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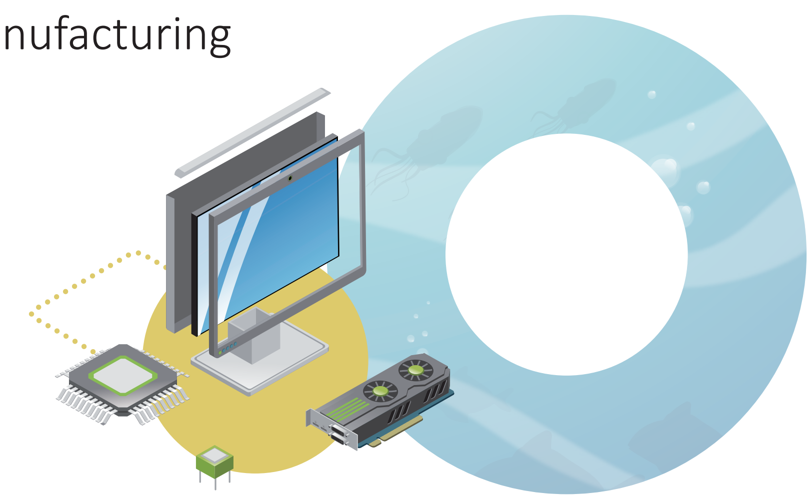
Guidelines for

# Carbon Footprint Calculation

in the Electronics Manufacturing
Services Industry



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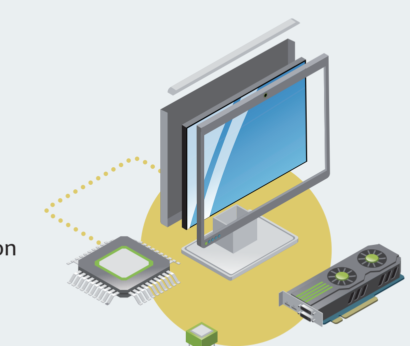

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# I. Preface

Amid global climate change challenges, product carbon footprint management has become a key requirement in international trade. As a crucial part of the global supply chain, the electronics assembly industry must manage its product carbon footprint not only to ensure corporate sustainable development but also to directly impact its international competitiveness.

In recent years, major markets such as the European Union and the United States have introduced regulations requiring imported electronic products to disclose environmental impact information. For example, the EU's Product Environmental Footprint (PEF) initiative, the Energy Star certification in the U.S., and the Electronic Product Environmental Assessment Tool (EPEAT) all incorporate environmental impact assessments into their frameworks. Additionally, leading global corporations such as Apple and Dell have begun requiring suppliers to provide product carbon footprint data as a reference for procurement decisions. Given this trend, and Taiwan's pivotal role in the global electronics supply chain, industry stakeholders must establish a comprehensive product carbon footprint management system.

This manual aims to provide Taiwan's electronics assembly industry with a practical guide for carbon footprint calculation, helping enterprises comply with increasingly stringent international supply chain requirements. The content begins with fundamental concepts of product life cycle and carbon footprint calculation, followed by a detailed explanation tailored to the characteristics of the electronics assembly sector. It covers key aspects such as life cycle process mapping, recommended data collection items, application of allocation principles, selection of emission factors, and calculation methodologies. This manual serves as a standardized reference, particularly for allocation principles and emission factor selection, to support companies that have already established a foundational understanding of carbon footprint calculation.

Furthermore, this manual features an in-depth case study on power supply units. As a critical component of electronic products, the power supply units are widely used across various electronic devices, and their carbon footprint calculation is both representative and complex. Through this case study, we aim to provide readers with a concrete and comprehensive example of carbon footprint calculation, helping enterprises grasp key methodologies and principles. Additionally, this manual seeks to support Taiwan's electronics assembly industry in securing a competitive position in the global supply chain's transition toward green and sustainable development.



This manual provides the following reading recommendations tailored to readers at different phases and with varying needs:

| Reader type | Reading suggestion | Related chapter |
|---|---|---|
| For readers new to product carbon footprint calculation | To establish a foundational understanding | Chapter 3: Terminology Definitions and Chapter 4: Life Cycle and Carbon Footprint Calculation Concepts' |
| | To learn how to initiate and plan a carbon footprint calculation project | Chapter 5: Product Function Description and Life Cycle Process Mapping |
| | To understand how to calculate any phases of product carbon footprint | Chapter 7 to 11 |
| For readers facing allocation issues when starting implementation | To understand allocation methods | Section 6.1: Allocation Principles |
| | A recommended reference table for emission source allocation | Section 6.1.3 Guidelines for Applying Allocation Methods |
| | Case studies illustrating practical applications | Section 6.1.4 Practical Case Study on Carbon Footprint Allocation |
| For readers collecting data and emission factors in any Lifecycle phases | To understand the key data collection of life cycle stages | Chapter 7 to 11 |
| | A guideline of data collection | The "Scope Definition" and "Data Collection Items and Requirements" in each chapter |
| | To select carbon footprint emission factors in raw material stage | Section 7.3 Recommendations for Emission Factor Sources of Key Materials |
| | How to apply the collected data to calculate | The "Calculation Example" in each Chapter |
| For readers preparing for internal and external verification | How to prepare verification document and conduct the verification process | Chapter 9<br>9.1 Document Records and Documentation<br>9.2 Internal Verification Process<br>9.3 External Verification Requirements |

# II. Scope of Application

This manual primarily applies to enterprises engaged in the assembly and manufacturing of electronic components and equipment. These enterprises utilize raw materials such as printed circuit boards, integrated circuits, resistors, and capacitors, integrating them into functional electronic products or subsystem modules through processes such as Surface Mount Technology (SMT) and assembly. Typical product categories include, but are not limited to: Computers and Peripheral Devices (e.g., computers, power supplies), Communication Equipment (e.g., networking devices, communication modules), Consumer Electronics (e.g., home appliances, audio equipment). According to the Ministry of Economic Affairs of Taiwan's Industrial Product Classification, the electronics assembly industry falls under the scope of "Computer, Electronic, and Optical Product Manufacturing" (Category Code 26). Under the United Nations International Standard Industrial Classification (ISIC Rev.4), the industry is classified under "Manufacture of Electrical and Electronic Equipment" (Divisions 26-27).

(The classification of manufactured goods by Commodity Classification Code (CCC Code) is provided in Appendix II.)

# III. Definition of Terms

### 3.1 | Terminology related to Product Carbon Footprint

| No. | Terms | Definition |
|---|---|---|
| 1. | Carbon footprint of a product (CFP) | The total greenhouse gas emissions associated with a product throughout its entire life cycle, expressed in terms of carbon dioxide equivalent ($CO_2e$). |
| 2. | System Boundary | The defined scope of processes and activities included in the calculation of a product's life cycle, specifying which unit processes should be incorporated into the carbon footprint assessment. |
| 3. | Functional Unit | A quantitative description of a product's function, encompassing key characteristics such as performance and usage duration. It serves as the fundamental reference unit for conducting life cycle assessments. |
| 4. | Declared Unit | An alternative reference unit used when a product's function cannot be fully defined, typically applied to intermediate products or components. |
| 5. | Reference Unit | A unit used for labeling or communicating a product's environmental performance, generally based on market conventions or consumer comprehension. |
| 6. | Carbon Dioxide Equivalent ($CO_2e$) | A standardized metric that converts the climate impact of various greenhouse gases into an equivalent amount of carbon dioxide, enabling a unified calculation method. |
| 7. | Product Category Rules (PCR) | A set of carbon footprint calculation rules and requirements established for specific product categories to ensure consistency and comparability of calculation results among similar products. |
| 8. | Primary Data | Specific data directly measured or collected on-site, such as actual energy consumption records and raw material usage. |
| 9. | Secondary Data | General data obtained from literature, databases, or other reference sources. |
| 10. | Emission Factor | A conversion factor used to translate activity data into greenhouse gas emissions. |
| 11. | Allocation | A method for reasonably distributing environmental impacts associated with inputs and outputs across different products or processes. |
| 12. | Cut-off Criteria | Quantitative thresholds that determine whether specific inputs or outputs should be included within the system boundary. |
| 13. | Data Quality | Indicators used to assess the reliability and representativeness of data, including aspects such as temporal, geographical, and technological relevance. |
| 14. | Carbon Footprint Verification | A process conducted by a third-party organization to confirm that carbon footprint calculations comply with relevant standards and regulations. |
| 15. | Life Cycle Assessment (LCA) | The process of collecting and quantifying all inputs and outputs throughout a product's life cycle. |

| No. | Terms | Definition |
|---|---|---|
| 16. | Scope 3 Emissions | Indirect greenhouse gas emissions occurring upstream and downstream within an organization's value chain, including emissions from product use, waste treatment, and other related activities. |
| 17. | Global Warming Potential (GWP) | A conversion factor used to translate different greenhouse gases into their carbon dioxide ($CO_2$) equivalent. |
| 18. | Cradle-to-Grave | A comprehensive life cycle assessment approach that covers the entire product life cycle, from raw material extraction, manufacturing, and distribution to usage and final disposal. |
| 19. | Cradle-to-Gate | A partial life cycle assessment approach that includes only the phases from raw material acquisition to the product's factory exit. |
| 20. | Uncertainty Analysis | A method for evaluating the impact of data variability and methodological choices on carbon footprint calculation results. |
| 21. | Sensitivity Analysis | A method for assessing the extent to which variations in key parameters influence carbon footprint calculation results. |
| 22. | Life Cycle Assessment Standard (ISO 14040) | Defines the principles and framework for life cycle assessment, encompassing four key phases: goal and scope definition, inventory analysis, impact assessment, and interpretation of results. 3 |
| 23. | Life Cycle Assessment Requirements (ISO 14044) | Specifies detailed technical requirements for life cycle assessment, including data collection, allocation methods, and sensitivity analysis. |
| 24. | Product Carbon Footprint Quantification Standard (ISO 14067) | An international standard specifically for assessing product carbon footprints, defining requirements for quantifying and disclosing product greenhouse gas emissions. |



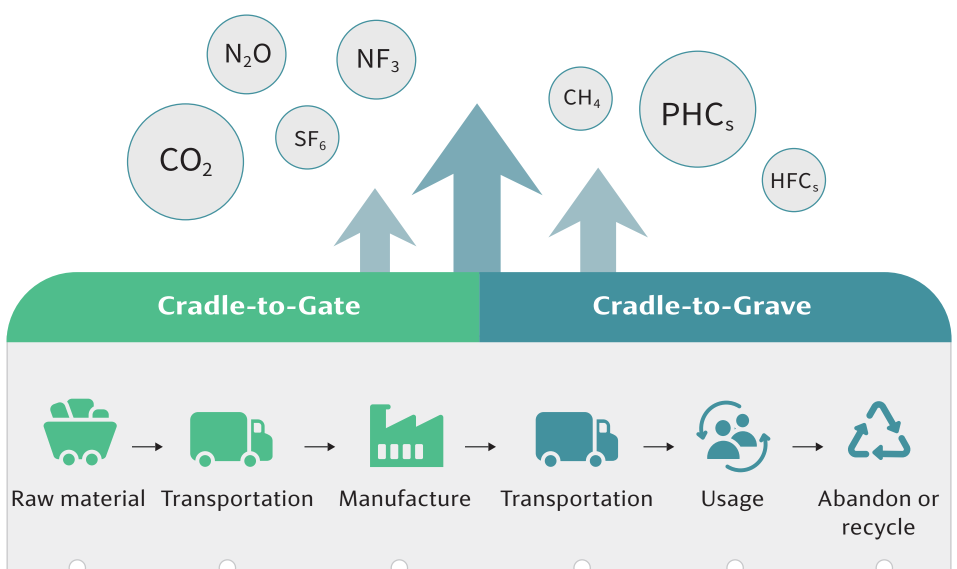
## 3.2 | Terminology related to Electronics Assembly Industry

| No. | Terms | Definition |
|---|---|---|
| 1. | Surface Mount Technology (SMT) | A manufacturing technique in which electronic components are directly mounted onto the surface of a printed circuit board, serving as the primary assembly method in modern electronic product manufacturing. |
| 2. | Printed Circuit Board (PCB) | A substrate used to secure and interconnect electronic components, serving as a carrier for electrical connections between components. |
| 3. | Integrated Circuit (IC) | A circuit that integrates numerous electronic components onto a single semiconductor chip, also known as a microcircuit or chip. |
| 4. | Active Components | Electronic components capable of generating, controlling, or converting electrical energy, such as diodes, transistors, and integrated circuits. |
| 5. | Passive Components | Fundamental electronic components that do not provide energy gain, including resistors, capacitors, and inductors. |
| 6. | Yield Rate | The ratio of the number of qualified products to the total number of units produced, serving as a key indicator of manufacturing efficiency. |
| 7. | Power Supply Unit (PSU) | A device that converts alternating current into direct current for use in electronic equipment. |
| 8. | Cleaning Agent | A chemical solvent used for cleaning PCB surfaces and electronic components. |
| 9. | Flux | A chemical substance that facilitates the soldering process and enhances soldering quality |
| 10. | Moisture-proof Packaging | A specialized packaging method designed to prevent electronic components from moisture exposure. |
| 11. | Test Fixture | A specialized jig or device used for functional testing of products. |
| 12. | Quality Control (QC) | The process of inspecting and controlling production to ensure products meet specified requirements. |
| 13. | Production Scheduling | The planning and optimization of production sequences and resource allocation. |

# IV. The Concepts of Lifecycle and Carbon Footprint Calculation

### 4.1 | Introduction to the Concept of Lifecycle

Lifecycle thinking is one of the core concepts of modern environmental management. It emphasizes a Cradle-to-Grave approach, enabling a comprehensive assessment of the environmental impact of a product or service throughout its entire life cycle. The life cycle of a product typically begins with raw material extraction and primary processing, followed by manufacturing, transportation and distribution, usage, and ultimately, end-of-life disposal. This holistic life cycle perspective allows for a thorough understanding of the transfer of environmental impacts across different phases and facilitates a more accurate evaluation of the overall environmental footprint of a product.




**Holistic Product Lifecycle**

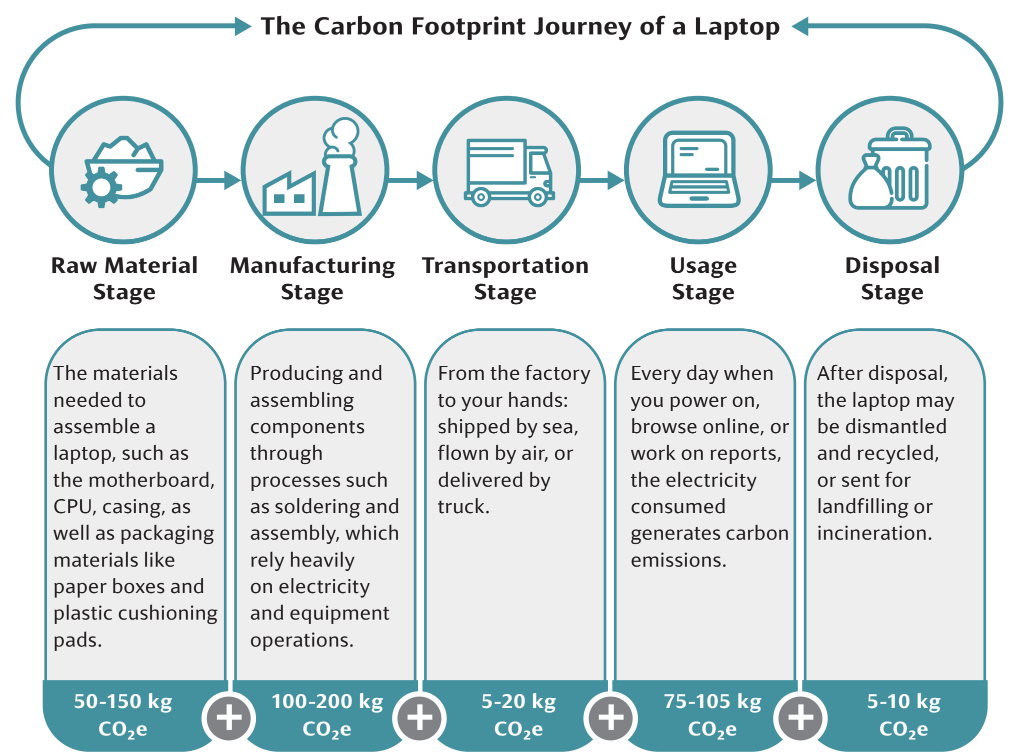
Taking consumer electronics as an example, the raw material acquisition phase involves the extraction and processing of various materials such as metals, plastics, and adhesives. The manufacturing phase encompasses energy consumption and waste generation associated with component production, assembly, and testing. During the distribution phase, environmental impacts primarily stem from emissions related to product transportation. The usage phase focuses on the energy consumption of the product throughout its operational lifespan. Finally, the end-of-life disposal phase requires an assessment of the environmental impact of product recycling, disassembly, and final disposal.



