reduction coming from the mechanical components. This indicates that increasing recycled metal content by 50 percent can marginally reduce climate impacts but that the operational phase continues to drive the majority of the emissions. The relatively small overall reduction of 1 percent is due to the fact that most GWP contributions come from the use phase, which is unaffected by changes in recycled metal content. Total operational energy remains the same because the switch is expected to perform the same networking functions regardless of material sourcing. Since device workload (e.g., data throughput, processing demand, and uptime) is unchanged, the model holds operational power constant. Changes in recycled metal content affect manufacturing and end-of-life impacts through material production pathways, but these stages contribute a relatively small share of total lifecycle emissions compared to the energy-intensive use phase.

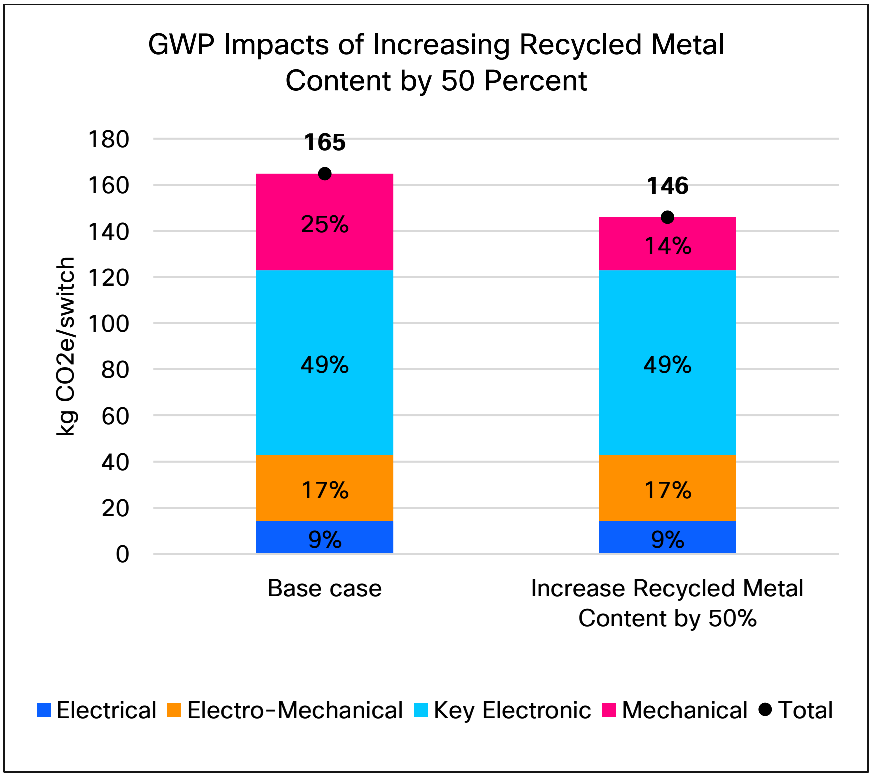

Figure 8: Sensitivity Analysis Results for the Manufacturing Phase when Increasing Recycled Metal Content by 50 Percent for GWP

As shown in Figure 9, when focusing on the manufacturing phases and excluding the energy consumed during assembly and testing, as well as the treatment of manufacturing waste and packaging, and focusing solely on the components processed within the upstream supply chain, the BWC decreases from 1,153 liters to 1,081 liters, which is a reduction of about 6 percent with most of the reductions coming from mechanical components. However, the overall reductions of the IE-3505-8P3S switch are less than 1 percent with total impacts reducing from 11,384 liters to 11,312 liters. This indicates that increasing recycled metal content by 50 percent can marginally reduce climate impacts but that the operational phases continue to drive the majority of the water consumption. The relatively small overall reduction of less than 1 percent is due to the fact that most BWC contributions come from the use phase, which is unaffected by changes in recycled metal content. Total operational energy remains the same because the switch is expected to perform the same networking functions regardless of material sourcing. Since device workload (e.g., data throughput, processing demand, and uptime) is unchanged, the model holds operational power constant. Changes in recycled metal content affect manufacturing and end-of-life impacts through material production pathways, but these stages contribute a relatively small share of total lifecycle water consumption compared to the energy-intensive use phase.

