Collaborating organizations:

香港電子業商會
The Hong Kong Electronic Industries Association

HKPCA
Hong Kong Printed Circuit Association
香港綫路板協會

香港綠色製造聯盟

香港電器業協會
HONG KONG ELECTRICAL APPLIANCE INDUSTRIES ASSOCIATION

港九電器商聯會

Sponsored by:

SGS

CLOVER DISPLAY

冠致有限公司
GOLD BEST LIMITED

Sunshine Global PCB Group

Terraillon

Project members:

Prof. Winco K.C. Yung
Tel: (852) 2766 6599
E-mail: wincokc.yung@polyu.edu.hk

Miss Jane Zhang
Tel: (852) 2766 4252
E-mail: jane.zhang@polyu.edu.hk

Miss Connie Chan
Tel: (852) 2766 4252
E-mail: cheuk-yi.chan@polyu.edu.hk

Website: http://www.pctech.ise.polyu.edu.hk/ecodesign/

ISBN: 978-988-18959-9-8

A SME Advisory Kit for ISO/TS 14067

ISBN: 978-988-18959-9-8

An SME Advisory Kit for

ISO/TS 14067-

"Greenhouse Gases - Carbon Footprint of Products - Requirements and Guidelines for Quantification and Communication"

Funded by:

「中小企業發展支援基金」撥款資助
Funded by SME Development Fund

工業貿易署
Trade and Industry Department

Organized by:

The Hong Kong Polytechnic University
Department of Industrial and Systems Engineering

Green Manufacturing and Eco-Design Research Group
The Hong Kong Polytechnic University
香港理工大學綠色生產及環保設計研究小組

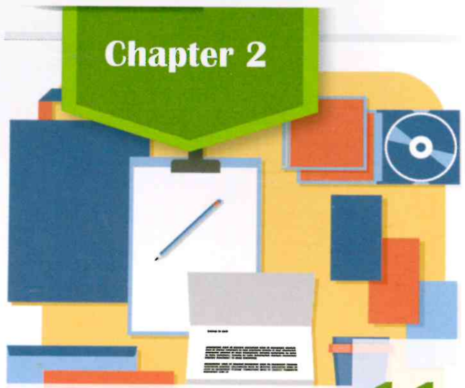
SME Development Fund Project

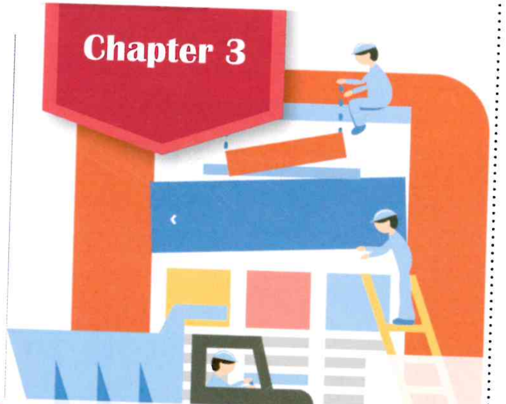
"Development of an embedded Greenhouse Gas (GHG) emissions database with a G-BOM analyzer and a SME advisory kit for electrical and electronic industries to respond to the implementation and compliance of ISO 14067 (carbon footprint of products)"

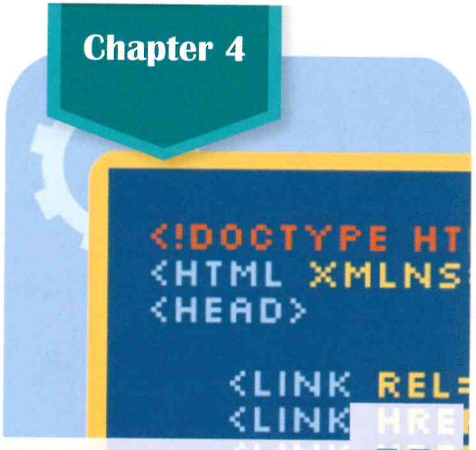
ABOUT THIS ADVISORY KIT

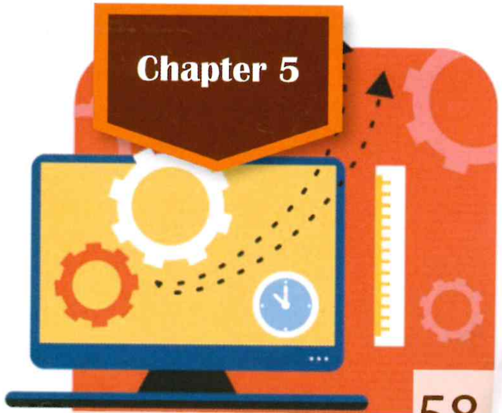
This Advisory Kit aims at developing guidelines for Hong Kong SMEs to better understand the newly launched ISO/TS 14067, its implication to the industry, and the processes to apply such standard. Along with this Advisory Kit, we have also developed a corresponding GHG emission database and an online carbon footprint quantification tool- the G-BOM Analyzer, and undertaken four showcases and a series of seminars and workshops, with key speakers including scholars, consultants, and representatives from industry. We hope all these efforts can assist local businesses in adapting to the low-carbon incentives driven economy.

Table of Contents









Acknowledgements

This project is organized by The Hong Kong Polytechnic University and funded by the SME Development Fund of the Trade and Industry Department, HKSAR Government.

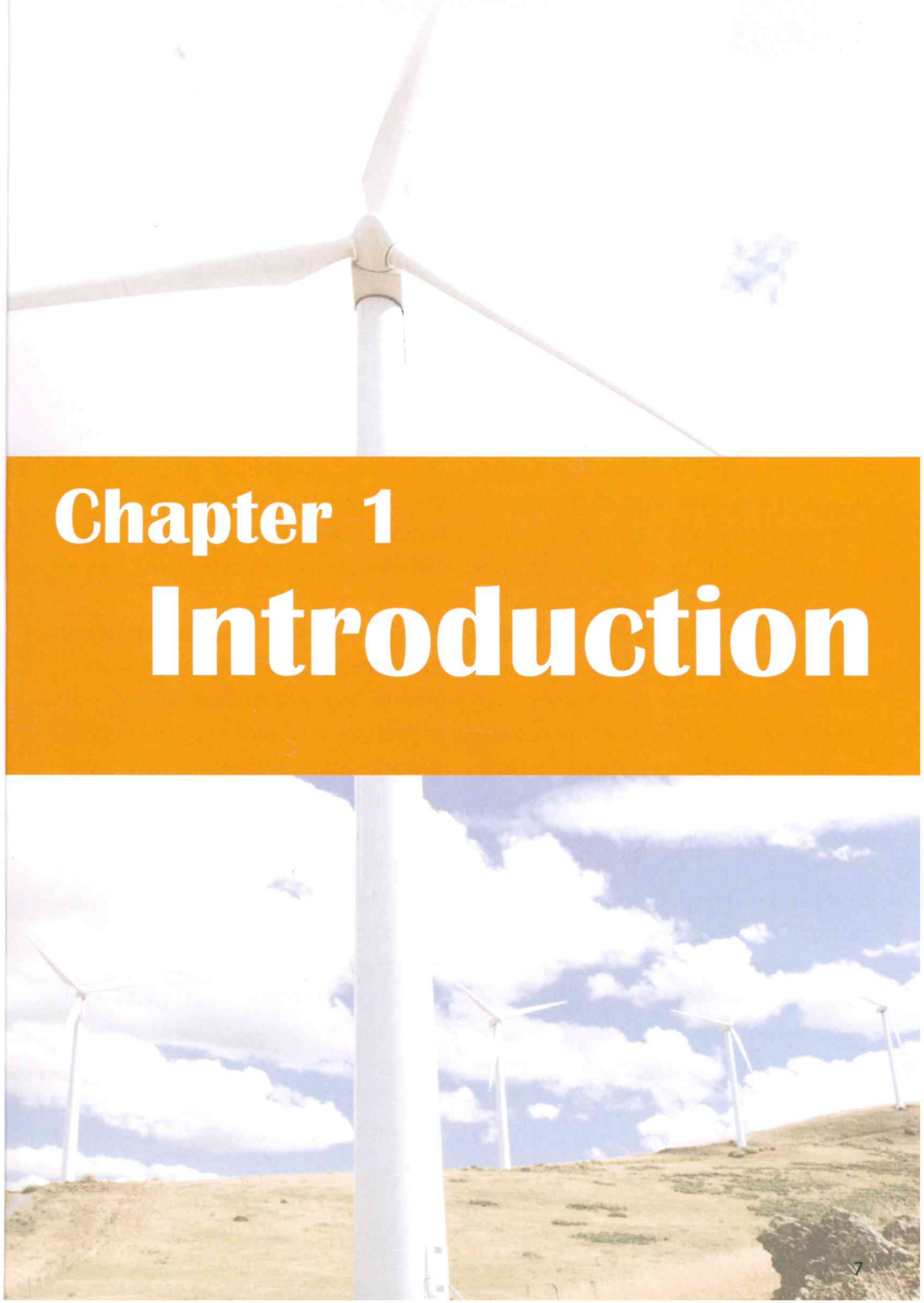
In addition, this advisory kit was made possible by the technical and financial contributions of a number of sponsors, listed as follows (in alphabetical order):