### What is a Carbon Footprint?

Carbon Footprint = the total greenhouse gas emissions generated by a product or service throughout its entire life cycle, expressed in terms of $CO_2$ equivalent ($CO_2e$).

**Practical Case**




**=Total Carbon Emissions: 235-485 kg $CO_2e$**

When conducting assessments based on a life cycle perspective, it is crucial to emphasize comprehensiveness and system integration. This means avoiding a narrow focus on a single life cycle phase and instead considering the interconnections between various environmental impacts. For example, selecting more environmentally friendly materials may lead to increased energy consumption during manufacturing, or improving recyclability could result in higher carbon emissions from transportation. These trade-offs must be evaluated holistically within the life cycle framework to ensure a balanced and sustainable approach.

## 4.2 | Overview of International Standards for Product Carbon Footprint

Under the framework of Life Cycle Assessment (LCA), carbon footprint calculation focuses on evaluating greenhouse gas (GHG) emissions across all phases of a product's life cycle, including raw material acquisition, manufacturing, distribution, product use, and end-of-life disposal. The carbon footprint assessment methodology specifically addresses the environmental impact category of climate change, using carbon dioxide equivalent ($CO_2e$) as the standardized unit to quantify a product's potential contribution to global warming throughout its life cycle. With increasing global attention on climate change, the quantification and management of product carbon footprints have become critical aspects of corporate sustainability. To enhance the accuracy, reliability, and comparability of carbon footprint calculations, multiple international standards have been developed. Among them, ISO 14067 is the most representative standard, providing a comprehensive framework and detailed requirements for the quantification of product carbon footprints.

**2008 — Standard Development Initiated**
ISO began formulating ISO 14067 in response to the need for standardizing product carbon footprints.

**2011 — Publication of Technical Specification (TS)**
A Technical Specification (TS) was first issued and made available for trial use in the market.

**2013 — First Edition of ISO 14067 Published in 2023**
Based on feedback from the trial period, ISO 14067 was officially established as an international standard.

**2018**
A significant revision was carried out to improve the assessment methodology, leading to the current standard.

## 4.3 | Description of the Carbon Footprint Calculation Process

The calculation of a product's carbon footprint is a systematic research process. First, it is essential to clearly define the objectives and scope of the study, which includes determining the system boundaries, understanding manufacturing processes, selecting appropriate functional units, and identifying data requirements. This phase directly influences the reliability of subsequent data collection and calculation results.

During the data collection phase, a comprehensive life cycle inventory must be established, encompassing all significant inputs and outputs. Primary data (e.g., actual measured values) should be prioritized; secondary data (e.g., database values or literature references) should only be used when primary data is unavailable.

The standard procedure for product carbon footprint calculation is as follows:

**Preliminary Preparation**
- Complete the goal setting, scope definition, PCR selection, and formation of the implementation team
- Ensure the participation and support of all relevant departments
- Establish a clear division of responsibilities and a well-defined project timeline.

**Data Collection and Management**
- Develop systematic data collection procedures to ensure data quality and traceability.
- Collaborate with external parties (e.g., suppliers) to collect raw material carbon footprint data or emission factors.

**Carbon Footprint Calculation and Analysis**
- Perform calculations based on the collected data and conduct a reasonableness analysis of the results.
- Pay special attention to ensuring consistency in calculation methodologies, the appropriate application of allocation principles, consideration of data uncertainty, identification of major emission sources, and validation and improvement of results.

**Results revealed and verified**
- Conduct result reviews, documentation, and periodic internal and external verification.
- Based on the calculation results, enterprises may formulate carbon reduction action plans, such as improving energy efficiency, adopting renewable energy, and enhancing supply chain management, to continuously reduce their carbon footprint.

The calculation of product carbon footprint is not a one-time task but an ongoing process that requires continuous updates and improvements. Through regular reviews and updates, we can ensure the accuracy and timeliness of the calculations while identifying opportunities for product optimization and carbon reduction. Additionally, proper documentation management and periodic internal and external verification are essential measures to maintain the quality and reliability of the calculations.

# V. Product Function Description and Life Cycle Process Flowchart Development

## 5.1 | Product Category Rules (PCR) Selection Guide

**Product Category Rules (PCR)** serve as a crucial basis for calculating product carbon footprints, providing calculation standards and requirements for specific product categories. Selecting an appropriate PCR is essential to ensuring the consistency and comparability of carbon footprint calculations for specific product categories.

First, it is important to understand the fundamental structure of a PCR. A PCR typically includes key elements such as product scope definition, functional unit specification, system boundary delineation, allocation rules, and data quality requirements. When selecting a PCR, priority should be given to internationally recognized and credible PCR platforms, such as Ministry of Environment Product Carbon Footprint Information Network and EPD International.

Taiwan Ministry of
Environment Product Carbon
Footprint Information Platform

EPD International/
The International EPD® System



When selecting a PCR, it is recommended to follow these steps:

**1.Identify the Product Category:**
- •Classify the product based on its function and intended use.
- •Refer to the UN CPC or other international product classification systems.
- •Verify whether the product falls within the scope of an existing PCR.

**2.Assess PCR Applicability:**
- •Confirm the validity period of the PCR.
- •Evaluate the geographical applicability of the PCR.
- •Review the technical requirements to ensure their relevance and feasibility.

**3.If No Fully Suitable PCR is Available:**
- •Use a PCR for a similar product category; or
- •Consider developing a new PCR; or
- •Refer to industry standards (such as those outlined in this manual).

## 5.2 | Definition of Reference Units

Selecting and defining reference units is a critical aspect of communicating product carbon footprint calculations with relevant stakeholders and is key to enhancing the comparability of results. The three commonly used reference units—functional unit, declared unit, and labeling unit—each serve specific purposes and are applicable in different contexts.The functional unit provides a quantitative description of a product's function and serves as the foundation for life cycle assessment. The declared unit is used for intermediate products where a complete functional definition is challenging. The labeling unit primarily caters to market communication needs, such as carbon labeling. Understanding the distinctions between these three units and their correct application is essential for ensuring the accuracy and reliability of carbon footprint calculations. The following table provides a detailed comparison of their characteristics and applications:

**Table 1 Comparison of Reference Units**

| Comparison Items | Functional Unit | Declared Unit | Labeling Unit |
|---|---|---|---|
| Definition | A quantitative description of a product's function, including performance and usage duration. | An alternative reference unit for intermediate products or components. | A unit used for labeling or communicating environmental performance. |
| Applicable Products | Suitable for end products with actual functionality. | Applicable to intermediate products, components, and end products. | Applicable to intermediate products, components, and end products with carbon labeling. |
| Key Elements | -Primary functions<br>-Performance requirements<br>-Usage duration<br>-Conditions of use | -Physical properties<br>-Industry standards<br>-Measurement feasibility | -Product form<br>-Market conventions<br>-Comprehensibility<br>-Comparability |
| Examples of Unit Definition | Product Function Description: A power supply unit providing 100W of stable DC output under rated operating conditions, with continuous operation for 8,760 hours. | Physical Quantities of the Product: Per kilogram of product, per component, per square meter. | Measurement Units of the Product: Per unit of product, per set of equipment, per item. |
| Usage Precautions | -All functional parameters must be fully defined<br>-Ensure reproducibility<br>-Comply with PCR requirements | -The rationale for selection must be explained<br>-Note of restrictions<br>-Maintain consistency | -Explain the conversion relationship with the functional unit<br>-Ensure consistency<br>-Avoid misleading information |

When selecting an appropriate communication unit, the following factors should be considered:

1. Purpose of calculation (e.g., internal assessment, external communication)
2. Product characteristics (whether it is a final product or an intermediate product)
3. Data availability
4. Industry practices
5. Relevant standard requirements

Regardless of the chosen reference unit, companies should clearly state the rationale for selection and any associated limitations in their study reports.



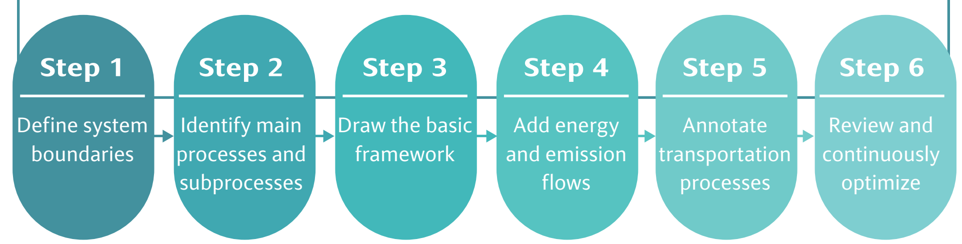
## 5.3 | Practical Guide to Life Cycle Process Flowchart

A life cycle flowchart intuitively illustrates the entire process of a product from raw material acquisition to final disposal. The accurate and comprehensive depiction of such a flowchart is critical for product carbon footprint calculations and serves as a powerful tool for communication and decision-making. This section provides guidance on constructing a life cycle flowchart for the target product under carbon footprint assessment.

### 5.3.1 Steps for Flowchart Drawing

**Practical Recommendations for Flowchart Drawing**

1. Use software tools to assist in drawing, ensuring clarity and consistency.
2. Consider using color coding to distinguish different types of flows (e.g., materials, energy, waste).
3. For complex processes, create subprocess diagrams to keep the main diagram concise.
4. Label data sources and assumptions to increase transparency.




**Step 1: Define System Boundaries**

Key Considerations:

- Determine the life cycle phases to be included. The complete life cycle consists of five phases: raw material acquisition, manufacturing, distribution, usage, and disposal treatment.
- Determine whether the target product adopts the Cradle-to-Grave approach, which encompasses all 5 life cycle phases, or the Cradle-to-Gate approach, which includes only the raw material acquisition and manufacturing phases. In general, products in the electronics assembly industry are typically intermediate products, for which the Cradle-to-Gate approach is more suitable for carbon footprint calculation. This manual provides a comprehensive disclosure of the calculation practices for all 5 life cycle phases of electronic assembly products. The raw material acquisition and manufacturing phases are detailed in Chapters 7 and 8, respectively, while the transportation, usage, and disposal phases are covered in Appendices 3, 4, and 5.

**Step 2: Identify Main Processes and Subprocesses**

Key Considerations:

- List the main activities of the target product at each phase of its life cycle (e.g., raw material input, manufacturing processes).
- Determine the level of process detail based on the research objectives.
- Consider whether to include auxiliary processes (e.g., equipment maintenance, packaging production).

**Step 3: Draw the Basic Framework**

Key Considerations:

- Use appropriate graphical elements (e.g., boxes to represent processes, arrows to indicate flow).
- Ensure a clear layout with appropriate simplification for ease of understanding.

**Step 4: Addition of Energy and Emission Flows**

Key Considerations:

- Indicate the major material inputs and outputs.
- Indicate energy consumption points (e.g., electricity, fuel usage).
- Include waste flow and emission points.

**Step 5: Annotation of Transportation Processes**

Key Considerations:

- Identify and label major transportation activities at each phase.
- Take into account different transportation modes (road, rail, sea, air).

**Step 6: Review and Continuous Optimization**

Key Considerations:

- Ensure the completeness and consistency of the flowchart.
- Verify compliance with the requirements of relevant standards (e.g., ISO 14040 series).

**5.3.2 Practical Recommendations for Drawing**

1. Utilize computer-aided design (CAD) software to ensure clarity and consistency.
2. Consider using color coding to distinguish different types of flows (e.g., materials, energy, waste).
3. Create subprocess diagrams for complex processes to maintain simplicity in the main diagram.
4. Label data sources and assumptions to enhance transparency.



**5.3.3 Definition of System Boundary Settings**

Based on product characteristics and research objectives, an appropriate system boundary should be selected:

1. Cradle-to-Grave

Applicable scenario: End-user consumer electronic products (e.g., smartphones, personal computers)

Features: Includes the phases of raw material acquisition, manufacturing, distribution, usage, and disposal.

2. Cradle-to-Gate

Applicable scenario: Electronic components or intermediate products (e.g., motherboards, connectors)

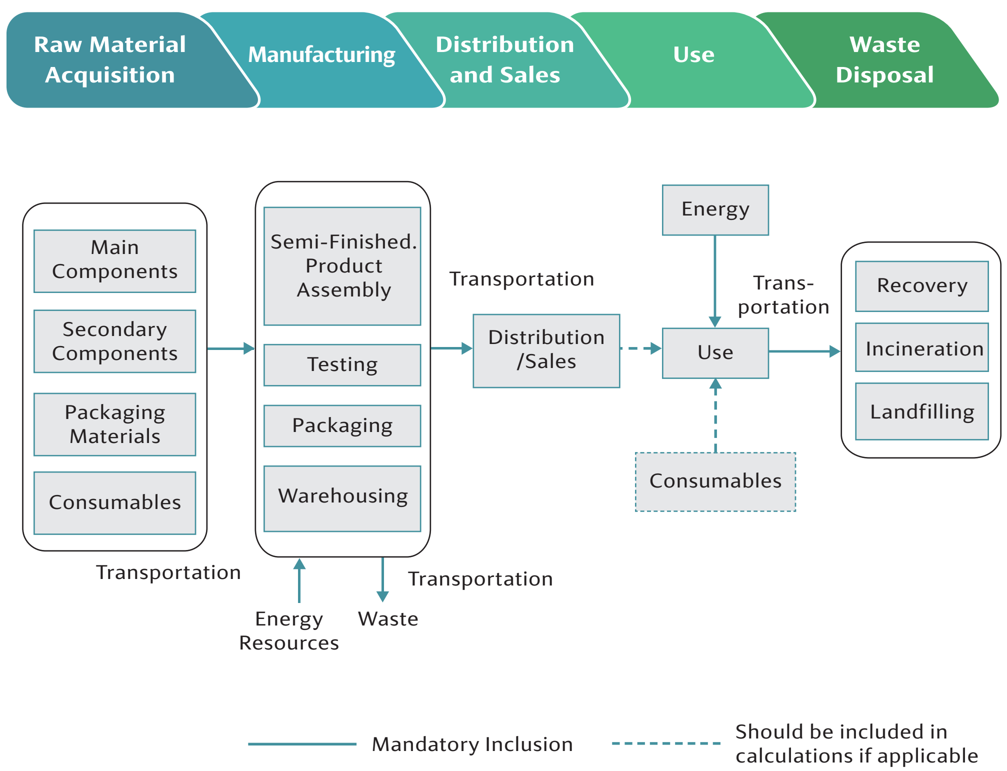
Features: Limited to raw material acquisition and manufacturing phases.

**5.3.4 Case Study: Life Cycle Flowchart for Electronic Products**

Description: This flowchart illustrates the life cycle of end-consumer electronic products, adopting a Cradle-to-Grave system boundary:

(For intermediate electronic products, only the raw material acquisition and manufacturing phases need to be depicted.)