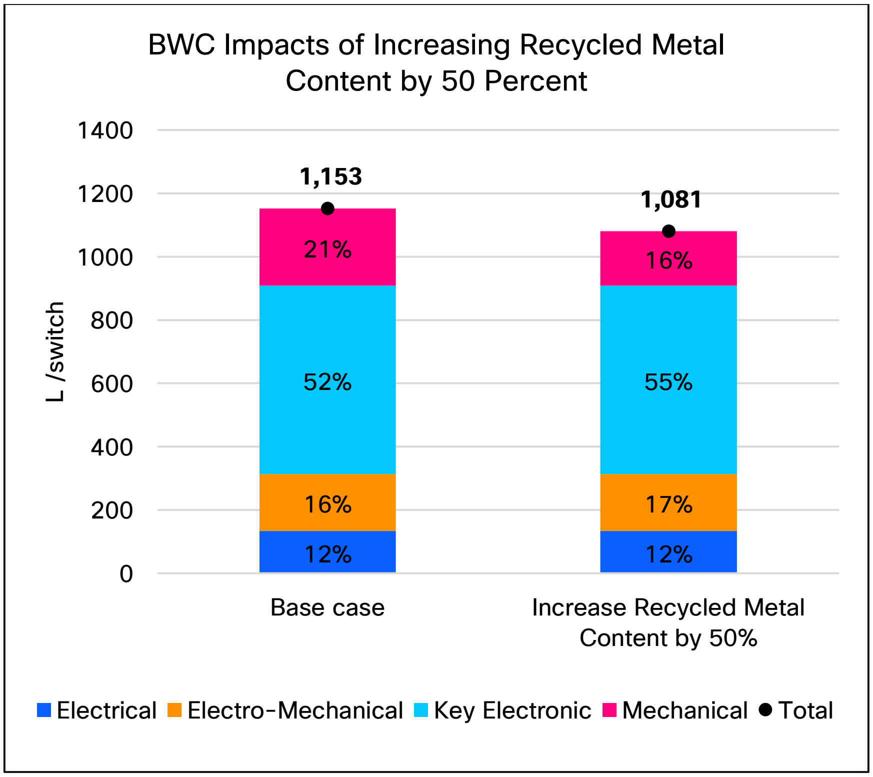

Figure 9: Sensitivity Analysis Results for the Manufacturing Phase when Increasing Recycled Metal Content by 50 Percent for BWC

5.3 Data Quality Assessment

The quality of fit, or representativeness, of model inputs will be evaluated across five indicator categories: reliability, completeness, temporal correlation, geographical correlation, and technological correlation. For each indicator, a score from 1 to 5 was assigned to each model input, where 1 indicates high representativeness of the product system and 5 indicates low representativeness (Table 9). The assessment was completed across life cycle stages for a final average score (rounded to the nearest whole number) in each indicator (Table 10).

Table 9: Pedigree Matrix Adapted from the United States Environmental Protection Agency

	Highest confidence				Lowest confidence
Data Quality Indicator	**1**	**2**	**3**	**4**	**5**
Reliability	Primary data from Cisco, measured data	Primary data from Cisco, estimated data	Data obtained from literature with an exact proxy match	Data obtained from literature with a proxy match	Data obtained from online sources and not an exact match, limited documentation

	Highest confidence				Lowest confidence
Data Quality Indicator	**1**	**2**	**3**	**4**	**5**
Completeness	Representative data from >80% of the relevant market, over an adequate period	Representative data from 60-79% of the relevant market, over an adequate period or representative data from >80% of the relevant market, over a shorter period of time	Representative data from 40-59% of the relevant market, over an adequate period or representative data from 60-79% of the relevant market, over a shorter period of time	Representative data from <40% of the relevant market, over an adequate period or representative data from 40-79% of the relevant market, over a shorter period of time	Unknown or data from a small number of sites and from shorter periods
Temporal correlation	Less than 3 years of difference	Less than 6 years of difference	Less than 10 years of difference	Less than 15 years of difference	Age of data unknown or more than 15 years
Geographical correlation	Data from same resolution and same area of study	Within one level of resolution and a related area of study	Within two levels of resolution and a related area of study	Outside of two levels of resolution but related area of study	From a different or unknown area of study
Technological correlation	All technology categories are equivalent	Three of the technology categories are equivalent	Two of the technology categories are equivalent	One of the technology categories is equivalent	None of the technology categories are equivalent

Source: (Edelen & Ingwersen, 2016)

Geographical resolution has seven levels of resolution: global, continental, sub-region, national, province/state/region, county/city, and site-specific (Edelen & Ingwersen, 2016). The sub-region level refers to regional descriptions (e.g., UAE), while the site-specific level, the most granular level, includes the physical address of the site. The geographical correlation is scored based on the level of the input data and the level of the dataset that is available.