- Clover Display Ltd.
- Gold Best Ltd.
- Hong Kong Electrical Appliance Industries Association
- Hong Kong Printed Circuit Association
- Hong Kong & Kowloon Electrical Appliances Merchants Association Ltd.
- SGS Hong Kong Ltd.
- Shenzhen Sunshine Circuits Technology Co., Ltd.
- Terraillon Asia Pacific Ltd.
- The Hong Kong Electronic Industries Association
- The Hong Kong Green Manufacturing Association

We would like to thank the above industrial sponsors who have given valuable contributions, participation, and financial support.

Abbreviations

B2B	business to business
B2C	business to customer
CFP	carbon footprint of a product
CFP-PCR	carbon footprint of a product- product category rules
CO_2	carbon dioxide
CO_2 eq.	carbon dioxide equivalent
GHG	greenhouse gas
GWP	global warming potential
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
LCA	life cycle assessment
LCIA	life cycle impact assessment
LCI	life cycle inventory
PCR	product category rules



Chapter 1 Introduction

1.1 Current Situation and Problem Identification

Climate change that has led to an increasing number of extreme weather events has become center of attention over the past few years. Our anthropogenic activities are believed to be the main cause behind it. The increasing atmospheric GHG emissions have been largely generated by human activities and about half of cumulative anthropogenic CO_2 emissions since the year 1750 have occurred after 1970 [1]. The industrial revolution not only brought about prosperity, but also a series of collateral impacts. To slow down the concentration of greenhouse gases (GHGs), especially the fast accumulating carbon dioxide in atmosphere, is one of the key strategies in combating climate change.

Currently, a large proportion of the carbon emissions is emitted from the consumption of various products. Since GHGs are emitted and removed over the life cycle of a product, from the raw material stage through the manufacturing stage, the use stage, and the end-of-life stage, there has been a move to reduce carbon emission by disclosing and addressing carbon footprint information to customers. GHG standards are applied for supporting business functions like carbon labelling, technology innovation for potential GHG revenues, supply chain management, and so on [2]. By using ISO GHG standards, companies are able to identify opportunities to bolster their bottom line and discover competitive advantages in the market.

With both market-based and political incentives that will direct economic growth on a low-carbon trajectory as impacts from climate change become more frequent and prominent, there is an urgent need to introduce ISO/TS 14067 to Hong Kong industry. Since there is no solid enforcement of any policy in Hong Kong yet, companies find it hard to see how it will affect industry and consumer behavior. Also, it is difficult to implement the standard since there are few precedent cases involve product carbon footprints have been undertaken in the local context in accordance with ISO/TS 14067.

1.2 Objectives of this Advisory Kit

In order to help industry adapt on the ways to achieve significant emission reductions, this advisory kit seeks to-

1) Conduct a precise overview of ISO/TS 14067 to help enterprises better under stand the standard;

2) Analyze the benefits of implementing ISO/TS 14067;

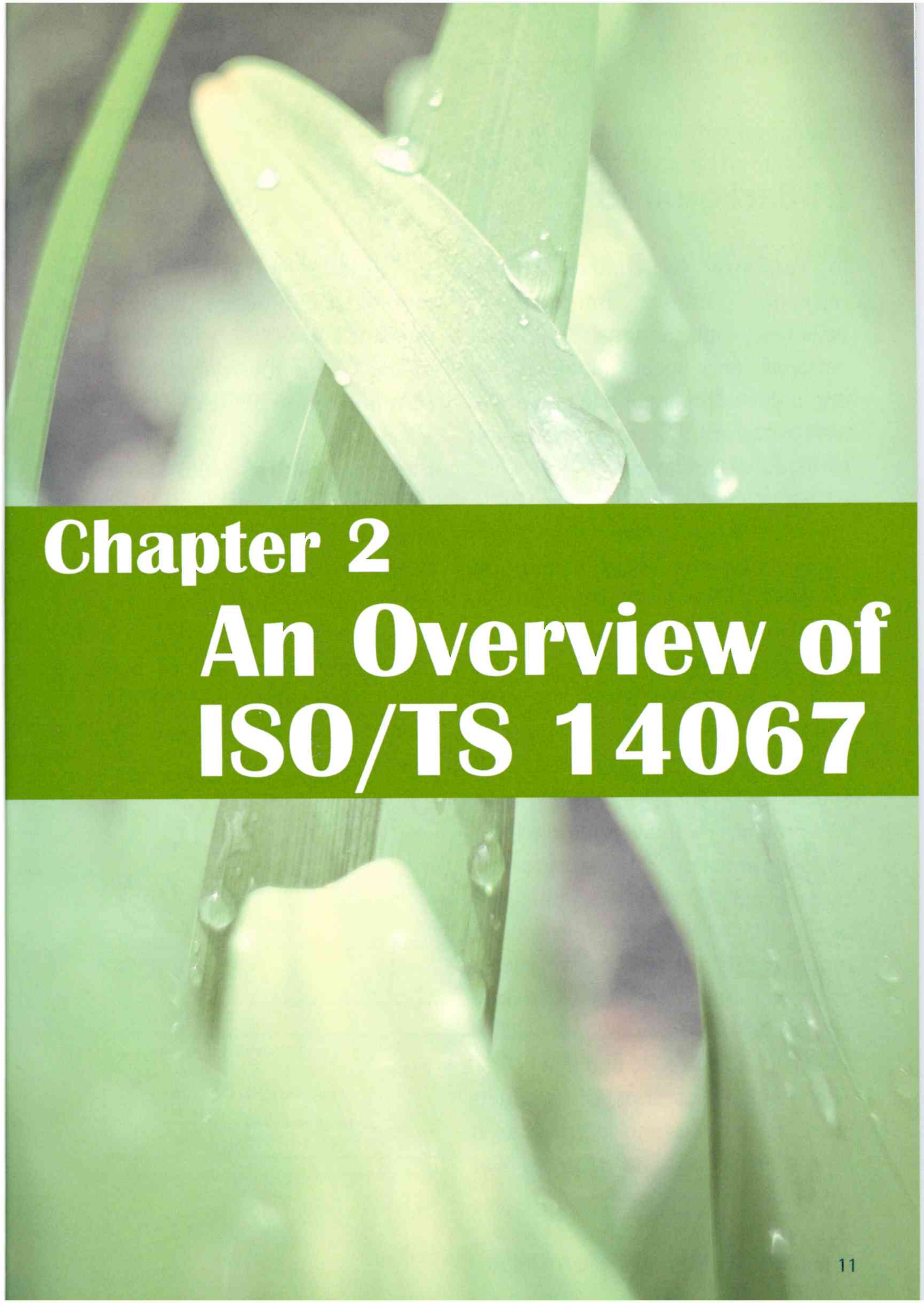
3) Provide a detailed description on conducting a product carbon footprint report, with focus on case studies of four electronic products from Hong Kong industry;