**Figure 1 Life Cycle Diagram of End-Consumer Electronic Products**



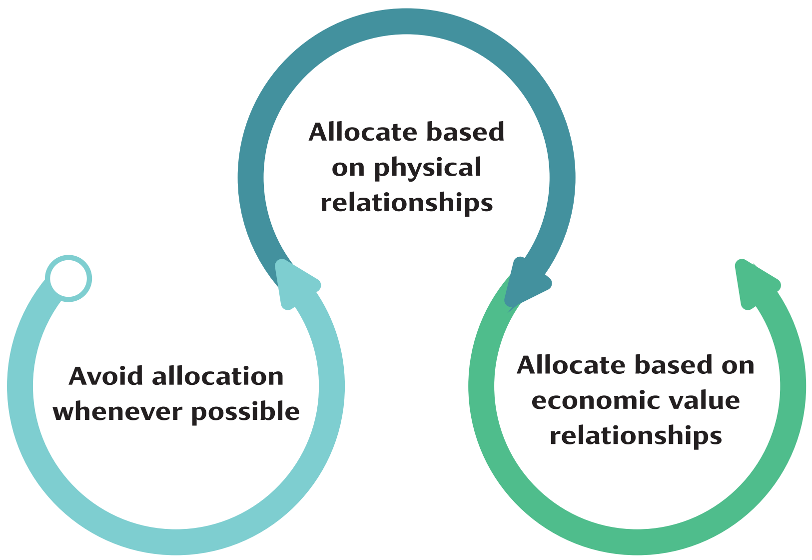
# VI. Key Principles for Carbon Footprint Calculation

## 6.1 | Principles of Allocation

When calculating the carbon footprint of a product, allocation principles are a critical consideration. These principles are primarily used to address the distribution of environmental impacts among different products or by-products within a product system. Proper application of allocation principles ensures the comparability and fairness of carbon footprint calculations.

### 6.1.1 Fundamental Concepts of Allocation Principles

Allocation refers to the rational distribution of greenhouse gas emissions from a single process among different products or by-products. According to the ISO 14044 standard, allocation should follow the following priority order:




The explanation of the allocation methods is as follows:

1. **Avoidance of Allocation:** The allocation process can be subdivided into smaller units until each unit generates only a single product. For example, when allocating electricity consumption, a dedicated meter can be installed for a specific production line to directly measure the total electricity consumption during the production process of the target product. However, due to cost considerations, the avoidance method is rarely implemented in practice.
2. **Allocation Based on Physical Relationships:** This is the most commonly used method in product carbon footprint calculations. The allocation basis should be selected according to the characteristics of the emission source. For instance, energy consumption and auxiliary materials for production lines are typically correlated with production time; therefore, allocation based on working hours is commonly adopted. Shared raw material inputs and manufacturing phase waste generation are recommended to be allocated based on product mass, whereas packaging materials should be allocated according to the actual number of packaged products. Selecting an appropriate allocation method ensures the rationality and credibility of carbon footprint calculations.
3. **Allocation Based on Economic Value Relationships:** This method allocates based on the proportional economic value of products. However, due to its lower accuracy, it is rarely used in practice. If this method is adopted, the rationale for its selection should be clearly explained.

### 6.1.2 Considerations for the Application of Allocation Principles

1. Consistency: The chosen allocation method should be applied consistently throughout the entire carbon footprint calculation process.
2. Transparency: Regardless of the allocation method used, the basis for allocation, calculation process, and data sources should be clearly documented.
3. Practicality: When selecting an allocation method, the availability of data and the feasibility of calculations should be considered.
4. Industry Standards: If industry-specific allocation guidelines or standards exist, they should be given priority.

### 6.1.3 Guidelines for the Application of Allocation Methods

Selecting an appropriate allocation method is critical to ensuring the accuracy of product carbon footprint calculations. Given that the electronics assembly industry typically involves multiple shared emission sources, a reference table has been compiled to assist inventory personnel in quickly identifying suitable allocation methods for different emission sources. This table outlines the recommended allocation bases for various common emission sources along with their underlying considerations, serving as a practical guide for implementation.

The formula for calculating the allocated energy resource consumption-related greenhouse gas emissions for a single target product is as follows:

**Energy resource consumption-related greenhouse gas emissions for a single target product**

$$= \frac{\text{(Allocated Item)} \times \text{(Emission Item)} \times \text{(GWP)} \times \text{(Allocation Ratio)}}{\text{(Annual Production Quantity of Target Product)}}$$

**Table 2 Allocation Method Guidance Table**

| Emission Items | Recommended Allocation Methods | Allocated Items | Allocation Ratio Calculation | Remarks |
|---|---|---|---|---|
| Non-shared raw materials and transportation | No allocation | Annual consumption of the raw material | 100% attributed to the target product | This allocation method is based on the assumption that the total annual input mass equals the output mass. |
| Factory-wide process-related electricity consumption | Allocation based on working hours | Annual electricity consumption | Allocated based on the proportion of the total annual working hours of the target product to the total annual working hours of all products in the factory. | |
| Factory-wide process-related energy consumption (e.g., natural gas) | Allocation based on working hours | Annual energy consumption | Allocated based on the proportion of the total annual working hours of the target product to the total annual working hours of all products using the energy during the manufacturing phase. | |
| Refrigerant leakage volume of the entire factory's cooling equipment | Allocation based on working hours | Annual refrigerant leakage volume | Allocated based on the proportion of the total annual working hours of the target product to the total annual working hours of all products in the factory. | |
| Auxiliary materials used in production lines (e.g., alcohol) | Allocation based on working hours | Annual consumption of the auxiliary material | Allocated based on the proportion of the total annual working hours of the target product to the total annual working hours of all products in the factory. | |
| Shared raw materials and transportation | Mass allocation | Annual consumption of the auxiliary material | Target product's BOM material consumption × Annual target production volume as a proportion of the total BOM material consumption for all products using the material in the factory × Proportion of the total annual production volume of all products. | This allocation method is based on the assumption that the total annual input mass equals the output mass. |
| Waste generated during the manufacturing phase | Mass allocation | Annual generation volume of such waste | Proportion of the target product's annual production mass to the total annual production mass of all products related to such waste in the factory. | To be used when waste attribution can be identified. |
| | | Annual generation volume of such waste for the entire factory | Proportion of the target product's annual production mass to the total annual production mass of all products in the factory. | To be used when waste attribution cannot be identified. |
| Packaging Materials | Actual quantity allocation | Annual consumption of the packaging materials | The allocation ratio is calculated based on the actual packaging conditions. For example, if 24 target products share the sealing mold and pallet, the allocation ratio for the sealing mold and pallet is 1/24. | This allocation method is based on the assumption that the total annual input mass equals the output mass. |

#### 6.1.4 Practical Case Study on Carbon Footprint Allocation

**Case Background**

An electronics company manufactures various specifications of power supplies on the same production line, producing three different power ratings: **100W**, **200W**, and **300W**. These products **share the same** production equipment, energy systems, and **some raw** materials. The Company needs to calculate the carbon footprint for each power supply specification.

Items requiring allocation:

1. **Energy consumption of the production line**
2. **Shared raw materials**
3. **Packaging materials**
4. **Waste disposal**

Allocation method:

**1. Allocation of production line energy consumption**

The production time-based allocation method is used:

| Model | Production time | Calculation of allocation ratios: (Production time/Total production time) |
|---|---|---|
| 100W | 30 hours | 30 / 120 = **25%** |
| 200W | 40 hours | 40 / 120 = **33.3%** |
| 300W | 50 hours | 50 / 120 = **41.7%** |

The Company will allocate the total energy consumption of the production line based on these ratios.

**2. Allocation of shared raw materials**

Adopting the mass allocation method:

| Model | BOM consumption mass of the shared raw material consumption mass of the shared raw material | Total BOM consumption mass of the shared raw material for the entire factory | Calculation of allocation ratios |
|---|---|---|---|
| 100W | 1 kg | x 500 = **500 kg** | 500 / 1,700 = **29.4%** |
| 200W | 1.5 kg | x 400 = **600 kg** | 600 / 1,700 = **35.3%** |
| 300W | 2 kg | x 300 = **600 kg** | 600 / 1,700 = **35.3%** |

The Company will allocate the total carbon footprint of the shared raw material based on these ratios.



**3. Allocation of packaging materials**

Adopting the actual packaging quantity allocation method:

| Model | Units per carton | Calculation of allocation ratios |
|---|---|---|
| 100W | 4 units | 100% / 4 = **25%** |
| 200W | 2 units | 100% / 2 = **50%** |
| 300W | 2 units | 100% / 2 = **50%** |

The Company will allocate the carbon footprint of packaging materials for each product based on these ratios.

**4. Allocation of waste disposal during the manufacturing phase**

Adopting the product mass allocation method:

| Model | Total mass of each product model | Total product mass for the entire factory | Calculation of allocation ratios |
|---|---|---|---|
| 100W | 10 kg | x 500 = **5,000 kg** | 5,000 / 17,000 = **29.4%** |
| 200W | 15 kg | x 400 = **6,000 kg** | 6,000 / 17,000 = **35.3%** |
| 300W | 20 kg | x 300 = **6,000 kg** | 6,000 / 17,000 = **35.3%** |

The Company will allocate the total carbon footprint of waste disposal during the manufacturing phase based on these ratios.

Conclusion: By applying different allocation methods, emissions sources can be more accurately distributed among the three different power supply models. This approach takes into account product characteristics (such as mass) and production conditions (such as labor hours and output), ensuring a fair and reasonable reflection of the actual carbon footprint of each product.

## 6.2 | Principle of Cut-off

The cut-off principle is a key concept in carbon footprint calculation, designed to simplify the calculation process while maintaining accuracy. This principle allows the exclusion of inputs and outputs that have a negligible impact on the overall results under certain conditions, thereby reducing the complexity and cost of data collection.

#### 6.2.1 Fundamental Concepts of the Cut-off Principle

Cut-off refers to the exclusion of certain input or output processes from the system boundary, provided that their omission does not significantly affect the study results. According to the ISO 14044 standard, the following cut-off criteria are applied:

The greenhouse gas emissions contribution of a single cut-off input must not exceed **1%** of the total emissions. The cumulative contribution of all cut-off inputs must not exceed **5%** of the total emissions.

#### 6.2.2 Steps for Applying the Cut-off Principle

| | |
|---|---|
| Determination of System Boundary | Identify and include all relevant inputs and outputs. |
| Data Collection | Gather data for all identified inputs and outputs. |
| Emission Calculation and Significance Assessment | Evaluate the significance of each input and output based on its contribution to total emissions. |
| Application of Cut-off | Exclude inputs and outputs that do not meet the significance threshold. |
| Documentation and Verification | Record all cut-off decisions in detail and verify that the cumulative cut-off impact complies with the established standards. |

#### 6.2.3 Considerations for Applying the Cut-off Principle

1. Cumulative Impact: While individual items contributing less than **1%** of total emissions may be cut-off, the total impact of all cut-off items must not exceed the **5%** threshold.
2. Transparency: This is the most commonly used Clearly document all cut-off decisions and their justifications.
3. Consistency: Ensure that the cut-off criteria remain consistent throughout the entire product life cycle.
4. Regular Review: The application of the cut-off principle should be continuously monitored, with an annual review recommended to assess the validity of cut-off decisions. Re-evaluation should be conducted in the following cases:
   - Change in production location
   - Significant variation in key raw material input (e.g., any raw material originally contributing more than 1% of total emissions should be used as a reference for reassessment)
   - Change in energy structure used for production

#### 6.2.4 Practical Case of Applying the Cut-off Principle

**Case Background**

A company is calculating the carbon footprint of a **200W** power supply unit. The product has a total weight of 1 **kg**, with an annual production volume of **10,000 units**.

**Step 1:** The system boundary determination comprehensively identifies all potential inputs, including primary raw materials, auxiliary materials, energy consumption, and packaging materials.

**Step 2: Data collection**

The Company has collected the following data on annual consumption:

| Primary Raw Materials | Auxiliary Materials | Energy Consumption | Packaging Materials |
|---|---|---|---|
| Electronic components: 2,000 kg<br>Copper wire: 5,000 kg<br>Plastic enclosure: 3,000 kg | Solder: 50 kg<br>Labels: 10 kg<br>Screws: 5 kg | Electricity: 100,000 kWh<br>Natural gas: 1,000 m$^3$ | Cardboard boxes: 1,000 kg<br>Plastic bags: 100 kg |

**Step 3: Emission calculation and significance assessment**

First, calculate the annual greenhouse gas emissions for each input using assumed emission factors:

| Primary Raw Material Emissions | |
|---|---|
| Copper wire | 5,000 kg x 3.5 kg $CO_2$e/kg = **17,500 kg $CO_2$e** |
| Plastic enclosure | 3,000 kg x 2.8 kg $CO_2$e/kg= **8,400 kg $CO_2$e** |
| Electronic components | 2,000 kg x 4.2 kg $CO_2$e/kg= **8,400 kg $CO_2$e** |

| Auxiliary Material Emissions | |
|---|---|
| Solder | 50 kg x 3.8 kg $CO_2$e/kg = **190 kg $CO_2$e** |
| Labels | 10 kg x 1.2 kg $CO_2$e/kg= **12 kg $CO_2$e** |
| Screws | 5 kg x 2.5 kg $CO_2$e/kg= **12.5 kg $CO_2$e** |

| Energy Consumption Emissions | |
|---|---|
| Electricity | 100,000 kWh x 0.5 kg $CO_2$e/kWh = **50,000 kg $CO_2$e** |
| Natural gas | 1,000 m³ x 2.1 kg $CO_2$e/m$^3$= **2,100 kg $CO_2$e** |

| Packaging Material Emissions | |
|---|---|
| Cardboard boxes | 1,000 kg x 0.8 kg $CO_2$e/kg = **800 kg $CO_2$e** |
| Plastic bags | 100 kg x 2.5 kg $CO_2$e/kg= **250 kg $CO_2$e** |

**Total Emissions: 87,664.5 kg $CO_2$e**

**Step 4: Application of the Cut-off Criteria**

Calculation of the percentage contribution of each input to total emissions:

| Primary Emission Sources (Retained) | |
|---|---|
| Electricity | **57.0%** |
| Copper wire | **20.0%** |
| Plastic enclosure | **9.6%** |
| Electronic components | **9.6%** |
| Natural gas | **2.4%** |

| Items Subject to Potential Cut-off (Proportion <1%) | |
|---|---|
| Solder | **0.22%** |
| Cardboard boxes | **0.91%** |
| Plastic bags | **0.29%** |
| Labels | **0.014%** |
| Screws | **0.014%** |

**Step 5: Cut-off Decision and Documentation**

| Cut-off Items | Reason for Cut-off Record |
|---|---|
| Labels (0.014%) | • Each of these items individually accounts for less than 1%<br>• The total cut-off emissions amount to: 12 + 12.5 + 190 + 250 = 464.5 kg$CO_2$e<br>• The cumulative proportion: 0.53% (which is below the 5% threshold) |
| Screws (0.014%) | |
| Solder (0.22%) | |
| Plastic bags (0.29%) | |



| Retained Item (Below 1% but Essential for Packaging) | Reason for Keep Record |
|---|---|
| Cardboard boxes (0.91%) | Retained as a primary packaging material essential for product protection and transportation. |

Conclusion: By applying the cut-off approach, the Company can streamline the carbon footprint calculation process for the same target product in the future. **Emissions from low-impact raw materials, such as screws and labels, can be excluded without significantly affecting the final results.** This will reduce the time and cost associated with data collection while maintaining both accuracy and consistency in calculations.

## 6.3 | Data Quality

Data quality management is a critical component in ensuring the credibility of product carbon footprint calculations. Given that carbon footprint assessments involve a vast and diverse range of data sources—including on-site measurements, supplier-provided emission factors, transportation records, and various activity data—it is essential to establish a robust data quality evaluation and management framework. High-quality data not only enhances the accuracy of calculations but also helps enterprises identify improvement opportunities and make informed carbon reduction decisions.

This section systematically introduces data quality assessment methodologies and provides practical scoring systems and management tools. These resources will support inventory personnel in establishing data quality control processes, ensuring that the collected data accurately reflects the carbon footprint characteristics throughout the product lifecycle.

### 6.3.1 Data Quality Requirements

| | |
|---|---|
| Timeliness | Data should reflect current conditions and generally not exceed 3 years. |
| Geographical | Data should originate from the same or similar geographical regions. |
| Technological | Data should accurately reflect the actual level of technology used. |
| Completeness | Data should cover all relevant emission sources. |
| Representativeness | Data should be representative of actual production or operational conditions. |
| Consistency | Consistent methodologies and data sources should be used throughout the product lifecycle. |
| Reproducibility | Data collection and calculation processes should be repeatable. |
| Source | Priority should be given to reliable and verified data sources. |

### 6.3.2 Data Quality Scoring System

A 5-point scoring system is adopted, where 1 represents the best quality and 5 represents the worst.