Technological correlation is represented using four categories: process design, operational conditions, material quality, and scalability. Process design refers to the set of conditions in a process that affects the product. Operational conditions refer to variable parameters such as heat, temperature, and pressure that are needed to make the product. Material quality refers to the type and quality of feedstock material. Scale refers to output per unit time or per line needs to be described.

Table 10: Pedigree Matrix Adapted from the United States Environmental Protection Agency

Data Quality Indicator	Data Quality Description by Phase	Average
Reliability	Materials: For key electronic components, the tool reads from a BOM and makes the best possible match for components based on	**2**

Data Quality Indicator	Data Quality Description by Phase	Average
	area/volume of die. Other material inputs are obtained from the user of the tool and are considered primary data. Therefore, the reliability of material data is highly representative of the product being assessed. Even though material and BOM data are primary, they cannot always be matched to exact datasets and proxies with scaling factors are used. Therefore, the reliability score for materials is 2. Manufacturing: Since the tool is expected to be applied across multiple products, the manufacturing inputs are automatically calculated based on the complexity of the product. Both assembly and testing are proxied using a three-level complexity scale – low, medium, high. This is based on literature sources for proxies and therefore manufacturing has a reliability score of 4. Transport: For upstream and downstream transport, the weight of the product, the distance travelled, and distribution mode is obtained from the user. There are some default values that can be used for distance if exact distances are not known by the user. This is considered primary data and is highly representative. But there are various datasets available for matching and the conservative options were chosen as representative datasets. Therefore, the reliability scores for upstream and downstream transportation are 2. Use: The location of use, the lifespan of the product, and annual energy consumption are obtained from the user to calculated total use phase energy. These are primary data that are matched to highly representative grid electricity data, which get updated annually. Therefore, the reliability score for use phase is 1. End-of-Life: The extent of product reuse and recycling is obtained from Cisco. Nevertheless, there can be significant variation in what happens to products not returned to Cisco and the waste management practices of the end customer. Therefore, the reliability score for end-of-life was averaged as 2.	
Completeness	Materials: The completeness of the material inputs will depend upon the manual user entries. For key electronic components, more than 80% of the inputs are accounted for through the BOM read. No BOM item is excluded because a proxy was identified for all BOM items. The processing associated with intermediate products like OEMs are partially covered. The completeness of remaining materials (electro-mechanical and mechanical) will depend upon user input. Therefore, the completeness score is conservatively assessed as 2. Manufacturing: Since assembly and testing are proxied using a complexity scale, the completeness of the manufacturing inputs and outputs within the model is lower. There is lower confidence in the completeness related to assembly and testing energy amounts, but higher confidence in the location of manufacturing. At least 50% of inputs and outputs are covered. Therefore, the completeness score for manufacturing is 3.	**3**