4) Introduce an online carbon footprint quantification tool (G-BOM Analyzer) and database developed by Hong Kong Polytechnic University for the industry to enable better and easier ways to quantify carbon emissions in the life cycle of a product.

1.3 Scope of this Advisory Kit

This advisory kit aims at covering the key points and requirements from the ISO/TS 14067 [3], which is crucial in undertaking carbon footprint quantification and communication.

This kit is applicable for parties that are interested in including carbon reduction policies in their businesses as well as environmental strategies by applying ISO/TS 14067 in their products for carbon footprint quantification.



Chapter 2
An Overview of ISO/TS 14067

2.1 Background

In response to climate change resulting from anthropogenic activities, international, regional, national, and local initiatives are under development and in practice to limit the atmospheric greenhouse gas (GHG) concentrations.

In order to standardize the carbon footprint benchmarking of products, the International Organization for Standardization (ISO) has developed ISO 14067 for the carbon footprinting of products (CFPs). The ISO/TS 14067 (Technical Specification) is based on existing ISO 14020, ISO 14024, ISO 14025, ISO 14040, and ISO 14044. It provides detailed principles, requirements, and guidelines for the quantification and communication of CFPs. ISO 14067 also sets specific requirements for the quantification and communication of a CFP based on the life cycle assessment (LCA) specified in ISO 14040 and ISO 14044. The carbon footprint of products covers both goods and services based on GHG emissions and removals over the product life cycle. A CFP study report that provides an accurate, relevant, and fair representation of the CFP is the foundation in the communication of the CFP.

However, ISO/TS 14067 addresses the single impact category of climate change and does not include other potential social, economic, and environmental impacts resulting from the provision of products. The overall environmental impacts of products are not indicated by product carbon footprints assessed in conformity with ISO/TS 14067.

2.2 The applications of ISO/TS 14067

The application of ISO/TS 14067 is to a) provide information to customers for decision-making; b) perform tracking of a product; and c) comparative assertion with additional requirements.

Quantified product carbon footprints offer opportunities to create business value by reducing the carbon footprints. However, a product carbon footprint has its limitation in that it only focuses on one of the environmental issues (global warming), and has methodological limitations as it is based on LCA.

2.3 Principles of ISO/TS 14067

Overall, the quantification and reporting of a CFP in accordance with ISO/TS 14067 is based on the principles of the life cycle assessment (LCA) methodology in ISO 14040 and ISO 14044 [4]. The CFP communication is based on the relevant principles of ISO 14020, ISO 14024, and ISO 14025 [5]. A typical flow in a product life cycle is demonstrated in **Figure 1**.

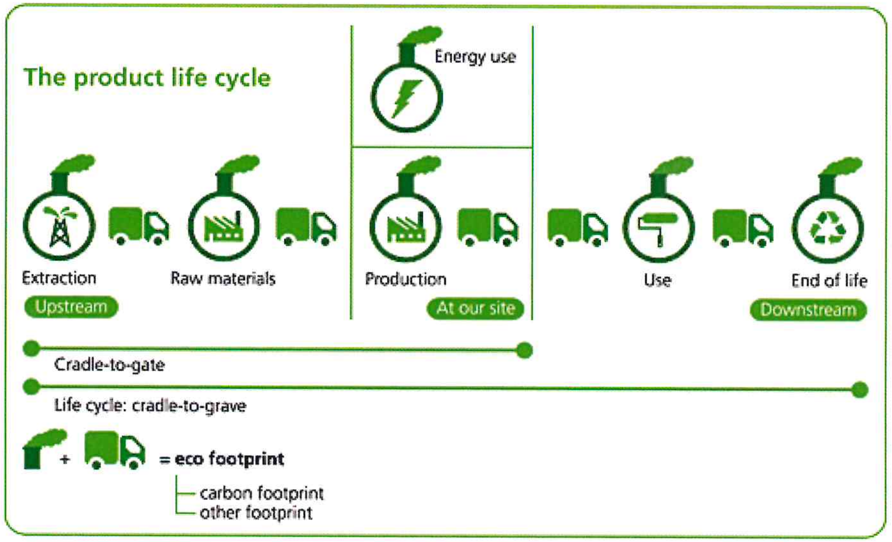


Image source: https://www.perstorp.com/en/Products/Coatings_and_Resins/Liquid_alkyd_and_polyester_resins/Voxtar_Carbon_Footprint

Figure1. Typical product life cycles stages

Regarding the life cycle perspective, the quantification and communication of CFP needs to take all stages of the product life cycle into consideration. In the meantime, a CFP study should be structured around a functional unit and the results calculated relative to the defined functional unit.

ISO/TS 14067 requires the implementation of iterative approach, scientific approach, and open, participatory processes when applying the LCA methodology to a CFP study.

Moreover, a CFP study should follow the principles of relevance, completeness, consistency, accuracy, transparency, fairness, and avoidance of double counting.

Detailed descriptions of each principle are listed in **Table 1** below.

Table1. Quantification and reporting principles of ISO/TS 14067

Calculation principle	Actions
Life cycle perspective	The development of CFP quantification and CFP communication takes into consideration all stages of the life cycle of a product, including raw material acquisition, production, distribution, use and the end-of-life stage.
Relative approach and functional unit	The result of PCF is based on the product functional unit.
Relevance	Choose appropriate data and methods to evaluate the amount of greenhouse gas emissions targeting the product or certain parts of the system
Completeness	Include all greenhouse gas emissions and removals which contribute to reducing greenhouse gas emissions from the target product or partial system
Consistency	In practicing product carbon footprint, manufacturers apply consistent hypotheses, methodologies and data
Accuracy	Reduce error and uncertainty

2.4 Methodology for CFP quantification

The major aspect of a carbon footprint project is the calculation of the product carbon footprint. The prime objective of the carbon partnership business is to reduce greenhouse gas emissions from the manufacturer and the cooperating manufacturers. By monitoring greenhouse gas emissions and limiting the amount emitted from the manufacturer and cooperating manufacturers can achieve the objective of reducing greenhouse gases emission.