Scoring Criteria: Reliability, Completeness, Temporal Relevance, Geographical Relevance, Technical Relevance

**Table 3 Data Quality Scoring Definition Table**

| Level / Indicator | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Reliability (Re) | Verified data based on measurements | Partially verified data derived from assumptions or unverified measurement-based data | Unverified data based on assumptions | Qualified estimates (e.g., estimates provided by industry experts) | Unqualified estimates or data from unknown sources |
| | •Verified measurement data<br>•Validated statistical data | •Data generated from process simulations (simulations must include all necessary parameters)<br>•Data derived from industry correlation analysis | •Data based on chemical reactions and patent information, incorporating assumptions on energy resource consumption, yield, and pollutant emissions | •Industry expert estimates based on statistical data or individual data<br>•Data derived solely from theoretical calculations, without sufficient consideration of yield, energy consumption, and pollutant emissions | •Data estimated from similar processes (lacking a theoretical basis)<br>•Data derived from research on energy/key raw material inputs related to manufacturing design |
| Completeness (Co) | Sufficient data obtained from the site, characterized by stable and representative fluctuations over an extended period | A limited number of representative data points obtained from the site, covering an appropriate period. | An appropriate number of representative data points obtained from the site, but covering a shorter period. | A limited number of representative data points obtained from the site over a shorter period, or an appropriate number of data points collected over a suitable period but with incomplete data. | Representation unknown, or a limited number of data points and/or incomplete data obtained from the site over a shorter period. |
| | •Representative data obtained from all relevant process sites (100%) over an appropriate time interval sufficient to smooth out normal fluctuations.<br>•100% data collection based on the production volume of the target product.<br>•Overall environmental impact >=95% | •Representative data obtained from more than 50% of the sites over an appropriate time interval sufficient to smooth out normal fluctuations.<br>•More than 50% data collection based on the production volume of the target product.<br>•Overall environmental impact between 85%~95%. | •Data obtained from less than 50% of the sites over an appropriate time interval sufficient to smooth out normal fluctuations, or representative data obtained from more than 50% of the sites but over a shorter time interval.<br>•For individual data points, the data represents the average from multiple limited manufacturing equipment units of the target product's manufacturer.<br>•Overall environmental impact between 75%~85%. | •Representative data from a single site or data from multiple sites over a short period.<br>•For individual data points, the data represents multiple limited manufacturing equipment units of the target product's manufacturer.<br>•Data collected over a short survey period, not annual averages (except when the survey period sufficiently covers the product's production cycle).<br>•Overall environmental impact between 50%~75%. | •Data with unknown representativeness.<br>•Data obtained from a limited number of sites over a short period.<br>•Overall environmental impact below 50%. |
| Temporal Relevance (Ti)[5] | Gap with research less than 3 years | Gap less than 6 years | Gap less than 10 years | Gap less than 15 years | Year unknown or gap exceeds 15 years |
| | Data from 2009–2012 | Data from 2006–2008 | Data from 2002–2005 | Data from 1997–2001 | Data from 1996 or earlier, or data with an unknown year |
| Geographical Relevance (Ge) | Data from the research region | Average data from a larger region that includes the research area | Data from a region with similar production conditions | Data from a region with slightly similar production conditions | Data from an unknown region or a region with significantly different production conditions |
| | Data from a specific area (location/site) within the research scope | National average data from the Country, the Asian average with identical production conditions, or the global average | Average data from Asian countries with similar production conditions | Data from Asian or other countries/continents with slightly similar production conditions | Data source unknown or data with significantly different production conditions (e.g., North America substituting for the Middle East, OECD-Europe substituting for Russia) |
| Technical Relevance (Te) | Data from the enterprise, process, and materials used in the study | Data from the process and materials in the study but from a different enterprise | Data from the process and materials in the study but involving a different technology | Data from the same process or materials but using the same technology | Data from an unknown technology or related to the process or materials but derived from a different technology |
| | Data obtained from technologies (including processes and materials) used by enterprises producing the target product | Data from a different enterprise but using the same technology (including the same process and materials) | •Data from the same process and materials but involving a different technology<br>•Substitution using partially similar technology within commercially viable and widely applicable technologies | •Data obtained using the same technology but sourced from a related process or material<br>•Data without commercial or general applicability | •Data with unknown technological attributes<br>•Data from laboratory-scale studies related to the process or from a different technology |

### 6.3.3 Implementation Steps

**Data Collection**

- Record the source, collection method, and timestamp for each data point.
- Prioritize primary data; use secondary data when necessary.

**Data Scoring**

- Evaluate each data item based on 5 criteria.
- Calculate the average score for each data point.

**Overall Assessment**

- Calculate the weighted average score for all data.
- Ensure that critical data (accounting for more than 10% of the total carbon footprint) has an average score of at least 3.

**Improvement Actions**

- Identify low-scoring data and develop improvement plans.
- Consider updating data sources or collection methods.

**Documentation**

- Maintain detailed records of all data scores and improvement measures.

### 6.3.4 Calculation of Data Quality Score

Calculation Formula:

**Quality Score for a Single Data Item**

$$\text{Data Quality Score (Q)} = \frac{\text{Temporal Relevance Score (T)} + \text{Geographical Relevance Score (G)} + \text{Technical Relevance Score (Te)} + \text{Completeness Score (C)} + \text{Reliability Score (R)}}{5}$$

**Overall Weighted Data Quality Score**

$$\text{Data Quality Rating (DQR)} = \frac{\Sigma\,(\text{Carbon Footprint Contribution of Data Item i (Vi)} \times \text{Quality Score of Data Item i (Qi)})}{\Sigma\ \text{Carbon Footprint Contribution of Data Item i (Vi)}}$$



### 6.3.5 Practical Case Study on Data Quality Calculation

**Case Background**

A company is calculating the carbon footprint of a power supply unit. The following is an example of **data quality assessment:**

| | Carbon Footprint Data for the Plastic Enclosure | Carbon Footprint Data for the Aluminum Radiator | Energy Consumption in the Power Supply Unit Assembly Process |
|---|---|---|---|
| Temporal Relevance | 2 (Data from within one year) | 3 (Data from two years ago) | 1 (Data from the current year) |
| Geographical Relevance | 1 (Data sourced from the actual production site) | 2 (Data sourced from a similar geographical region) | 1 (Data sourced from the actual production line) |
| Technical Relevance | 1 (Data derived from the actual production technology) | 2 (Slight variations in technology) | 1 (Data based on the actual assembly technology) |
| Completeness | 2 (Covers most but not all production processes) | 1 (Covers the entire production process) | 2 (Covers the main assembly process but may omit some auxiliary operations) |
| Reliability | 1 (Obtained from a reliable internal monitoring system) | 3 (Derived from an industry database, not a specific supplier) | 2 (Based on company production records with minor estimations) |
| **Quality Score** | (2 + 1 + 1 + 2 + 1) / 5 = 1.4 | (3 + 2 + 2 + 1 + 3) / 5 = 2.2 | (1 + 1 + 1 + 2 + 2) / 5 = 1.4 |

Assuming that the contributions of the following components to the total carbon footprint of the power supply unit are as follows: plastic casing (40%), aluminum radiator (20%), and assembly process (10%).

**Overall Data Quality Weighted Score Calculation**

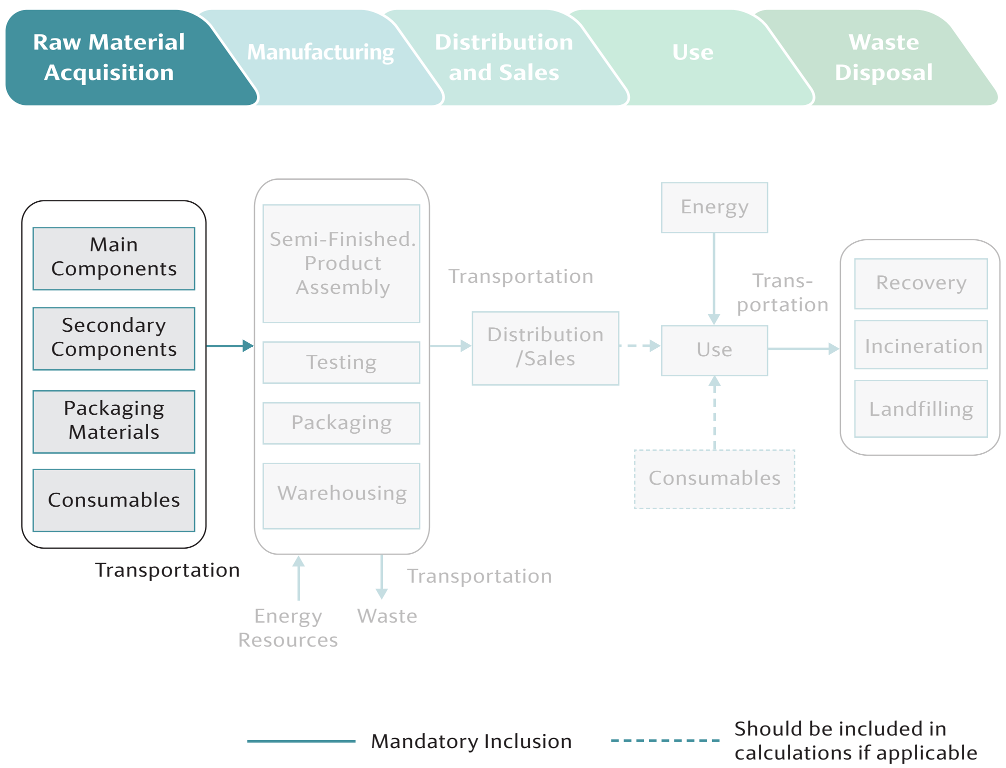
$$\text{DQR} = \frac{(40\% \times 1.4 + 20\% \times 2.2 + 10\% \times 1.4)}{(40\% + 20\% + 10\%)} = 1.63$$

The overall data quality score is 1.63, indicating good data quality (with a score closer to 1 being optimal). However, the data quality of the aluminum radiator is relatively lower. It is advisable to consider improving data collection methods or increasing the update frequency for this component in the future.

# VII. Inventory Practices of Raw Material Acquisition phase

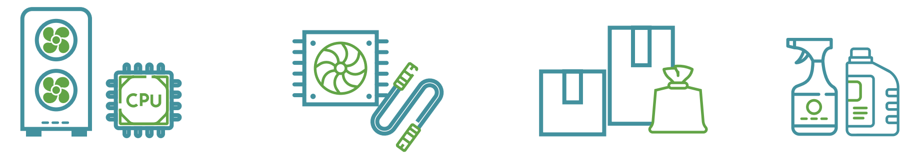
## 7.1 | Scope Definition

The raw material acquisition phase encompasses **the production and transportation processes of all primary components, secondary components, packaging materials, and consumables** that constitute the product. The **system boundary** for this phase begins with the extraction of natural resources, followed by processing or manufacturing, and concludes when the raw materials arrive at the production factory.



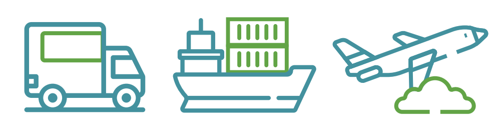



## 7.2 | Data Collection Items and Requirements




| Main Components | Secondary Components | Packaging Materials | Consumables |
|---|---|---|---|
| Key components that constitute the core functionality of the target product | Accessories or minor parts that support the product's functionality but are not core components. | All materials used for protecting, displaying, and transporting the product. | Materials consumed during the manufacturing process but not incorporated into the final product. |
| Chassis, motherboard, CPU, GPU, memory, storage devices (e.g., hard drives, SSDs), power supply unit, etc. | Connectors, cables, radiators, fans, batteries, switches, indicator lights, antennas, adhesives, protective coatings, etc. | Cardboard boxes, plastic bags, foam, cushioning materials, labels, instruction manuals, protective films, etc. | Solder, cleaning agents, alcohol, wipes, lubricants, etc. |

| Required Data Collection | • Raw material composition or Safety Data Sheet (SDS), if applicable.<br>• Physical quantities allocated to a unit product (e.g., weight, volume, surface area, quantity, etc.). |
|---|---|



### Raw Material Transportation

All transportation-related information from suppliers to manufacturing factories or warehouses and subsequently to the factory

Truck, train, ship, airplane, etc.

| Required Data Collection | • Mode of transportation<br>• Transportation distance<br>• Product weight<br>• Loading rate |
|---|---|

## 7.3 | Recommendations for Emission Factor Sources of Key Materials

When conducting product carbon footprint calculations in the electronics assembly industry, data should be categorized based on their origin.

| Carbon footprint data/factors of raw materials provided by suppliers. | The shortest transportation distance for raw materials obtained via Google Maps. |
|---|---|
| **Primary Data**<br>Actual data obtained directly from suppliers or through direct measurements. | **Secondary Data**<br>Data sourced from literature, databases, or other reference materials. |
| Priority usage | Utilized when primary data is unavailable. |

**Note**

If the environmental impact of the manufacturing phase is less than 10% of the total impact at the raw material phase, the scope of primary data collection must be expanded until it reaches or exceeds 10%.

However, identifying suitable emission factors remains a significant challenge in corporate carbon footprint assessments. To assist inventory personnel in efficiently selecting appropriate emission factors for different materials and to ensure consistency in calculations across the industry, **this section provides recommendations for selecting emission factors for commonly used key materials.**

**Ecoinvent** is one of the most globally recognized and credible life cycle assessment databases and is widely adopted by leading international corporations for product carbon footprint calculations. Therefore, **when carbon footprint data or emission factors cannot be obtained directly from suppliers, it is recommended to use SimaPro software (version 9.5 or later) in conjunction with the Ecoinvent database (version 3.8 or later) to select appropriate carbon footprint factors.**



For the electronics assembly industry, commonly used materials are categorized into the following 8 groups:

### 01 Active Components

| Material Item | Emission Factor Keyword |
|---|---|
| Integrated Chips (IC) | Integrated circuit, logic type |
| Diode | Diode, glass-, for surface-mounting |
| Transistor | Transistor, surface-mounted |
| Bridge Rectifier | Diode, glass-, for surface-mounting |

### 02 Passive Components

| Material Item | Emission Factor Keyword |
|---|---|
| Inductor | Inductor, ring core choke type |
| Capacitor | Capacitor, for surface-mounting |
| Resistor | Resistor, surface-mounted |

### 03 Substrates

| Material Item | Emission Factor Keyword |
|---|---|
| Printed Circuit Board (PCB) | Printed wiring board, for surface mounting, Pb free surface |

### 04 Display Panels

| Material Item | Emission Factor Keyword |
|---|---|
| LCD Panel | Liquid crystal display, unmounted, mobile device |
| LED Panel | Light emitting diode |
| Touch Screen | Backlight, for liquid crystal display |

## Data Storage Devices 05

| Material Item | Emission Factor Keyword |
|---|---|
| SSD | Hard disk drive, for desktop computer (For Substitution Only) |
| HDD | Hard disk drive, for desktop computer |
| RAM | Hard disk drive, for desktop computer |

## Battery 06

| Material Item | Emission Factor Keyword |
|---|---|
| Li-ion Battery | Battery, Li-ion, NCA, rechargeable, prismatic |
| Nickel-Metal Hydride Battery | Battery, NiMH, rechargeable, prismatic |

## Power Supply and Cables 07

| Material Item | Emission Factor Keyword |
|---|---|
| Power Cable | Cable, connector for computer, without plugs |
| Plug | Plug, inlet and outlet, for computer cable |
| Power Adapter | Power adapter, for laptop |

## Plastic 08

| Material Item | Emission Factor Keyword |
|---|---|
| Polyethylene(PE) | Polyethylene |
| Polypropylene(PP) | Polypropylene |
| Polyvinyl Chloride(PVC) | Polyvinylchloride |
| Corrugated Box | Corrugated board |
| Glass | Glass |

*** When selecting carbon footprint emission factors, the following considerations should be taken into account:**

1. Whether the physical properties of the material align appropriately.
2. Whether the representativeness of the production region is suitable.
3. Whether the timeliness of the emission factors meets the required standards.