Data Quality Indicator	Data Quality Description by Phase	Average
	Transport: For both upstream and downstream transport, the distance is user input. Typically, the distance measured for transportation is an approximation based on origin and location, and not on the route. Incomplete information on packaging for products affects the completeness of the transportation model. Even though there are some limitations with regards to completeness, there is confidence that there is 70% coverage in all inputs and outputs. Therefore, the completeness score for transport is 2. Use: The use phase of the product is modeled using different locations and corresponding grids. This covers more than 80% of all product use locations. Therefore, the completeness score in the use phase is 1. End-of-Life: Traditional disposal mechanisms (e.g., landfilling and recycling) are considered at end-of-life, along with custom take back programs that Cisco has deployed. From the end-of-life perspective, the completeness score is 1 because this covers 100% of the product disposal. Overall, from the perspective of the whole system, there are specific processes that are currently excluded. One example is the warehousing of products and the influence of warehousing on the changes in transportation routes. Packaging of product before transport is also another stage that is only partially covered by this system boundary, which affects the overall completeness of the model.	
Temporal correlation	Materials: All material data inputs from the user and BOM are dependent on time of generation and data collection. The data that are matched to the material inputs are valid for 2024, with some valid through 2025 and 2026.The input data used in the model have high representativeness with regards to temporal correlation. However, many of the Sphera datasets that represent electrical components (especially ICs) are based on older data. Meaning, that while the “background” datasets such as electricity mix are updated each year, the underlying data collected for the dataset is older. Therefore, the score for materials phase was averaged to 2. Manufacturing: Assembly and testing input data obtained from Cisco are representative of individual data collection periods. The datasets to which the input data have been matched are valid for 2025, with some datasets having extended validity through 2025 and 2026. Manufacturing data for the model are highly representative and have a temporal correlation score of 1. Transport: Transport data for the product are provided as an input and are from 2025. The transport datasets used in the model are all valid for the year 2025. Therefore, the transportation model has high temporal correlation with a score of 1 for both upstream and downstream transportation. Use: The product is used is dependent on data collection period for the product and through end-of-life. The electricity dataset is valid for 2025, and some regional electricity data are valid through 2026.	**2**

Data Quality Indicator	Data Quality Description by Phase	Average
	Product can consume electricity beyond these time periods, with some products being used up to 2030. Therefore, the temporal correlation of the use phase is scored at 3. End-of-Life: The product will be disposed of at its end-of-life, which will be at least 5 to 10 years after production, depending on the product. All the datasets used to model end-of-life are for 2025. Therefore, at end-of-life, the data are thought to have average representativeness with a score of 3.	
Geographical correlation	Materials: All material inputs are matched to datasets that are either global averages or an Asian country's datasets. This assumes that most electronics production occurs in Asia. The datasets chosen are within two levels of resolutions and within the area of study. It might be known that the activity occurs in a specific country, but the datasets available are global averages. Therefore, the geographical correlation for materials is 3. Manufacturing: Assembly and testing are modeled based on energy use that is specific to a country. The energy dataset that the inputs are matched to are at the same level of resolution in most cases, but regional datasets are used when country-specific information is not available but are within the same area of study. The geographical correlation for manufacturing is 2. Transport: A region-specific calculation is not carried out in the tool. The dataset used is a global average for the truck, ship, and air modes. This is a difference of at least two levels of resolution but is still related to the study area. Therefore, the geographical correlation score for transport is 4. Use: Use phase is modeled based on energy use at the country level. The inputs are matched to country-specific datasets in most cases, but regional grid datasets are used when country-specific datasets are unavailable, which leads to a difference of one level of resolution (within the same area of study). The geographical correlation for manufacturing is 2. End-of-Life: There is no regional specificity with regards to the end-of-life location. Even though the processes considered are within the scope of this study, the geographic specification of the dataset is a global average. Therefore, the geographical correlation for end-of-life is 4.	**3**
Technological correlation	Materials: For electrical components, the input data and the chosen datasets represent similar material quality and scalability but are not equivalent for process design and operation conditions. For example, proxy resistors were used when an exact resistor dataset match was not available. Similarly, there have been significant changes over time in the production process of ICs, which may not be accurately represented by the datasets chosen, especially for ICs with lower tech nodes. For plastic and metal parts, material quality and scalability are equivalent, but there could be deviation in	**3**