2.4.1 Application of product category rules (PCR)

A CFP study requires the usage of CFP-PCR or PCR, which shall be made publicly available. The CFP-PCR or PCR is used for identifying and documenting the goal and scope of the CFP study. It also determines the included life cycle stages, covered parameters, and the method of parameter collection and documentation.

A detailed description can be found in ISO/TS 14067 Section 6.2.

2.4.2 LCA approach

A CFP study should cover all four phases of LCA- a) goal and scope definition; b) life cycle inventory (LCI); c) life cycle impact assessment (LCIA); and d) life cycle interpretation. **Figure 2** shows the framework of life cycle assessment from ISO 14040.

The goal of a CFP study is to calculate the potential contribution of a product to global warming by quantifying all significant GHG emissions and removals throughout the product life cycle and expressing the final results as CO_2 eq. The scope of a CFP study should be consistent with its goal and should also take the following items into consideration- a) product system and its functions; b) product functional unit; c) the system boundary; d) data, data quality requirements, time boundary for data; e) assumptions made in the process; f) allocation procedure; g) specific GHG emissions and removals;

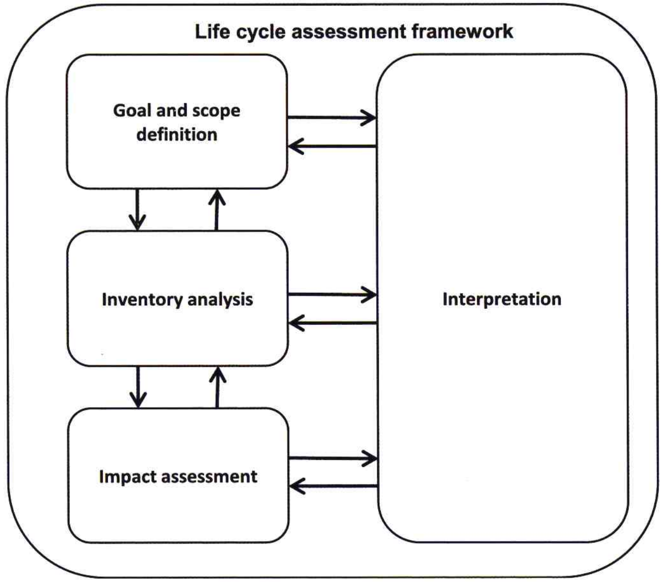


Figure 2. Framework of life cycle assessment [6].

h) CFP study report; i) limitations of the CFP study; etc. Under certain circumstances, the scope of CFP study can be revised due to unforeseen factors, but all the modifications and explanations shall be documented.

2.4.3 Carbon emission calculation

The unit processes comprising the product system are grouped into selected life cycle stages in this study, i.e. raw material acquisition, manufacturing, and transportation. GHG emissions and removals from the product's life cycle are assigned to the life cycle stage in which the GHG emissions and removals occur. Partial PCFs may be added together to quantify the total PCF, provided the same methodology is used and there are no gaps and overlaps. The product carbon footprint (PCF) is calculated and presented as a carbon dioxide equivalent (kg CO_2 eq.) using the relevant 100-year global warming potential (GWP 100). Findings in the impact assessment and the sensitivity and contribution analysis, performed as part of the interpretation, help identify the most relevant and contributing ("key") processes and basic flows of the system.

Carbon Emission
= Activity Data × Emission Factor × Global Warming Potential

The unit of the "Emission Factor" is "kg CO_2 eq. /unit".

During the quantification of study, values are rounded off to four decimal places in the life cycle inventory data input. The results of the assessment are rounded off to two significant figures [7].

2.5 Communication

2.5.1 ISO/TS 14067 requirements for communication

The requirements for CFP communication differ depending on the form of communication and availability to the public. The following **Figure 3** shows the requirements of ISO 14067 for different CFP communication options.

The communication target audiences of ISO14067 include "Business to Business (B2B)" and "Business to Customers (B2C)".

2.5.2 Current trend of carbon footprint related communications

Nowadays, consumers are increasingly concerned by the

	CFP external communication report (9.1.2)	**CFP performance tracking report (9.1.3)**	**CFP label (9.1.4)**	**CFP declaration (9.1.5)**
CFP communication **intended to be publicly available (9.2)**	CFP communication programme optional	CFP communication programme optional	CFP communication programme mandatory	CFP communication programme mandatory
	CFP-PCR optional	CFP-PCR optional	CFP-PCR mandatory	CFP-PCR mandatory
	3rd party CFP verification or CFP disclosure report mandatory	3rd party CFP verification or CFP disclosure report mandatory	3rd party CFP verification or CFP disclosure report mandatory	3rd party CFP verification or CFP disclosure report mandatory
CFP communication **not intended to be publicly available (9.3)**	CFP communication programme optional	CFP communication programme optional		CFP communication programme mandatory
	CFP-PCR optional	CFP-PCR optional		CFP-PCR mandatory
	Independent CFP verification or CFP disclosure report optional	Independent CFP verification or CFP disclosure report optional		Independent CFP verification or CFP disclosure report mandatory

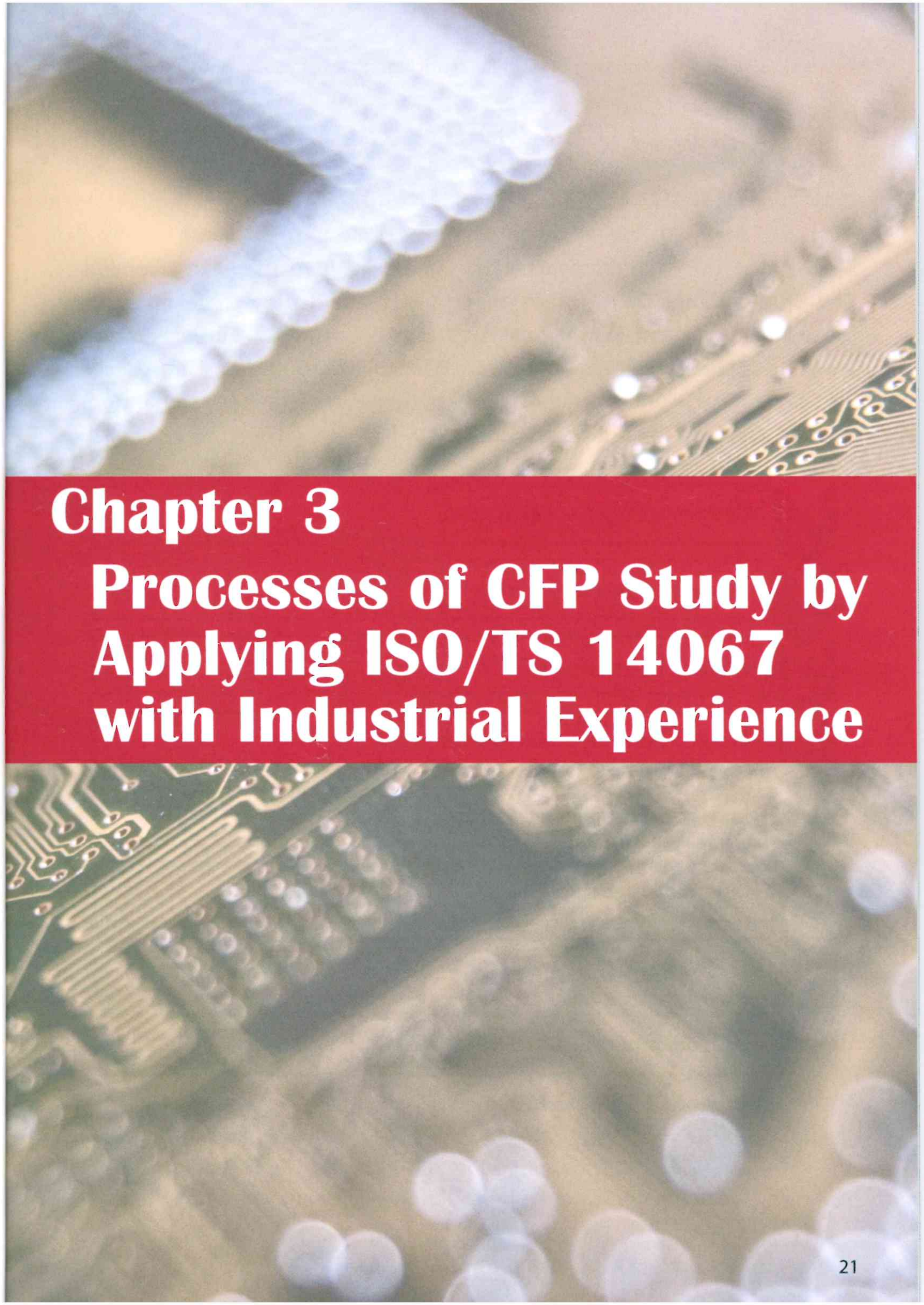
Figure 3. Requirements for different CFP communication [3]