**Interpretation of SimaPro emission factors Names:**

Nylon 6-6 (RER)I market for nylon 6-6 | Cut-off, S
Nylon 6-6 (RER)I market for nylon 6-6 | Cut-off, U
Nylon 6-6 (RoW) | r | market for nylon 6-6 | Cut-off, S
Nylon 6-6 (RoW) | market for nylon 6-6 | Cut-off, U

**1. Geographic Representation of Data:**
- GLO: Global
- RER: European Union
- RoW: Regions outside the European Union
- CN: China
- US: United States
- … and other country/region-specific classifications.

**2. Included Life Cycle phases and Allocation Principles:**
- Cut-off: Excludes parts that do not directly occur in this product.
- APOS: Considers both the main product and by-products, applying allocation calculations.
- Conseq: Accounts for the potential long-term environmental impacts of the product.

**3. Analysis Process**
- U (Unit Process): Displays the calculation results for each process unit, requiring a longer processing time.
- S (System Process): Provides only the overall calculation result, requiring a shorter processing time.

※ Both options yield the same final carbon footprint coefficient.

## 7.4 | Special Scenario Handling

During the raw material acquisition phase of product carbon footprint calculation, certain special scenarios may require specific handling. The following are common scenarios and their corresponding solutions:

### 7.4.1 Handling Raw Materials from Multiple Suppliers

When a raw material is sourced from multiple suppliers, the collection and calculation of carbon footprint data can be conducted using the following methods:

| | Applicable Scenario | Method |
|---|---|---|
| Comprehensive Data Collection Method | Suitable when the number of suppliers is relatively small (e.g., 5 or fewer). | Collect carbon footprint data from all suppliers and calculate a weighted average based on their respective supply proportions. |
| Major Supplier Method | Suitable when there are numerous suppliers. | •Identify major suppliers: Suppliers whose cumulative supply volume exceeds 10% of the total.<br>• Collect carbon footprint data from major suppliers.<br>• Perform a weighted average calculation based on supply proportions.<br>• Scale the result to 100% to represent the carbon footprint data for the raw material. |

#### 7.4.2 Handling of Recycled Materials

When calculating the product carbon footprint, special consideration must be given to recycled materials. The specific handling method for such materials is as follows:

Recycled Materials

1. Scope of Calculation: Should include the environmental impact of the recycling process, including collection, sorting, cleaning, and reprocessing.
2. Data Source Prioritization:
   - Officially published environmental footprint datasets for recycled materials
   - Specific recycling process data provided by suppliers
   - Industry average data or relevant research literature
3. Avoiding Double Counting: Ensure that the environmental impact of the original production phase is not counted multiple times.
4. Accounting for Quality Loss: If material quality deteriorates during the recycling process, this should be appropriately reflected in the calculations.

### 7.5 | Calculation Method

**The formula for calculating the carbon footprint of the raw material acquisition phase**

**Carbon footprint of the raw material acquisition phase (CFP Raw Material Acquisition)** = **Σ(Consumption of the i-th type of raw material (Mi) x Carbon footprint coefficient of the i-th type of raw material (Efi) + Transportation distance of the i-th type of raw material (Di) x Weight of the i-th type of raw material (Wi) x Loading rate for the transportation of the i-th type of raw material (Li) x Carbon footprint coefficient for the transportation of the i-th type of raw material (tEFi))**

Raw material carbon footprint: Consumption of the i-th type of raw material (Mi) x Carbon footprint coefficient of the i-th type of raw material (Efi)

Transport carbon footprint: Transportation distance of the i-th type of raw material (Di) x Weight of the i-th type of raw material (Wi) x Loading rate for the transportation of the i-th type of raw material (Li) x Carbon footprint coefficient for the transportation of the i-th type of raw material (tEFi)

**Note**

1. If the transportation of raw material i involves 2 or more segments, the transportation distance, loading rate, and transportation carbon footprint coefficient should be collected separately and combined to calculate the total transportation emissions.
2. If the load factor is unavailable, it should be set at 100%.

### 7.6 | Calculation Example

The following is a simplified example of the carbon footprint calculation for the raw material acquisition phase of a power supply unit:

**Case Background**

Assume that a power supply unit consists of the following primary materials: Plastic, Circuit boards, Chips, Packaging box

The plastic and packaging box are transported by truck; while, the circuit boards and chips are delivered to the plant via international air freight and truck transportation.



**Transportation 100km**
- Plastic enclosure 500g
- Packaging box 3,000cm$^2$

**Transportation 50km**
- Circuit boards 200g
- Chips 50g

+

**Transportation 1000km**
- Circuit boards 200g
- Chips 50g

**Transportation Status:**

1. Plastics and Cardboard Boxes: Transported by truck for 100 km.
2. Circuit Boards and Chips: Transported via air freight for 1,000 km, followed by truck transport for 50 km.

| | Project | Emission factors | Emission factors Source |
|---|---|---|---|
| Carbon Footprint of Raw Materials | Plastics 500g | 3 kg $CO_2$e/kg | Taiwan Environmental Protection Administration Carbon Footprint Information Platform, average value for general plastics |
| | Circuit Boards 200g | 40 kg $CO_2$e/kg | Ecoinvent 3.8 Database, printed circuit boards |
| | Chips 50g | 130 kg $CO_2$e/kg | Ecoinvent 3.8 Database, semiconductor chips |
| | Cardboard Box 3,000 cm$^2$ | 1 kg $CO_2$e/ m$^2$ | Taiwan Environmental Protection Administration Carbon Footprint Information Platform, corrugated cardboard boxes |
| Carbon Footprint of Transportation | Truck Transport | 0.1 kg $CO_2$e/t·km | Taiwan Environmental Protection Administration Carbon Footprint Information Platform, general truck transport |
| | Air Freight | 0.8 kg $CO_2$e/t·km | Source: Ecoinvent 3.8 Database, average value for general plastics |

(Example values; please refer to the latest life cycle assessment database for actual application and cite the data source accordingly.)

Calculation Process:

| Carbon Footprint of Raw Materials | |
|---|---|
| Plastic | 0.5 kg x 3 kg $CO_2e$/kg = **1.5 kg $CO_2e$** |
| Circuit Boards | 0.2 kg x 40 kg $CO_2e$/kg= **8 kg $CO_2e$** |
| Chips | 0.05 kg x 130 kg $CO_2e$/kg= **6.5 kg $CO_2e$** |
| Cardboard Box | 3,000 $cm^2$ x 1 kg $CO_2e/m^2$= **0.3 kg $CO_2e$** |

| Carbon Footprint of Transportation | |
|---|---|
| Truck transportation of plastic and cardboard box | (0.5 + 0.3) kg x 100 km x 0.1 kg $CO_2e$/t·km = **0.008 kg $CO_2e$** |
| Air freight of circuit board and chip | (0.2 + 0.05) kg x 1000 km x 0.8 kg $CO_2e$/t·km = **0.2 kg $CO_2e$** |
| Truck transportation of circuit board and chip | (0.2 + 0.05) kg x 50 km x 0.1 kg $CO_2e$/t·km = **0.00125 kg $CO_2e$** |

**Total Carbon Footprint**

**CFP Raw Materials** = ( 1.5 + 8 + 6.5 + 0.3 + 0.008 + 0.2 + 0.00125) kg $CO_2e$

= 16.50925 kg $CO_2e$

Therefore, the carbon footprint of the raw material acquisition phase for a single power supply unit is approximately **16.51 kg $CO_2e$**.

**Note**

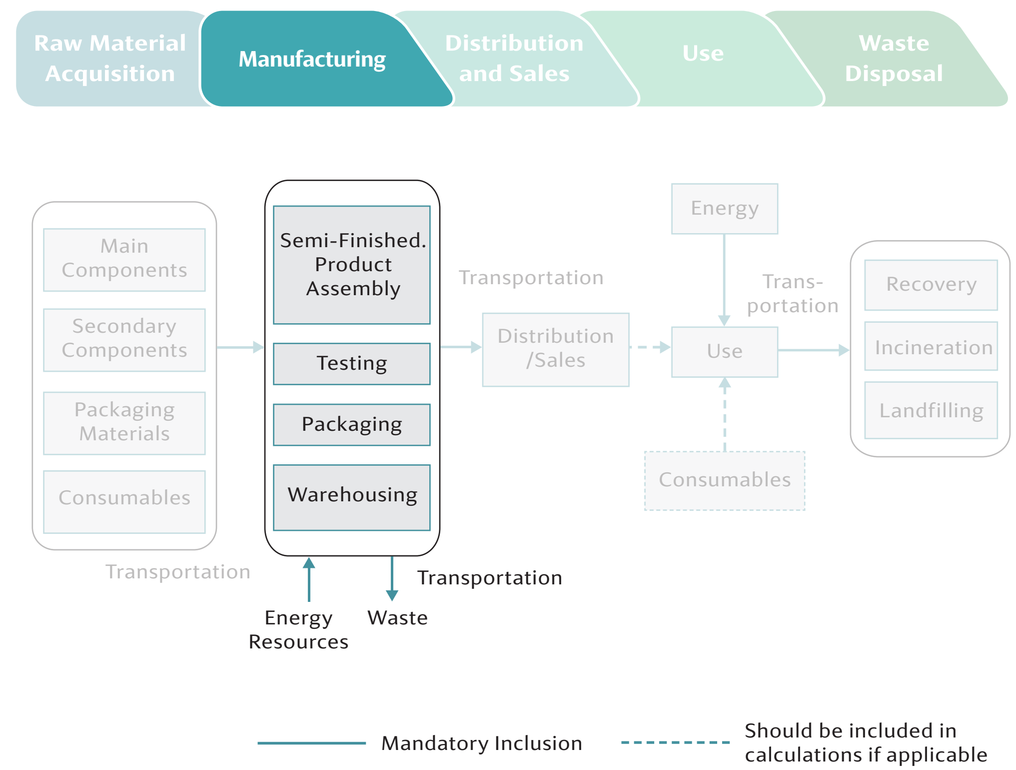
This example has been simplified. In actual calculations, all raw materials and transportation processes should be accounted for, and more precise carbon footprint coefficients should be used.



# VIII. Practical Guidelines for Manufacturing Phase Inventory

## 8.1 | Scope Definition

The manufacturing phase encompasses all processes from the entry of raw materials into the production factory to the dispatch of finished products. The system boundary for this phase includes all activities related to product manufacturing, such as assembly, testing, packaging, and warehousing. It should also account for energy resource inputs, as well as waste transportation and treatment associated with the manufacturing phase. If energy resource consumption data for non-production office areas within the factory can be clearly distinguished, data collection for such areas may be excluded.



## 8.2 | Data Collection Items and Requirements

| Energy Input | Waste Generation and Transportation | Direct Process Emissions |
| --- | --- | --- |
| Various forms of energy used during the manufacturing process. | Solid and liquid waste generated during the manufacturing process. | Greenhouse gas emissions directly generated during the manufacturing process. |
| Electricity and fuels (e.g., natural gas, diesel) consumed in the manufacturing process. | Metal scraps, plastic waste, wastewater, etc. | Gas emissions from welding processes, volatile organic compound (VOC) emissions from parts cleaning processes, methane emissions from septic tanks associated with production line personnel, etc. |

**Required Data Collection**

| Energy Input | Waste Generation and Transportation | Direct Process Emissions |
| --- | --- | --- |
| • Consumption volume of each type of energy.<br>• Energy sources (e.g., self-generated solar power or purchased electricity). | • Quantity of each type of waste generated.<br>• Waste transportation method and distance.<br>• Waste disposal method (e.g., recycling, incineration, landfill). | • Activity data related to emission sources. |

**On-Site Transportation (If applicable)**

Energy consumption associated with internal transportation within the factory.

Fuel consumption of transportation equipment such as forklifts and pallet stackers.

**Required Data Collection**

• Energy consumption of transportation equipment.

**Note**

1.When calculating the product carbon footprint, the emissions of energy use shell include upstream indirect carbon footprint of energy.

2.The collection of energy use data should prioritize that which is directly related to production and manufacturing. However, if segregation is impossible, (e.g., when the factory and office share the same electricity meter.), it's recommended to apply a conservative approach by including both in the calculation.



When conducting product carbon footprint calculations in the electronics assembly industry, data should be categorized based on their origin.

| Electricity bills, water bills, and fuel usage records. | The shortest transportation distance for waste obtained via Google Maps. |
| --- | --- |
|  |  |
| **Primary Data**<br>Actual data obtained directly from suppliers or through direct measurements. | **Secondary Data**<br>Data sourced from literature, databases, or other reference materials. |
| Priority usage | Utilized when primary data is unavailable. |

## 8.3 | Special Scenario Handling

In the manufacturing phase of product carbon footprint calculation, certain special scenarios may require specific handling. The following are common scenarios and their corresponding solutions:

### 8.3.1 Considerations for Seasonal Production

For production affected by seasonal variations:

1. Data Collection Scope: Ensure coverage of the complete production cycle (typically one year).
2. Key Considerations: Seasonal energy consumption (e.g., heating in winter, cooling in summer), fluctuations in raw material supply, etc.
3. Calculation Method: Apply the annual average method or a weighted average based on actual production months.

### 8.3.2 Handling of New Products or Production Lines

For newly launched products or production lines:

1. Initial Data Utilization: Design values or data from similar products may be used, with explicit documentation.
2. Data Update: Upon achieving stable production (e.g., 3–6 months), update calculations using actual operational data.
3. Continuous Optimization: Record and analyze discrepancies between initial production and the stable phase to support process improvements.

**8.3.3 Impact of Regular Maintenance and Overhauls**

Consider the impact of regular maintenance and overhauls on carbon footprint:

1. Routine Maintenance: Treated as part of normal production operations.
2. Overhaul or Upgrades:
   - Record energy consumption and material usage during the overhaul period.
   - Allocate the impact across all products within the overhaul cycle.

## 8.4 | Calculation Method

**The formula for calculating the carbon footprint of the manufacturing phase**

**(Σ(Consumption of the i-th type of energy (Ei) x Carbon footprint coefficient of the i-th type of energy (EFi)) + Σ(Transportation distance of the j-th type of waste (Dj) x Treatment volume of the j-th type of waste (Wj) x Loading rate for the transportation of the j-th type of waste (Lj) x Carbon footprint coefficient for the transportation of the j-th type of waste (tEFj) + Treatment volume of the j-th type of waste (Wj) x Carbon footprint coefficient for the treatment of the j-th type of waste (EFj) + Direct emissions of the k-th type (e.g., process-related direct emissions or septic tank emissions) (DEk))**

= ―――――――――――――――――――――――――――――――――

**Total production volume of the target product (n)**

## 8.5 | Calculation Example

The following is a simplified example of the carbon footprint calculation for the manufacturing phase of a power supply unit:

### Case Background

Assume that a factory produces 100 power supply units per year, with the manufacturing process involving the following major emission sources:

1. Electricity consumption: 200 kWh
2. Natural gas consumption: 10 m³
3. (Septic system) Total annual working hours related to the product: 2,000 hr
4. Waste generation: 50 kg (including 30 kg recycled and 20 kg incinerated)
5. Waste transportation method and distance: Truck transportation 100 km



**Electricity consumption**

200 kWh

**Natural gas consumption**

10 m³

**Waste generation**

50 kg
- recycled: 30 kg
- incinerated: 20 kg

**(Septic system) Total annual working hours related to the product**

2,000 hr

+

**Waste transportation**

100 km

| | Project | Emission factors | Emission factors Source |
|---|---|---|---|
| Carbon Footprint from Energy Consumption | Electricity | 0.494 kg $CO_2e$/kWh | Taiwan Power Company, 2024 Electricity Emission Factor |
| | Natural Gas | 2.093 kg $CO_2e/m^3$ | IPCC 2006 Guidelines for National Greenhouse Gas Inventories |
| Carbon Footprint from Process-Related Direct Emissions | Septic System | 0.004439448 kg $CO_2e$/hr | Primary Data |
| Carbon Footprint of Waste Treatment During the Manufacturing Phase | Truck Transport | 0.1 kg $CO_2e$/t·km | Taiwan Environmental Protection Administration Carbon Footprint Information Platform, general truck transport |
| | Waste Recycling | 0 kg $CO_2e$/kg | Primary Data |
| | Waste Incineration | 0.8 kg $CO_2e$/kg | Taiwan Environmental Protection Administration Carbon Footprint Information Platform, general waste incineration |

(Example values; please refer to the latest life cycle assessment database for actual application and cite the data source accordingly.)