Data Quality Indicator	Data Quality Description by Phase	Average
	the process design and operation conditions between the data inputs and datasets used in the model. For example, plastic extrusion can occur at different operating conditions at different locations that are not fully captured within the global average dataset used. There are only two equivalent categories, material quality and scalability, in the materials phase. Therefore, the technological correlation of materials is scored at 3. Manufacturing: The manufacturing process for a product is consistent, regardless of production location. However, manufacturing is modeled using the three-level complexity metric, which is not equivalent to the manufacturing process of the product. Therefore, it is not possible to establish process design and operational conditions equivalence between the input data and the dataset chosen for the model. The quality of materials used in the production process are high for Cisco and in the datasets used, but the material types used are not equivalent between the Cisco products and the products used to proxy the three-level complexity metric. The technological correlation of the data is low with equivalence in only one category. Therefore, the score is 4. Transport: The transportation datasets used assume standard fuel efficiencies for these modes. The scale at which parts and products are moved are relatively consistent with some variation in packaging ratio and storage capacities, but overall, the technological correlation of transport is good and is scored at 2. Use: The products under consideration from Cisco consume electricity. The process flow, operation conditions, and scale of electricity production technology (for coal, natural gas, solar, wind, hydroelectric, etc.) are largely consistent across the world and are accurately captured in the datasets used for different regions. The quality of material used to generate electricity can change between regions. But all efficiencies, source distribution, and losses are captured accurately by energy datasets that are used. Hence the technological correlation of the use phase is high and is scored at 1. End-of-Life: The product is typically disposed of by either landfilling or recycling. Product lifetime extension through reuse is also considered. The datasets used accurately represent the process of disposal, incorporating the efficiencies and recovery associated with the corresponding disposal technology. Disposal operations and scale of these operations vary significantly across the world, which are not represented well by a global average dataset. Therefore, the technological correlation of end-of-life is scored at 3.	

5.4 Conclusions and Recommendations

The findings of this report demonstrate that one IE-3505-8P3S switch creates 1,573 kg CO_2e of GHG emissions, demands 26,328 MJ of fossil-fuel-based primary energy, and consumes 11,384 liters of blue water. According to the EPA GHG equivalence calculator, driving 2.6 miles in a passenger vehicle emits 1 kg CO_2e (US EPA, 2019). The GHG emissions created by one IE-3505-8P3S switch are equivalent to driving 4,090 miles in an average United States passenger vehicle over the product's lifetime of average use.

The use phase dominates GHG emissions, PED, and BWC impacts due to the substantial amount of electricity produced from fossil-fuel-based generation sources such as coal and natural gas. In addition, complex manufacturing processes, which involve energy intensive and high impact raw materials also contribute to environmental impacts. Manufacturing is the largest contributor to ADP, with an emphasis placed on the electro-mechanical and key electronic components. Overall, transportation, assembly, testing, and EOL processes have lower contributions to environmental impacts.

When evaluating the influence of recycled metal materials on overall impacts of GWP and BWC, the overall environmental results did not have substantial change. This indicates that variations in recycled content do not have a large impact on the product's life cycle impacts in the broader context. Instead, it could be recommended that Cisco consider developing customer education programs to promote renewable energy adoption, influencing users to minimize environmental impacts when using the product.

Based on this study, it is recommended that Cisco consider the following actions to reduce GHG emissions, PED, and BWC and ADP. First, continue to focus on energy efficiency during the use phase of IE-3505-8P3S switch products to reduce impacts. This could include implementing features like Energy Efficient Ethernet (EEE), which allows devices to enter low-power idle states during periods of low data activity, thus reducing energy consumption and environmental impacts. In addition, Cisco could empower customers to adopt energy conservation practices. This could involve providing guidance or system recommendations that encourage the use of low-power idle states during low data activity, helping build customer awareness and engagement in energy-efficient practices, and offering energy optimization assessments.

Second, Cisco could empower customers to transition toward renewable energy by facilitating the integration of clean power sources into network operations, thereby increasing the proportion of renewable energy used during smart switch operation. Third, Cisco could focus on partnerships with manufacturers to increase the use of renewable energy in production to further reduce the environmental impact of this product.

5.5 Limitations and Assumptions

The Scalable LCA Model has some limitations and assumptions that affect its precision. The main limitations are related to the assumptions made for the electrical components and the manufacturing processes. The model focuses on the most impactful electrical components, such as ICs and PCBs, but it does use scaling factors and proxies when direct matches are not available in the relevant LCI databases. This means that there is uncertainty in the comparison of component related impacts between the products. As an uncertainty range has not been quantitatively assessed due to a lack of quantitative data for uncertainty analysis, comparing the component impacts between the products should be done with the understanding that the underlying model lacks the precision for comparison for small differences (less than a 20% difference should be considered essentially on par) in results.