environmental impact of the product they buy. The carbon footprint has become one of the most widely known and recognised environmental impacts. Among all the format of delivering carbon footprint related messages, carbon footprint labeling is the most common one.

There are lots of carbon footprint labeling schemes worldwide. The most developed areas are in European countries, like the UK, Switzerland, Germany, and other countries such as the USA, Japan, and Korea.

Figure 4 is a collection of examples of current carbon footprint labels in the market from different countries.

Figure 4. Examples of current available carbon footprint



Chapter 3

Processes of CFP Study by Applying ISO/TS 14067 with Industrial Experience

3.1 Summary of steps of CFP study

Based on the requirements for CFP study from ISO/TS 14067, the following steps as listed in **Figure 5**, are to be applied.

The list of steps is a summary and generalization of the requirements, and the CFP study processes should not be limited to only these items. The following sections are detailed demonstrations of each single step.

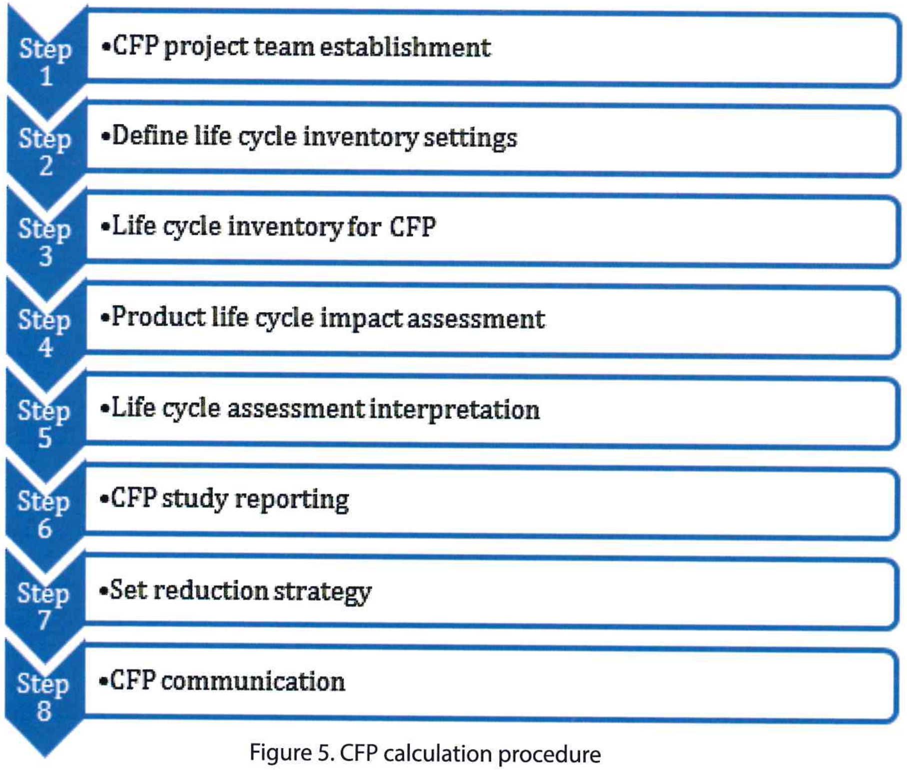


Figure 5. CFP calculation procedure

3.2 A step-by-step implementation of CFP study

In this section, a step-by-step instruction will be provided to conduct a CFP report with the industrial experience from four case studies. The products selected for the showcases are as follows.

Step 1 - CFP project team establishment

Manufacturers should call up a CFP project team for the CFP program. Before data collection from the manufacturing processes, the CFP project team should tour around the manufacturing line to obtain basic information of the current manufacturing status and mark down findings that might cause difficulties in the data collection procedure.

After the CFP project team has executed the data collection and review of the manufacturing line, the manufacturer and suppliers should appoint a manager as a contact person for the CFP program.

Education regarding basic knowledge of data collection for carbon footprinting should be provided to the head of each section of the production line and the personnel involved.

Step 2 - Define life cycle inventory settings

As ISO 14067 is LCA based, the CFP team needs to complete the following items before actual data collection:

a) Define the goal for CFP calculation

In the process of defining the goal of the CFP study, the reporting company should consider i) the intended application of the study; ii) the reason for carrying out the CFP study; and iii) the intended communication plan and target audience.

Examples of setting CFP study goal:

- Reason why CFP calculation is needed:

To acquire carbon information to communicate with customers

- Utilization of CFP:

To acquire a carbon label for use as a marketing strategy

- Target audience:

Carbon label verification organization and customers

b) Set system boundary of the product system:

In this step, the CFP team needs to identify or define function, function unit, and reference flow of the product system.