Calculation Process:

| Carbon Footprint from Energy Consumption | |
|---|---|
| Electricity | 200 kWh x 0.606 kg $CO_2$e/kWh = **121.2 kg $CO_2$e** |
| Natural Gas | 10 m³ x 2.093 kg $CO_2$e/m³ = **20.93 kg $CO_2$e** |

| Carbon Footprint from Process-Related Direct Emissions | |
|---|---|
| Septic System $CH_4$ | 2,000 x 0.004439448 kg $CO_2$e/hr = **8.878896 kg $CO_2$e** |

| Carbon Footprint of Waste Treatment During the Manufacturing Phase | |
|---|---|
| Waste Transportation | 50 kg x 100 km x 0.1 kg $CO_2$e/t·km = **0.05 kg $CO_2$e** |
| Waste Recycling | 30 kg x 0 = **0 kg $CO_2$e** |
| Waste Incineration | 20 kg x 0.8 kg $CO_2$e/kg = **16 kg $CO_2$e** |

**Total Carbon Footprint**

$$CFP_{\text{Manufacturing}} = \frac{(98.8 + 20.93 + 8.878896 + 0.05 + 16)\ \text{kg } CO_2e}{100}$$

$$= 1.447\ \text{kg } CO_2e$$

Therefore, the carbon footprint of the raw material acquisition phase for a single power supply unit is approximately **1.447 kg $CO_2$e**.

**Note**

This example has been simplified; the actual calculation should include all resource use, direct emissions related to manufacturing processes, and waste treatment, with appropriate allocation and the use of more precise carbon footprint coefficients.



# IX. Documentation Records and Data Verification

## 9.1 | Document Records and Documentation

Document management for product carbon footprint calculation is critical to ensuring traceability and transparency throughout the calculation process. Comprehensive documentation not only supports internal and external verification but also aids in future updates and improvements. **The document management system should cover the entire process, from data collection to the final report, ensuring that all key information is appropriately preserved.**

Effective document management should begin with recording basic product information, including product specifications, bill of materials, and manufacturing processes. During the data collection phase, a complete data source file should be established, documenting the methods of data acquisition, time frames, and responsible personnel. The documentation of the calculation process should provide detailed records of the calculation methods, allocation principles, and relevant assumptions used.

All documents should implement a version control mechanism, including clear version numbers, creation dates, and review records. If an electronic document management system is used, standardized file naming conventions and directory structures should be established to ensure document security and accessibility. Regular document reviews and updates will ensure that the document system continues to meet organizational needs and supports the reliability of carbon footprint calculations.

## 9.2 | Internal Verification Process

Internal verification is the first line of defense in ensuring the quality of carbon footprint calculations. It should be carried out by individuals with relevant expertise; however, independence must be maintained, and personnel should not be assigned to verify data for which they have directly participated or are responsible. Establishing a robust internal verification process not only helps identify issues early but also prepares the organization for external verification.

The implementation of internal verification can be divided into the following phases:

1. **Pre-verification Preparation**
   A verification team should be established, and a verification plan should be formulated, clearly defining the scope and focus areas. The verification team should at a minimum include:
   - Verification Team Leader: Responsible for coordinating the overall verification work
   - Verification Personnel: Responsible for performing the actual verification tasks

**2. Verification Execution**

A systematic approach should be employed during verification. The main verification tasks include:

**Table 4 Internal Verification Key Item List**

| Verification Items | Verification Focus | Verification Methods |
|---|---|---|
| Scope Definition | -System Boundary Integrity<br>-PCR Compliance<br>-Assumption Reasonableness | Document Review, Expert Discussions |
| Data Quality | -Data Source Reliability<br>-Data Representativeness<br>-Calculation Accuracy | Sampling Inspection, Cross-verification |
| Calculation Method | -Appropriateness of Allocation Principles<br>-Correctness of emission factor Selection<br>-Logical of Calculations | Recalculation, Method Evaluation |

**3. Verification Report and Improvement**

Upon completion of the verification, a formal verification report should be prepared, including:

- Verification Findings and Recommendations
- Improvement Action Plan
- Follow-up Mechanism

## 9.3 | External Verification Requirements

External verification is conducted by an independent third-party organization with the aim of ensuring the credibility and impartiality of the product carbon footprint calculation results. When selecting an external verification body, factors such as professional competence, credibility, and relevant accreditations should be considered.

The main requirements for external verification include:

**1. Qualification of the verification body**

- Should possess relevant certification qualifications
- Should have experience in carbon footprint verification for the electronics industry
- Verification personnel should possess professional qualifications



**2. Verification Preparation Documents**

**Table 5 List of documents required for external verification**

| Document Type | Mandatory Documents | Supporting Documents |
|---|---|---|
| Basic Information | -Organization and Product Information<br>-Life Cycle Process Flowchart<br>-PCR Compliance Statement | -Product Specification Description<br>-Relevant Certification Documents |
| Calculation Data | -Complete Carbon Footprint Calculation Inventory<br>-Data Collection Records and Supporting Evidence<br>-Allocation Method Description | -Data Quality Assessment<br>-Cut-off Usage Records |
| Management Documents | -Carbon Footprint Research Report<br>-Internal Verification Report | -Internal Verification Training Records<br>-Document Management Procedures<br>-Corrective Action Plan Follow-up |

**3. Verification Process Cooperation**

External verification typically involves document review and 2 onsite verification phases. During the onsite verification phase, the organization should:

- Arrange for relevant personnel to participate in interviews
- Provide necessary onsite inspections
- Prepare supporting documents and records
- Cooperate with sampling inspection requirements

**4. Post-Verification Management**

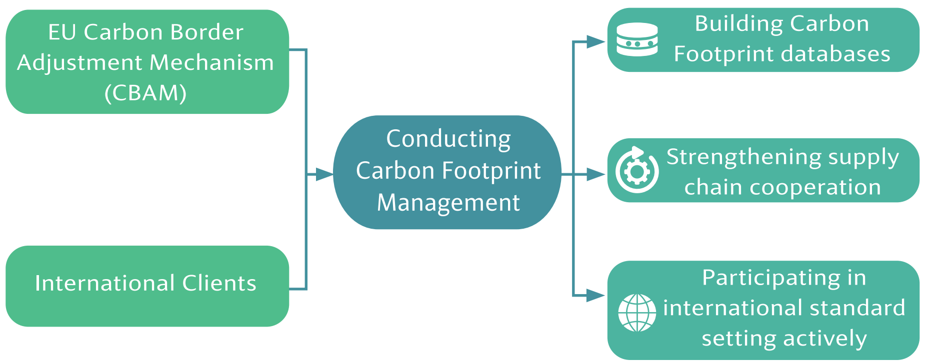
External verification typically involves document review and 2 onsite verification phases. During the onsite verification phase, the organization should:

- Implement improvements based on verification findings
- Establish a regular update mechanism
- Maintain document integrity
- Plan for periodic re-assessment activities

Proper document management and verification systems not only ensure the quality of carbon footprint calculations but also assist organizations in continuously improving their sustainable development performance. Through a comprehensive internal and external verification mechanism, companies can establish a reliable carbon footprint management system, laying a solid foundation for future carbon reduction efforts.

# X. Conclusion and Recommendations

With the implementation of international regulations such as the European Union's Carbon Border Adjustment Mechanism (CBAM) and the increasing demands from international customers for green supply chain management, product carbon footprint management will become increasingly critical. The standardized approach outlined in this manual will assist Taiwanese electronics manufacturers in effectively responding to these requirements, maintaining a competitive edge in the wave of sustainable development. However, product carbon footprint management is a dynamic field, and there remain many areas for attention and improvement in the future. It is recommended that companies, when performing carbon footprint calculations, continually strengthen the following aspects:




First, establish a product carbon footprint database, and through long-term data accumulation, develop emission factors that are more aligned with industry characteristics. Second, enhance supply chain collaboration by establishing a carbon footprint information exchange mechanism with upstream suppliers, improving the timeliness and accuracy of data. Third, actively participate in international standard-setting to ensure that industry practices are reflected in future standard requirements. In addition, companies should integrate carbon footprint data with the product design phase, incorporating low-carbon design principles from the outset, and establish a tracking mechanism for carbon reduction targets. It is also suggested that industry associations organize carbon footprint calculation exchange platforms to promote experience sharing among peers and jointly enhance the industry's carbon management capabilities.

From a technological development perspective, attention should be given to the potential application of emerging technologies such as the Internet of Things (IoT) and blockchain in carbon footprint data collection and verification, as well as the development of artificial intelligence (AI) in carbon footprint analysis and optimization. These technological innovations may bring breakthrough advancements in future product carbon footprint management. Companies can establish a comprehensive product carbon footprint calculation system based on this manual and, on this foundation, continue to monitor international trends, promptly updating calculation methods and management practices to ensure a leading position in the global sustainable supply chain.



## Appendix 1: References


[1] ISO 14040：2006 Environmental management — Life cycle assessment — Principles and framework

[2] GHG Protocol Product Life Cycle Accounting and Reporting Standard

[3] ISO 14044：2006 Environmental management — Life cycle assessment — Requirements and guidelines

[4] ISO 14067：2018 Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification

[5] PAS 2050：2011 Specification for the assessment of the life cycle greenhouse gas emissions of goods and services

[6] IPCC Guidelines for National Greenhouse Gas Inventories

[7] ISO 14064-1：2018 Greenhouse gases — Part 1： Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals

[8] ISO/TS 14027:2017 Environmental labels and declarations — Development of product category rules

[9] IPCC AR6 WGI Climate Change 2021: The Physical Science Basis

[10] Product Environmental Footprint Category Rules (PEFCR) for IT Equipment (EU Commission, 2020)

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[12] EPEAT/IEEE 1680.1-2018 Environmental Assessment of Electronic Products

[13] Energy Star Program Requirements for Computers - Final Test Method (EPA, 2020)

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[15] Guidelines for Measuring and Managing CO2 Emission from Freight Transport Operations (ECTA, 2011)

[16] Electronic Industry Citizenship Coalition (EICC) Code of Conduct Environmental Standards

[17] Carbon Trust - Product Carbon Footprinting: The New Business Opportunity Pack (2020)

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[22] UN CPC Ver.2.1 - Central Product Classification for Electronic and Electrical Equipment

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[27] The International EPD® System - General Programme Instructions for Environmental Product Declaration

[28] Apple Supplier Responsibility Standards - Environmental Requirements (2023)

[29] Dell's Supply Chain Sustainability Progress Report Methodology (2023)

## Appendix 2: Applicable CCC Code List

**8471 Main Applicable CCC Codes for the Electronics Assembly Industry**

| CCC Code | Item Description |
|---|---|
| 8471.30 | Portable Automatic Data Processing Machines, weighing no more than 10 kg, containing at least a central processing unit, keyboard, and display |
| 8471.41 | Systems with at least a central processing unit and input/output units within the same casing |
| 8471.49 | Other system machines |
| 8471.50 | Processing units, regardless of whether they are in the same casing, containing memory, input, or output units |
| 8471.60 | Input or output units, regardless of whether they are in the same casing, containing memory devices |
| 8471.70 | Memory devices |
| 8471.80 | Other automatic data processing machine units |
| 8471.90 | Others |

**8473 Parts and Accessories List**

| CCC Code | Item Description |
|---|---|
| 8473.30 | Parts and Accessories of Machines in Section 8471 |
| 8473.50 | Parts and Accessories Applicable to Machines in Section 8471 |

**8504 Power Supply Units and Related Equipmentt**

| CCC Code | Item Description |
|---|---|
| 8504.40 | Static converters (e.g., Rectifiers) |
| 8504.50 | Other inductors |
| 8504.90 | Parts |

**8517 Communication Equipment and Related Equipment**

| CCC Code | Item Description |
|---|---|
| 8517.11 | Wired telephones, including wireless mobile phones |
| 8517.12 | Mobile phones or other wireless network telephones |
| 8517.61 | Base stations |
| 8517.62 | Machines for receiving, converting, transmitting, or reproducing sound, images, or other data |
| 8517.69 | Others |
| 8517.70 | Parts |

**8518 Audio Equipment and Related Equipment**

| CCC Code | Item Description |
|---|---|
| 8518.10 | Microphones and stands |
| 8518.21 | Single speaker cabinets |
| 8518.22 | Multi-speaker cabinets |
| 8518.40 | Audio frequency amplifiers |
| 8518.90 | Parts |

**8523 Storage Devices and Related Equipment**

| CCC Code | Item Description |
|---|---|
| 8523.51 | Solid-state non-volatile storage devices |
| 8523.52 | Smart cards |
| 8523.59 | Other semiconductor media |



**8528 Display Devices and Related Equipment**

| CCC Code | Item Description |
|---|---|
| 8528.42 | Cathode ray tube displays, designed or primarily used for Automatic Data Processing Systems in Section 8471 |
| 8528.52 | Other displays, designed or primarily used for Automatic Data Processing Systems in Section 8471 |
| 8528.62 | Projectors, designed or primarily used for Automatic Data Processing Systems in Section 8471 |

## Appendix 3: Distribution Phase Inventory Practices

### A3.1 | Scope Definition

The distribution phase encompasses all transportation and storage processes from the manufacturing factory to the point of use. The system boundary of this phase begins **when the product leaves the production factory** and continues through various logistics distribution networks until it reaches the final point of use. Key factors to consider include energy consumption during **transportation, transport transshipment rates, and the weight of related packaging materials**. It is important to note that if the product in question is **an intermediate product** (e.g., electronic components, motherboards), the carbon footprint of the distribution phase should be analyzed based on the actual circumstances by its customer during the product carbon footprint calculation, and therefore, the distribution phase's carbon footprint **does not need to be considered**.

Applicable Scenario:

**Final Products**

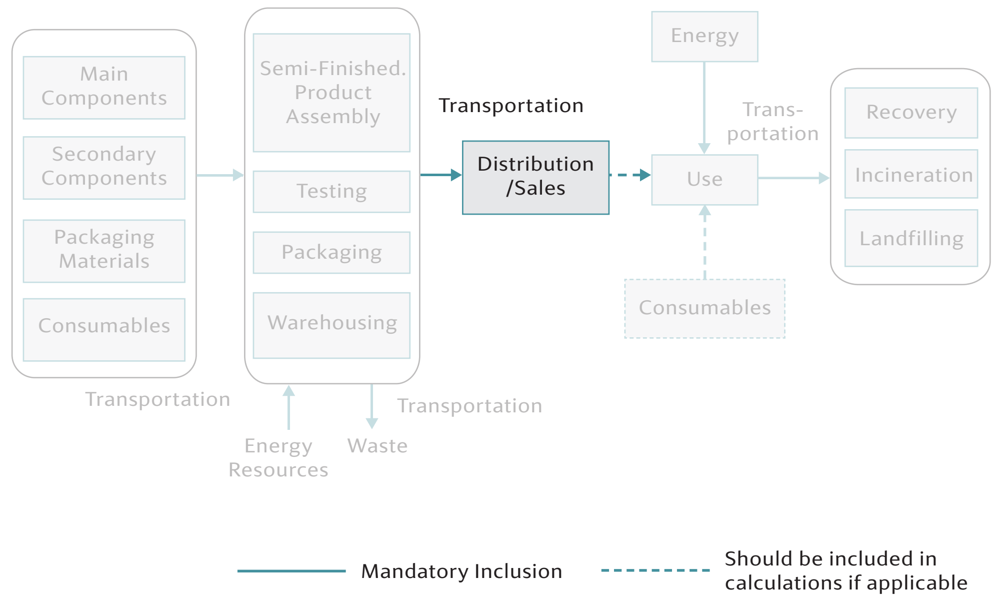
- Personal Computers
- Displays
- Household Appliances
- Power Supply Units (depending on system boundary definition)

Carbon footprint of the distribution phase **needs** to be calculated

**Intermediate Products**

- Motherboards
- Memory Modules
- Electronic Components
- PCB

Carbon footprint of the distribution phase **does NOT need** to be calculated


## A3.2 | Data Collection Items and Requirements

**Transportation Process**

All transportation activities involved in the distribution process of the product

**Distribution Packaging Materials**

Additional packaging materials used in the distribution process

**Required Data Collection**

| | |
|---|---|
| • Mode of transportation<br>• Transportation distance<br>• Transport capacity<br>• Loading rate<br>• Energy consumption of the transportation vehicle | • Types and weight of packaging materials<br>• Reuse frequency of packaging materials (if applicable) |



Data should be classified based on its source:

| Transportation mileage charts, fuel consumption records, warehouse electricity consumption records. | Standard loading rate, average energy consumption emission factors. |
|---|---|
|  |  |
| **Primary Data**<br>Data obtained directly from logistics providers or actual records. | **Secondary Data**<br>Average or generic data from literature or databases. |
| Priority usage | Utilized when primary data is unavailable. |

## A3.3 | Special Scenario Handling

Special scenarios and their handling methods during the distribution phase:

**A3.3.1 Handling of Intermodal Transportation**

1. Scenario Description: The product transportation process involves multiple modes of transport.
2. Handling Method:
   - Record the distance and energy consumption for each transportation mode in segments.
   - Calculate the carbon footprint for each segment separately.
   - The total transportation carbon footprint is obtained.