The model also uses secondary data from ecoinvent to estimate the manufacturing burdens for assembly. This is a significant gap that should be filled with primary data in the future. In addition, the model uses average data for the EOL disposal and manufacturing waste, which could be improved with more specific data. As a result, it does limit the results' utility in identifying areas of improvement and tracking changes over time for these operations.

An important consideration regarding the scope of the assessment is the functional unit. This assessment presents results per a declared unit of one device across its life cycle, including the use phase, compared to a functional unit which would relate the burdens of the products to its function. Without a functional unit, it is not possible to analyze its environmental performance in relation to its technical performance.

Another limitation of the model is the data quality, which varies across the life cycle stages and has some instances of low representativeness as noted in the data quality assessment. The data quality assessment shows that the data have an average score of 2 to 3. As such, while the assessment encompasses all the relevant mass and energy flows of the systems under study, it assesses Cisco-specific products and their components using generic electronics processes and data. This limitation should be addressed by collecting more primary data and updating the secondary data sources in the future iterations of the model.

No co-products during manufacturing were identified. Therefore, this study did not perform allocation. Allocation of environmental burdens to material and energy co-products throughout the upstream supply chain is embedded in the LCI data used in this study and described in the documentation of these datasets. In addition, no mass was excluded within non-electricals, plastic, or product packaging. One exclusion was made in packaging materials for raw materials and semi-finished components. In terms of energy, one exclusion was made in the case of warehouse storage burdens. No other primary data or mass and energy flows were knowingly excluded.

References

Edelen, A. & Ingwersen, W., 2016. *Guidance on Data Quality Assessment for Life Cycle Inventory Data..* s.l.:Environmental Protection Agency.

EPA, 2019. *Greenhouse Gas Equivalencies Calculator.* [Online] Available at: https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

EPA, 2022. *Cleaning Up Electronic Waste (E-Waste).* [Online] Available at: https://www.epa.gov/international-cooperation/cleaning-electronic-waste-e-waste

FHWA, 2022. *Freight Analysis Framework.* [Online] Available at: https://ops.fhwa.dot.gov/freight/freight_analysis/faf/

Gonzalez, A., Chase, A. & Horowitz, N., 2012. What We Know and Don't Know about Embodied Energy and Greenhouse. *ACEEE Summer Study on Energy Efficiency in Buildings.*

Güvendik, M., 2014. From Smartphone to Futurephone: Assessing the Environmental Impacts of Different Circular Economy Scenarios of a Smartphone Using LCA. *Master thesis in Industrial Ecology at Delft University of Technology and Leiden University.*

IEC, 2024. *TC 111: Environmental standardization for electrical and electronic products and systems.* [Online] Available at: https://www.iec.ch/ords/f?p=103:38:611367437665866::::FSP_ORG_ID,FSP_APEX_PAGE,FSP_PROJECT_ID:1314,23,104630

ISO, 2006. *ISO 14044: Environmental Management - Life Cycle Assessment - Requirements and Guidelines..* s.l.:International Organization for Standardization.

Sphera, 2023a. *Process data set: Electricity grid mix; AC, technology mix; consumption mix, to consumer; <1kV (en).* [Online] Available at: https://sphera.com/2022/xml-data/processes/6b6fc994-8476-44a3-81cc-9829f2dfe992.xml

Sphera, 2023. *Sphera Product Sustainability Files.* [Online] Available at: https://sphera.com/sphera-product-sustainability-zip-thank-you/?download=Download+Data

The International EPD System, 2024. *PCR Library.* [Online] Available at: https://www.environdec.com/pcr-library

Union of Concerned Scientists, 2010. *How it Works: Water for Electricity.* [Online] Available at: https://www.ucsusa.org/resources/how-it-works-water-electricity

US EPA, 2019. *Greenhouse Gas Equivalencies Calculator.* [Online] Available at: https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

Wernet, G. et al., 2016. The ecoinvent database version 3 (part I): overview and methodology. *The International Journal of Life Cycle Assessment,,* Volume 21(9), p. pp.1218–1230..

WRI, 2020. *World Resources Institute - Guidance for Calculating Water Use Embedded in Purchased Electricity.* [Online] Available at: https://www.wri.org/research/guidance-calculating-water-use-embedded-purchased-electricity