Case Study-Activities

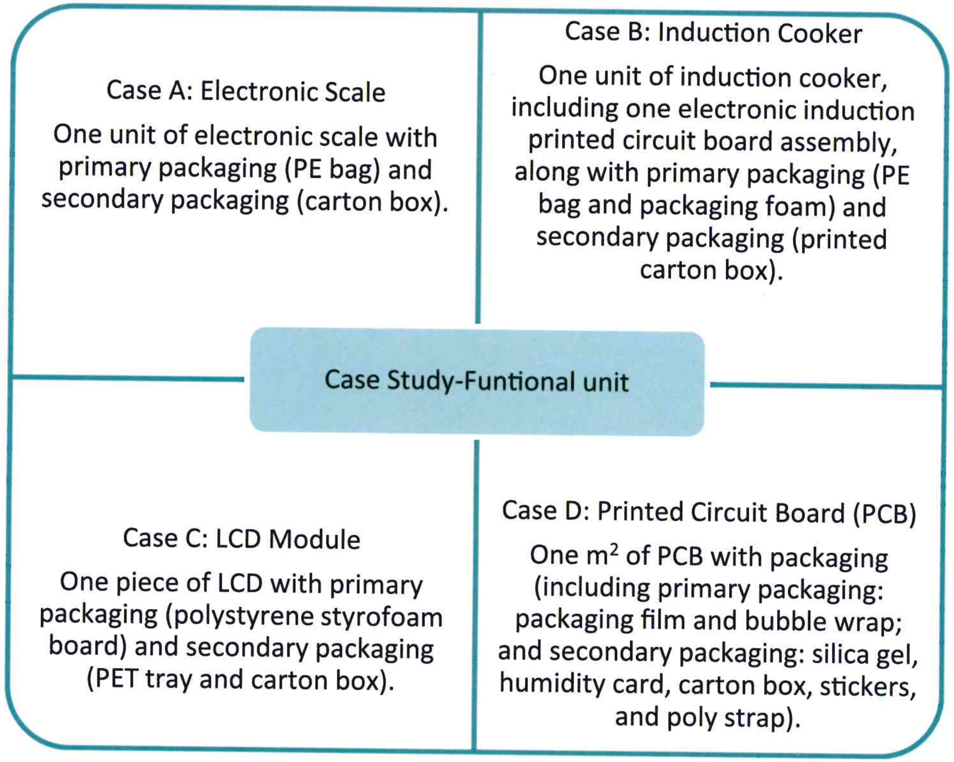
Case A: Electronic Scale Businiess to Customers (B2C)	Case B: Induction Cooker Businiess to Customers (B2C)
Case C: LCD Module Businiess to Business (B2B)	Case D: Printed Circuit Board (PCB) Businiess to Business (B2B)

Case Study-Product funtion

Case A: Electronic Scale Home appliance for measuring body weight. The scale is mainly made from glass and stainless steel. It also provides the weight memory saving history for up to 4 users. The scale is powered by 4 AAA batteries	Case B: Induction Cooker Home appliance for cooking. The cooker is mainly made from ceramic, plastic and metals. It provides 3 types of cooking methods- heating with set temperatures (60°C, 90°C, 120°C, 160°C, and 200°C), boiling, and steaming/ stewing. Electricity is used to power this cooker.
Case C: LCD Module A semi-finished product that is used as one of the components in a household thermometer.	Case D: Printed Circuit Board (PCB) A semi-finished product used as a component in ignition systems in automobiles.

Case Study-Reference flow

Case A: Electronic Scale One unit of electronic scale	Case B: Induction Cooker One unit of induction cooker
Case C: LCD Module One piece of LCD module	Case D: Printed Circuit Board (PCB) One m^2 of PCB



Later on, which life cycle stages (for example: raw material, manufacture, distribution, use and disposal) should be included in the product life cycle is determined according to the project status. These stages are shown in **Figure 6**.

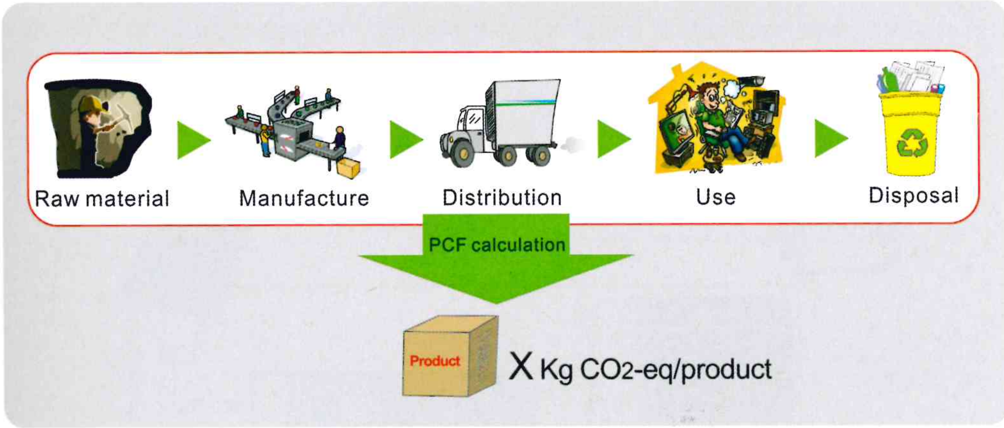


Figure 6. Life cycles stages of product

Use of materials in the "Raw Material" stage is an upstream activity, which refers to Bill of Material (BOM) of the targeted product.

Manufacturing processes of suppliers are also included in this step. Since most products consist of various components, the components with insignificant greenhouse gases emission can be excluded by using cut-off criteria, and the cut-off standards should be applied with consistency.

The "Manufacturing Stage" only includes those processes within the production line of the manufacturer. Carbon emissions from all the input and output of materials should be counted in the process.

In terms of "distribution", "use" and "disposal" are downstream activities. The boundary of these activities should be defined by creating scenarios based on available documents, like testing reports, recycling policies, and so on.

Moreover, a process tree can be developed to show the connection among processes within the system boundaries.

Demonstrations of system boundaries of 4 cases are shown in the following pages.

As a final product, the system boundary of the selected electronic scale covers all five stages of life cycle.

System boundary of Case A: Electronic Scale

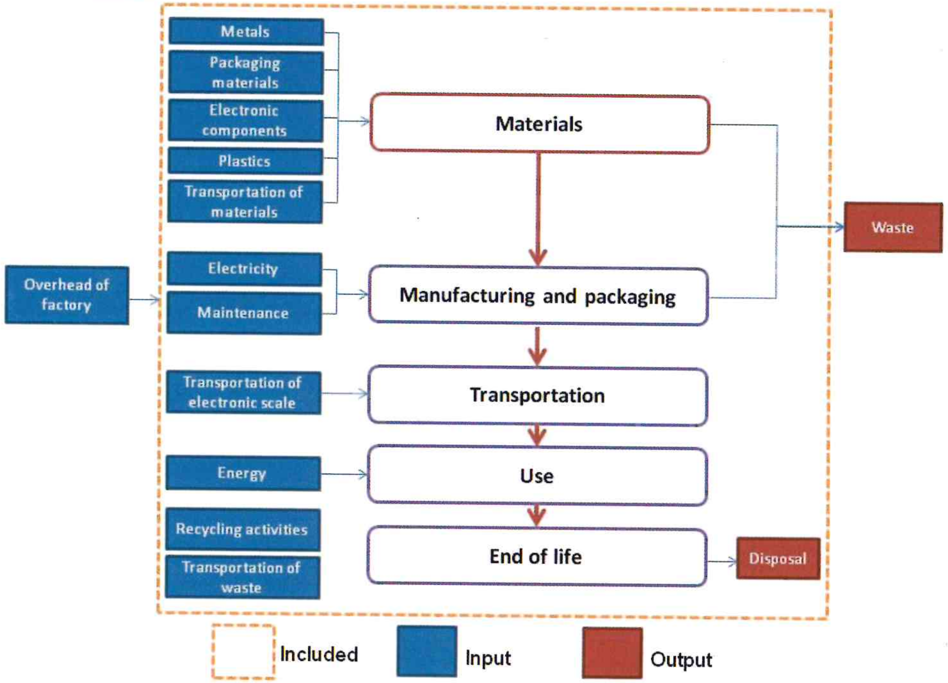


Figure 7. System boundary of carbon footprint analysis of "the scale"

As a final product, the system boundary of an induction cooker should cover all five life cycle stages. However, use stage and end-of-life stage are excluded in this case since there is no sufficient documents available to build use profile and relavant scenarios.