**A3.3.2 Allocation for Joint Delivery**

1. Scenario Description: Sharing transportation vehicles or storage facilities with other products.
2. Handling Method:
   - Prioritize allocation based on weight or volume.
   - Adjust according to the actual loading rate.
   - Document the allocation methods and basis.

## A3.4 | Calculation Method

### The formula for calculating the carbon footprint of the distribution phase

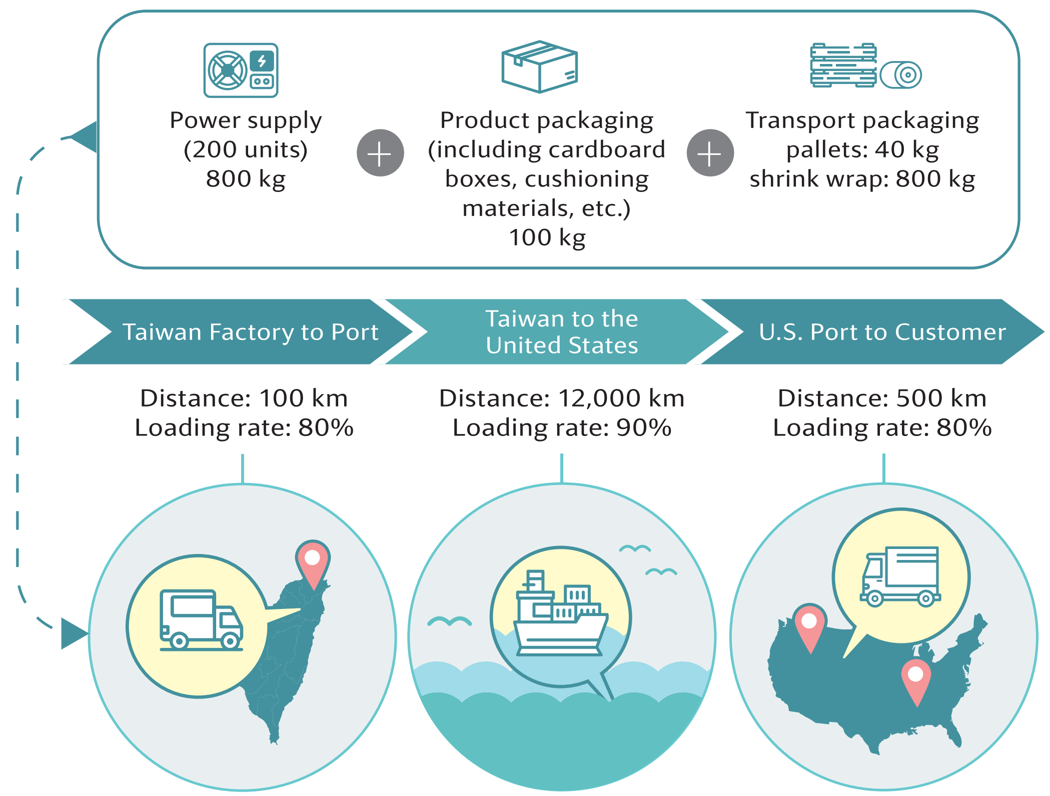
**Carbon footprint in the distribution phase phase (CFP Delivery)** = **Σ(Transportation distance of the i-th mode of transportation (Di) x (Weight of the transported goods (Wi) + Quantity of delivery packaging material used for the i-th type (Pi)) ÷ Loading factor for the i-th mode of transportation (Li) x Carbon footprint coefficient for the i-th mode of transportation (tEFi))**

## A3.5 | Calculation Example

Here is a carbon footprint calculation example for the distribution phase of power supply units:

**Case Background**

A batch of power supply units is being shipped from a manufacturing factory in Taiwan to a customer in the United States, involving both land transportation and sea freight.






| | Project | Emission factors | Emission factors Source |
|---|---|---|---|
| Carbon Footprint Coefficients for Transportation | Land Transportation | 0.1 kg $CO_2$e/t·km | Taiwan Ministry of Environment Carbon Footprint Information Network, General Truck Transport |
| | Sea Freight | 0.02 kg $CO_2$e/t·km | Ecoinvent 3.8 database, General average shipping costs |

Calculation Process:

| Taiwan Land Transportation Carbon Footprint |
|---|
| 100 km x (0.8 + 0.2)t x (1/0.8) x 0.1 kg $CO_2$e/t·km = **12.5 kg $CO_2$e** |

| Sea Freight Carbon Footprint |
|---|
| 12,000 km x (0.8 + 0.2)t x (1/0.9) x 0.02 kg $CO_2$e/t·km = **266.67 kg $CO_2$e** |

| U.S. Land Transportation Carbon Footprint |
|---|
| 500 km x (0.8 + 0.2) t x (1/0.8) x 0.1 kg $CO_2$e/t·km = **62.5 kg $CO_2$e** |

### Total Carbon Footprint

**CFP Delivery** = **12.5 + 266.67 + 62.5 = 341.67 kg $CO_2$e**

### Carbon Footprint per Unit

**Distribution phase carbon footprint per unit** = **341.67 kg $CO_2$e ÷ 200 units = 1.71 kg $CO_2$e/ units**

Therefore, the distribution phase carbon footprint for each power supply unit is approximately **1.71 kg $CO_2$e**.

**Note**

This example has been simplified; the actual calculation should include all resource use, the entire delivery process's energy resource usage should be included, with appropriate allocation and the use of more precise carbon footprint coefficients.

# Appendix 4: Practical Guidelines for the Usage Phase Inventory

## A4.1 | Scope Definition

The usage phase encompasses **all usage processes of the product from the point it is obtained by the consumer until it is discarded.** For finished products, the primary consideration is the carbon footprint resulting from energy consumption during the use phase. It is important to note that if the product in question is an intermediate product (e.g., electronic components, motherboards, etc.), the usage phase carbon footprint is not considered, as the final usage scenario is not accounted for.

**Final Products**

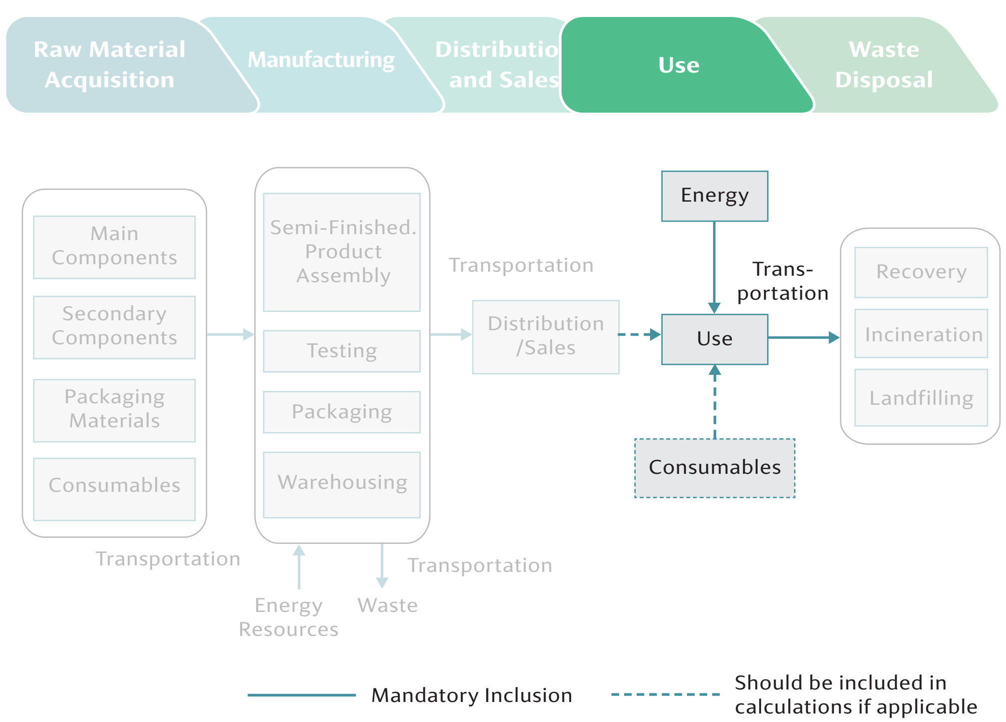
- Personal Computers
- Displays
- Household Appliances
- Power Supply Units (depending on system boundary definition)

Carbon footprint of the distribution phase **needs** to be calculated

**Intermediate Products**

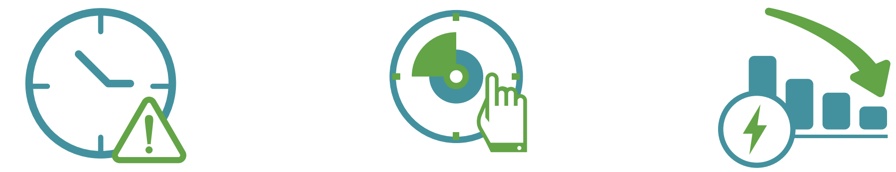
- Motherboards
- Memory Modules
- Electronic Components
- PCB

Carbon footprint of the distribution phase **does NOT need** to be calculated






## A4.2 | Data Collection Items and Requirements



**The expected operational lifespan of a product.**

- Design lifespan of the product
- Warranty period of the product
- Actual service life based on market

**The distribution of time a product operates in different states.**

- Active time
- Standby time
- Sleep mode time
- Shutdown time

**Energy consumption across various usage patterns.**

- Power consumption in each mode
- Annual total electricity

Data should be classified based on its source:

| Product power test data, Market research data | Industry-average service life, Standard usage patterns |
| --- | --- |
| **Primary Data**<br>Data obtained through direct measurement or actual usage records. | **Secondary Data**<br>Data from literature or industry averages |
| Priority usage | Utilized when primary data is unavailable. |

## A4.3 | Calculation Method

**The formula for calculating the carbon footprint of the usage phase**

**Carbon footprint during the usage phase (CFP)** = **Σ(Power consumption in the i-th usage mode (kW) (Pi) x Daily operating time in the i-th usage mode (hours/day) (Ti) x Annual operating days (days/year) × Service life (years) (D) x Carbon footprint coefficient of electricity in the usage region (kg $CO_2$e/kWh) (EF))**

## A4.4 | Calculation Example

### Case Background

Calculate the carbon footprint during the usage phase for a 200W power supply unit primarily sold in Taiwan.

| Usage Time Settings | Usage Pattern Distribution (Minimum Usage Scenario) | Power consumption in each mode |
|---|---|---|
| • Expected service life: 3 years<br>• Annual operating days: 52 days (used once per week) | • Full load (100%): 0.5 hours/day<br>• Medium load (50%): 1 hour/day<br>• Light load (20%): 1 hour/day<br>• Standby mode: 21.5 hours/day | • Full load: 200W = 0.2 kW<br>• Medium load: 120W = 0.12 kW<br>• Light load: 60W = 0.06 kW<br>• Standby mode: 0.5W = 0.0005 kW |

**0.494 kg $CO_2$e/kWh (Bureau of Energy, 2023 electricity emission factor)**

Calculation Process:

| Full Load Mode Carbon Footprint |
|---|
| 0.2 kW x 0.5 hr/day x 52 day/yr x 1 yr x 0.494 kg $CO_2$e/kWh<br>= **12.57 kg $CO_2$e** |

| Medium Load Mode Carbon Footprint |
|---|
| 0.12 kW x 1 hr/day x 52 day/yr x 1 yr x 0.494 kg $CO_2$e/kWh<br>= **13.08 kg $CO_2$e** |

| Light Load Mode Carbon Footprint |
|---|
| 0.06 kW x 1 hr/day x 52 day/yr x 1 yr x 0.494 kg $CO_2$e/kWh<br>= **1.54 kg $CO_2$e** |

| Standby Mode Carbon Footprint |
|---|
| 0.0005 kW x 21.5 hr/day x 52 day/yr x 1 yr x 0.494 kg $CO_2$e/kWh<br>= **0.28 kg $CO_2$e** |



## Total Carbon Footprint

**CFP Usage = 2.57 + 3.08 + 1.54 + 0.28 = 7.47 kg $CO_2$e**

Therefore, the carbon footprint of this power supply unit over a 3-year usage period is **22.41 kg $CO_2$e.**

**Note**

This example has been simplified; in the actual calculation, appropriate usage scenarios that accurately reflect the product's conditions should be established, and more precise carbon footprint coefficients should be used.

## Appendix 5: Waste Disposal Phase Inventory Practices

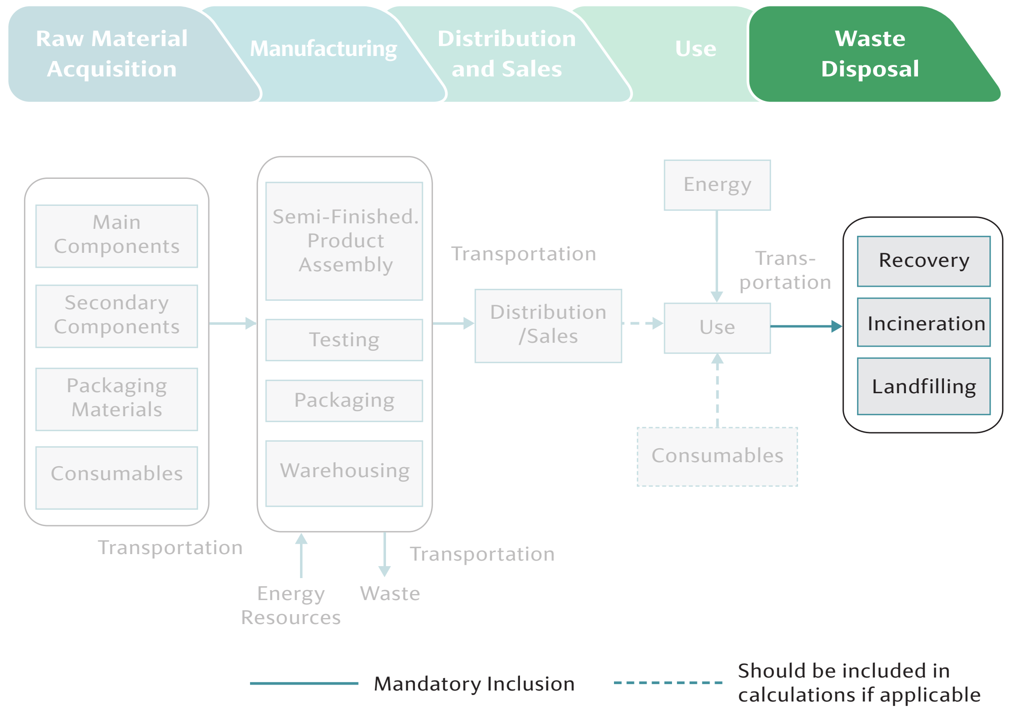
### A5.1 | Scope Definition

The waste disposal phase encompasses **all processes following the end of a product's life cycle**, including collection, sorting, disassembly, recovery, incineration, or landfilling. The system boundary for this phase begins at the point when the product becomes **waste in the hands of the consumer** and extends through various disposal processes until final disposal. It is important to note that if the subject product is an intermediate product (such as electronic components or motherboards), the waste disposal phase should be included in the product life cycle assessment by its customer. Therefore, the carbon footprint of the waste disposal phase does not need to be considered for such intermediate products.

| Final Products | Intermediate Products |
|---|---|
| • Personal Computers<br>• Displays<br>• Household Appliances<br>• Power Supply Units (depending on system boundary definition) | • Motherboards<br>• Memory Modules<br>• Electronic Components<br>• PCB |
| Carbon footprint of the distribution phase **needs** to be calculated | Carbon footprint of the distribution phase **does NOT need** to be calculated |

For electronic products, special attention should be given to:

1. **General Waste Disposal:** e.g., packaging materials
2. **Resource Recovery Processes:** e.g., metal, plastic components
3. **Special Waste Disposal:** e.g., electronic components, batteries




## A5.2 | Data Collection Items and Requirements

| Product Composition Analysis | Waste Treatment Methods | Transportation Process | Treatment Methods and Emission Factors |
|---|---|---|---|
| The composition and weight of various materials within the product. | The disposal pathways for different material categories. | The transportation of waste from collection points to treatment facilities. | Emission factors associated with various waste treatment methods. |

**Required Data Collection**

| | | | |
|---|---|---|---|
| • Weight of each material category<br>• Recyclability of materials | • Proportion of materials processed through recovery<br>• Proportion of materials processed through incineration<br>• Proportion of materials processed through landfill<br>• Special treatment requirements | • Mode of transportation<br>• Transportation distance<br>• Load capacity<br>• Loading rate | • Emission factor for landfill disposal<br>• Emission factor for incineration<br>• Emission factor for recycling<br>• Emission factor for special treatment (e.g., electronic waste processing)<br>• Regional variations in emission factors for different treatment methods |



Data should be classified based on its source:

| Emission factors provided by local treatment facilities, Environmental declarations of actual treatment facilities. | Life cycle databases, Emission factors published by the Ministry of Environment. |
|---|---|
| **Primary Data**<br>Emission factor data obtained directly from treatment facilities. | **Secondary Data**<br>Generic emission factors sourced from literature or databases. |
| Priority usage | Utilized when primary data is unavailable. |

## A5.3 | Special Scenario Handling

### A5.3.1 Regional Treatment Emission factors Variations

1. Considerations:
   - Local treatment technology levels
   - Differences in energy structure
   - Scale of treatment facilities
   - Variations in treatment efficiency
2. Handling Method:
   - Prioritize the use of locally published official emission factors
   - Use emission factors from international databases as a secondary option
   - Apply geographical adjustments when necessary

### A5.3.2 Allocation of Co-Treatment

1. Scenario Description: Co-treatment of multiple waste types
2. Handling Method:
   - Allocation based on weight
   - Consideration of treatment difficulty emission factors
   - Documentation of allocation basis

**A5.3.3 Handling of Recycled Materials**

1. Included in Scope:
   - Energy consumption during the recovery process
   - Emissions generated from transportation
2. Excluded from Scope:
   - Carbon reduction benefits from the reuse of recycled materials
   - Benefits of substituting raw materials

## A5.4 | Calculation Method

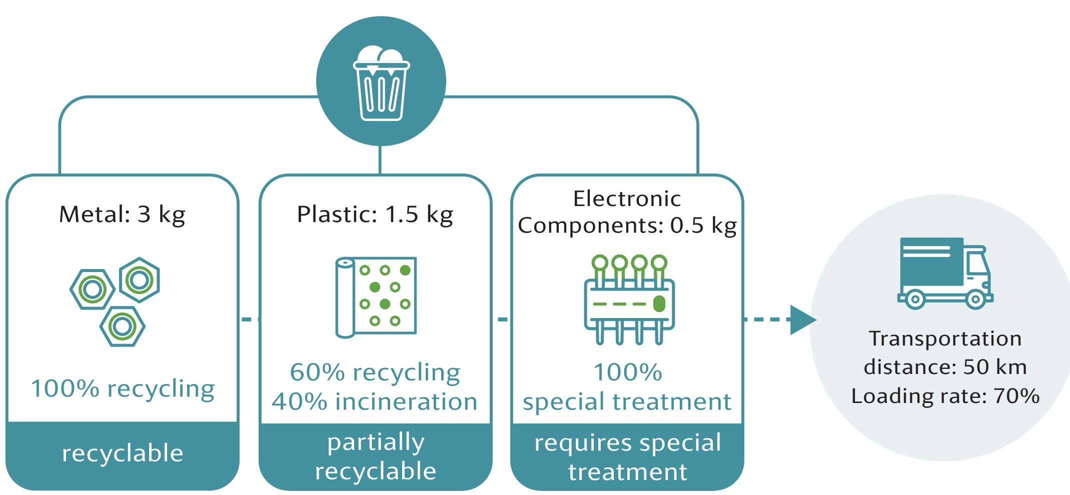
**The formula for calculating the carbon footprint of the waste disposal phase**

**Carbon footprint in the waste disposal phase (CFP Waste)** = **Σ(Weight of the i-th type of waste (Wi) x Transportation distance (Di) x Transportation loading factor (Li)) x Transportation carbon footprint coefficient (tEFi)) + Σ(Weight of the i-th type of waste treated by the treatment method (Wj) x Carbon footprint coefficient for the i-th type of treatment method (EFj))**

## A5.5 | Calculation Example

**Case Background**

Calculate the carbon footprint in the waste disposal phase for a discarded power supply unit (total weight: 5 kg).






| | Project | Emission factors | Emission factors Source |
|---|---|---|---|
| Carbon footprint coefficients for transportation | Lan | 0.1 kg $CO_2$e/t·km | Taiwan Ministry of Environment Carbon Footprint Information Network, General Truck Transport |
| Treatment method emission factors | General recycling treatment | 0.5 kg $CO_2$e/kg | According to local environmental agency published values |
| | Plastic incineration treatment | 2.0 kg $CO_2$e/kg | According to local environmental agency published values |
| | Electronic waste treatment | 3.0 kg $CO_2$e/kg | According to local environmental agency published values |

Calculation Process:

| Carbon Footprint of Transportation |
|---|
| 5 kg x 50 km x (1/0.7) x 0.1 kg $CO_2$e/t·km ÷ 1000<br>= **0.036 kg $CO_2$e** |

| Treatment Carbon Footprint | |
|---|---|
| Metal recycling treatment | 3 kg x 0.5 kg $CO_2$e/kg = **1.5 kg $CO_2$e** |
| Plastic recycling treatment | 1.5 kg x 60% x 0.5 kg $CO_2$e/kg = **0.45 kg $CO_2$e** |
| Plastic incineration treatment | 1.5 kg x 40% x 2.0 kg $CO_2$e/kg = **1.2 kg $CO_2$e** |
| Electronic component special treatment | 0.5 kg x 3.0 kg $CO_2$e/kg = **1.5 kg $CO_2$e** |

**Total Carbon Footprint**

**CFP waste = 12.5 + 266.67 + 62.5 = 341.67 kg $CO_2$e**

Therefore, the carbon footprint in the waste disposal phase for this power supply unit is approximately **4.69 kg $CO_2$e**.

**Note**

This example is simplified; in the actual calculation, appropriate waste treatment scenarios should be set based on the product's specific circumstances, and more precise carbon footprint coefficients should be used.

# Appendix 6: Practical Guidelines for the Usage Phase Inventory

## A6.1 | Ministry of Environment Product Carbon Footprint Information Network Database User Guide

### I. Introduction to the Product Carbon Footprint Information Network Database

The Ministry of Environment's Product Carbon Footprint Information Network is a comprehensive platform that provides product carbon emission information for inquiry and carbon footprint label application. The platform includes a public carbon emission factor database, which covers emission data for various materials and processes, offering scientific support for Life Cycle Assessment (LCA) and carbon footprint calculations.

Platform URL: https://cfp-calculate.tw/cfpc/WebPage/WebSites/CoefficientDB.aspx

### II. Operating Steps:

The following is an example query for common plastic materials used in the electronics industry:

1. Select the plastic material used in the manufacturing process from the platform.


2. Choose the relevant inventory year or the most recent published values.

| 碳係數名稱 | 生產區域名稱 | 數值 | 宣告單位 | 公告年份 | 加入我的最愛 |
|---|---|---|---|---|---|
| 聚丙烯(PP) | 臺灣 | 1.95E+0 kgCO₂e | 公斤(kg) | 2023 | 加入 |
| 聚丙烯(PP) | 臺灣 | 2.01E+0 kgCO₂e | 公斤(kg) | 2013 | 加入 |

## A6.2 | Simapro Demo Version Basic User Guide

### II. Introduction to SimaPro Software

SimaPro is a professional Life Cycle Assessment (LCA) software used to analyze the environmental impacts of a product or service throughout its entire life cycle. From raw material extraction and manufacturing to use and waste treatment, SimaPro helps users quantify the environmental impacts at each phase, providing data-driven decision support.

### III. Software Installation

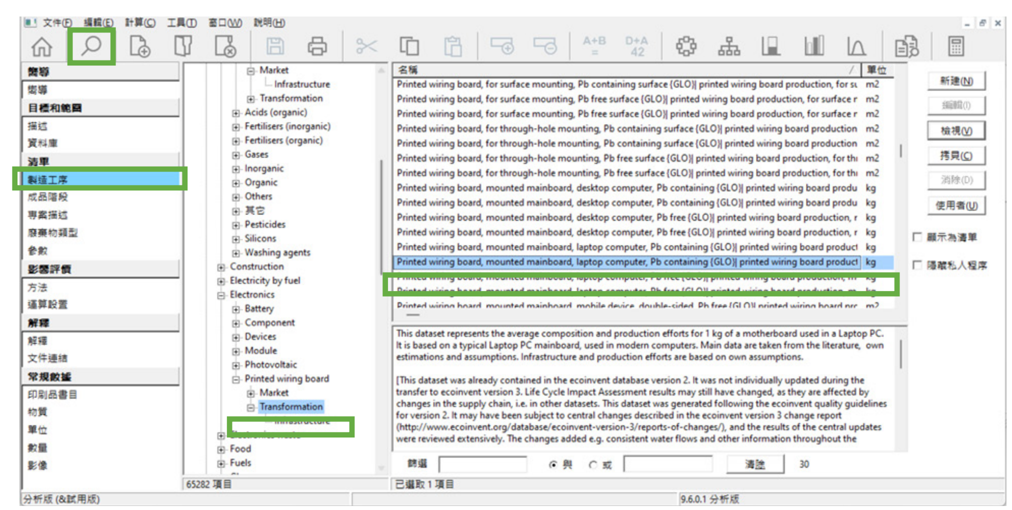
SimaPro is a paid software. To try the demo version, you can download it from the website. The demo version is for internal analysis reference purposes only.

Demo Version URL: https://simapro.com/try/

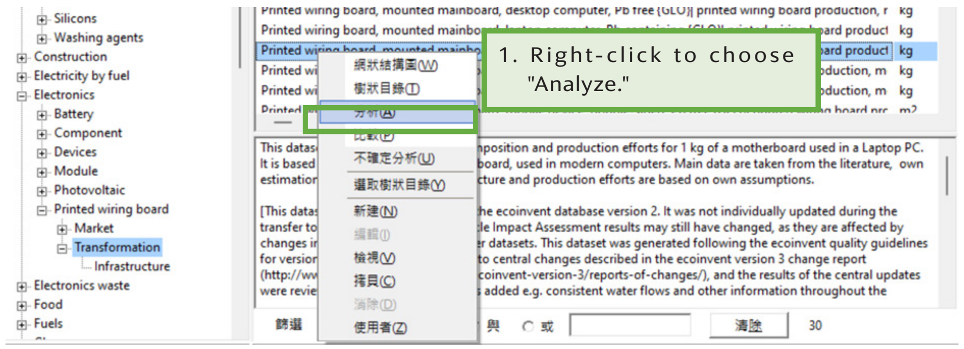
### IV. Operating Steps:

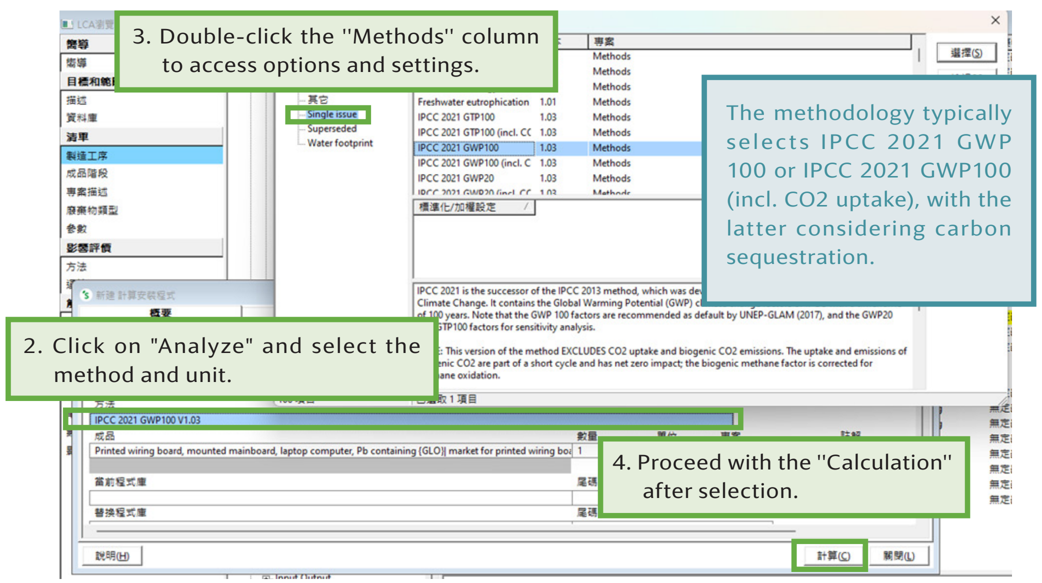
Below is an example of coefficient query for printed circuit boards, a common material used in the electronics industry process:

1. Select Material: After launching the software project, search for the material that fits the process scenario in the process steps. You can also use the search function to query with the keyword "Printed wiring board" and select the appropriate scenario from the search results.

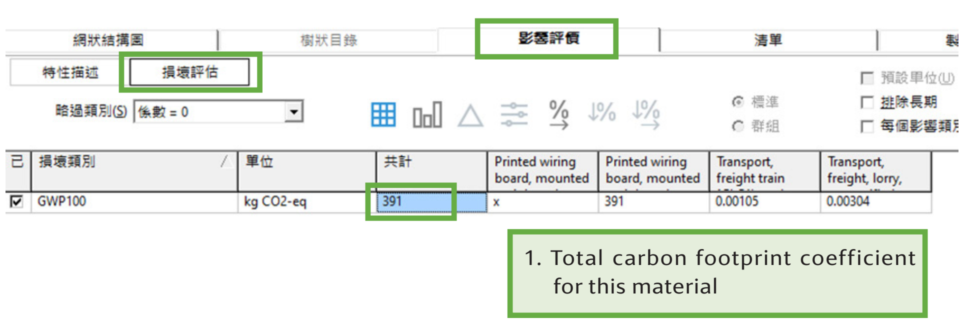


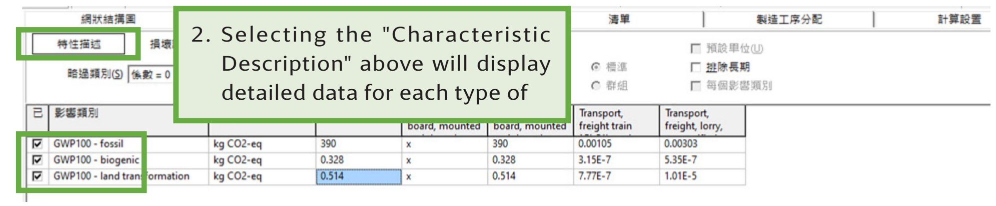
2. Proceed with Analysis after Selecting the Material Type:




3. Calculation Results:




**Fossil: Fossil carbon**
**Biogenic: Biogenic carbon**
**Land transformation: Carbon emissions from land use change**

## Appendix 7: Carbon Footprint Research Report Table of Contents

**XX Company**

**XX Product**

**(XX Year) Product Carbon Footprint**

**Research Report**

**Please include product photo**

**Release Date: XX Year XX Month XX Day**

**Version X**



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# Guidelines for Carbon Footprint Calculation in the Electronics Manufacturing Services Industry

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