System boundary of Case B: Induction Cooker

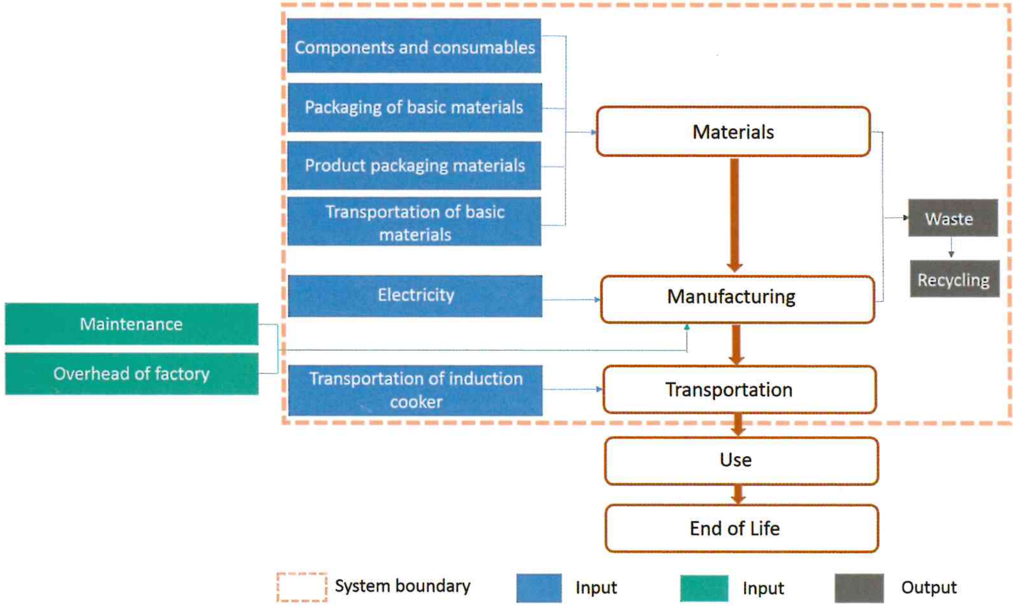
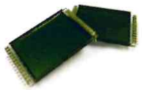


Figure 8. System boundary of carbon footprint analysis of "the cooker"

As a component, the system boundary of the selected LCD module does not include use stage and end-of-life stage.

The transportation is for reference and not included in the final product carbon footprint result.



System boundary of Case C: LCD Module

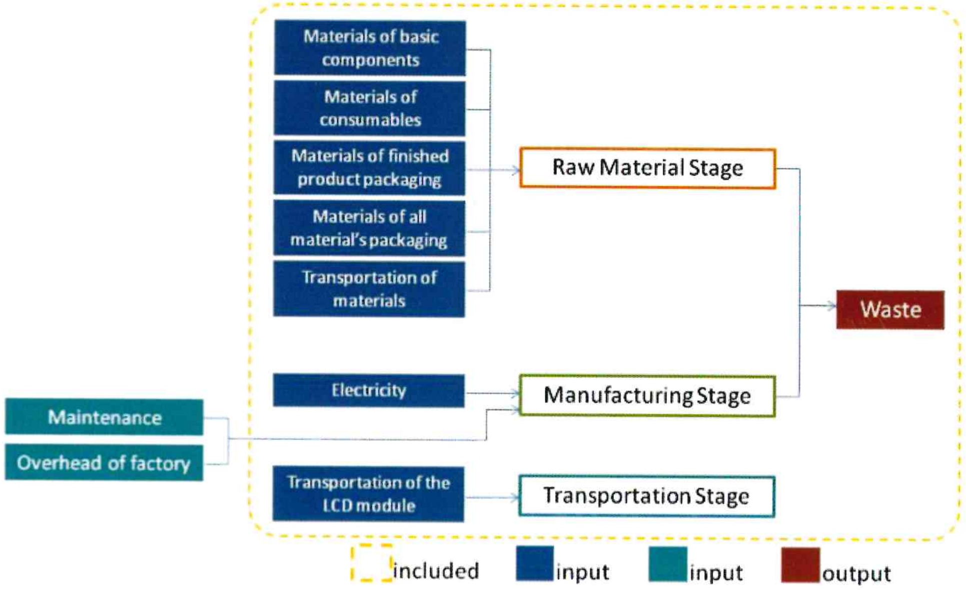


Figure 9. System boundary of carbon footprint analysis of "the LCD module"

As a component, the system boundary of the PCB does not include use stage and end-of-life stage.

The transportation is for reference and not included in the final product carbon footprint result.

System boundary of Case D: Printed Circuit Board

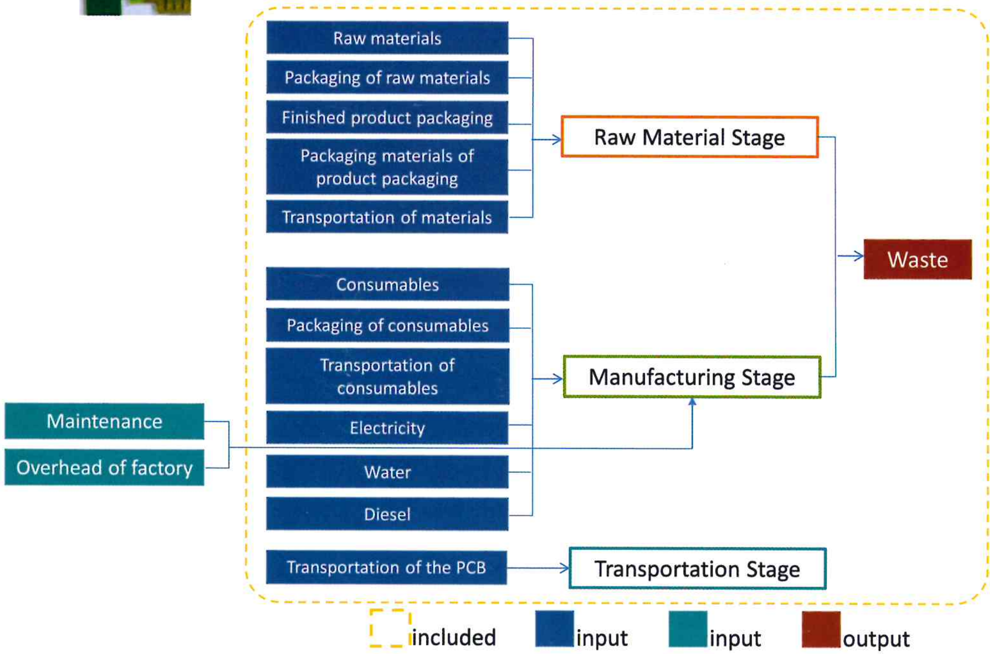


Figure 10. System boundary of carbon footprint analysis of "the PCB"

c) Determine allocation methods (if needed)

During the data collection, manufacturers may encounter many allocation issues regarding inputs/ outputs. Manufacturers should set and follow allocation strategies with consistency.

d) Set time boundary for data collection

Deatiled examples of allocation of emission, geographic and time boundary are shown in the folloing table.

Case Study-Allocation of emission, geographic and time boundary

Case A: Electronic Scale

Allocation: based on the ratio of electronic scales manufactured and total number of products manufactured.

Location and time period: Shenzhen; Oct 2012 to Mar 2013.

Application: in the electricity, water and consumables used in the manufacturing stage

Case B: Induction Cooker

Allocation: based on production volumes of domestic and commercial models.

Location and time period: Guangzhou; Aug 2013 to Jul 2014.

Application: in the electricity used in the manufacturing stage of domestic induction cookers based on their total production volume.

Case C: LCD Module

Allocation: based on the ratio of the manufactured quantities of the studied product and the total production.

Location and time period:

Fo Shan City; Jan 2013 to Dec 2013.

Application: in electricity, water, and consumables used in manufacturing stage.

Case D: Printed Circuit Board (PCB)

Allocation: based on the ratio of the manufactured quantities of the studied product and the total production.

Location and time period: Shenzhen; Feb 2014 to Aug 2014.

Application: in electricity, water, consumables usage, and waste amount generated from the production .

e) Determine source and collection methods for data

Data collected should include primary data and secondary data. In the end, the result of the collection should be counted and presented as the amount per functional unit.

f) Confirm report format in accordance with ISO/TS 14067 as well as the scope and objectives of the CFP study.

Step 3 - Life cycle inventory for CFP

In the life cycle inventory for CFP, all input and output data should be collected, such as raw material, energy input, and waste generated from all processes within the boundary of product system. Data should be collected by measuring inputs and outputs in practice. For example, the amount of zinc plated steel plate, electricity, steam and SF_6 used in manufacturing process are input/ output parameters.

Normal data collection steps consist of five steps given below in **Figure 11**:

a) Establish data management plan

In order to design a data management plan, the following steps should be followed:

- Design a data management plan
- Use the data management plan as a base to perform data quality checks
- Run specific data quality checks
- Greenhouse gases emission data review and reporting
- Improve data collection, processing and documentation steps
- Design reporting, documentation and recording procedure

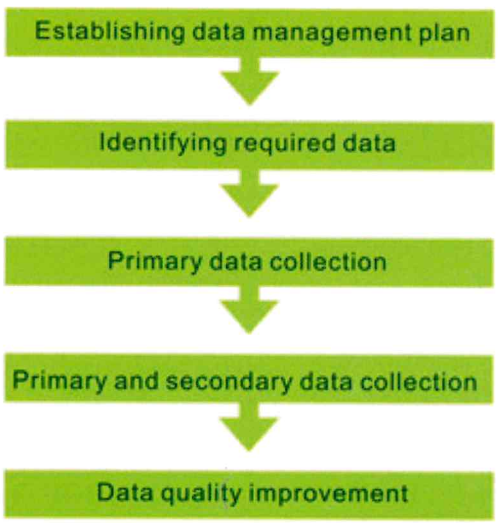


Figure 11. Data collection and processing steps

b) Identify significant processes and activities

This step aims at making a complete process flow for data collection and CFP calculation. A completed process flow consists of all the unit proceeses.

The data of the unit processes follow an appropriate flow and must be consistent with the goal and scope of the CFP study,incluing

- Processes which emit/remove a large amount of greenhouse gas
- Processes which require significant material input
- Processes which require large amounts of energy, materials or other waste outputs/ discharge

Process flow in manufacturing stage of Case A: Electronic Scale

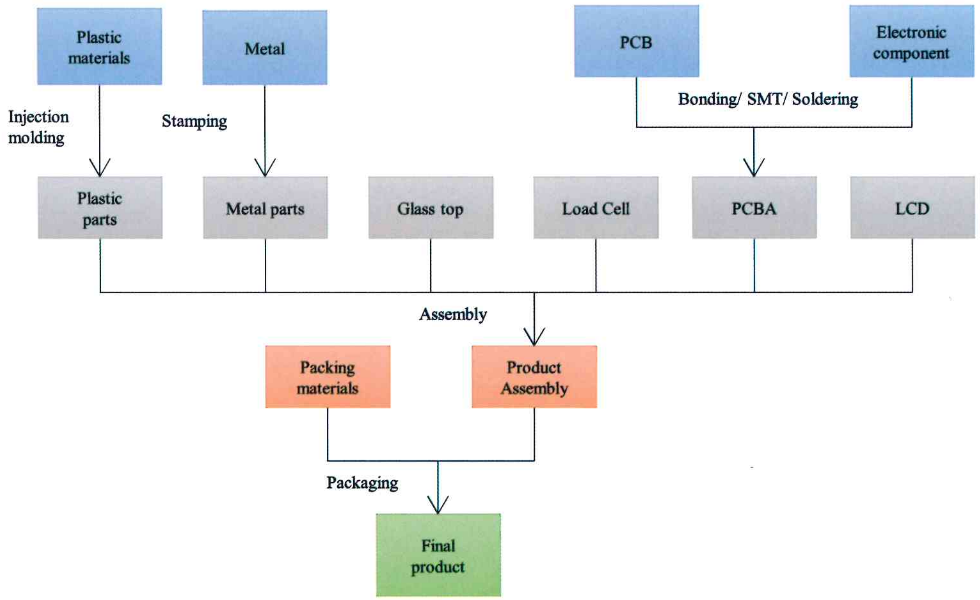


Figure 12. Process flow in themanufacturing stage of Case A: Electronic Scale

Process flow in manufacturing stage of Case B: Induction Cooker

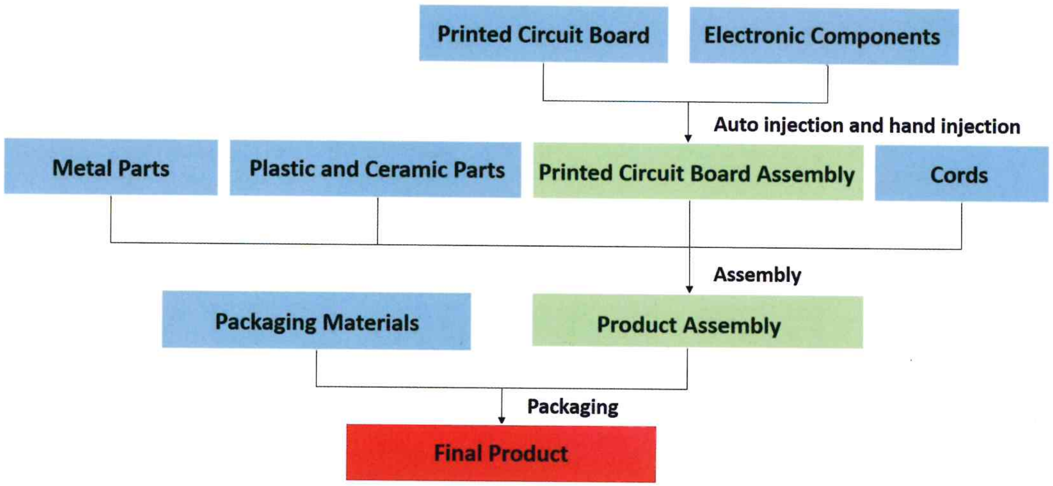


Figure13. Process flow in the manufacturing stage of Case B: Induction Cooker

Process flow in manufacturing stage of Case C: LCD Module

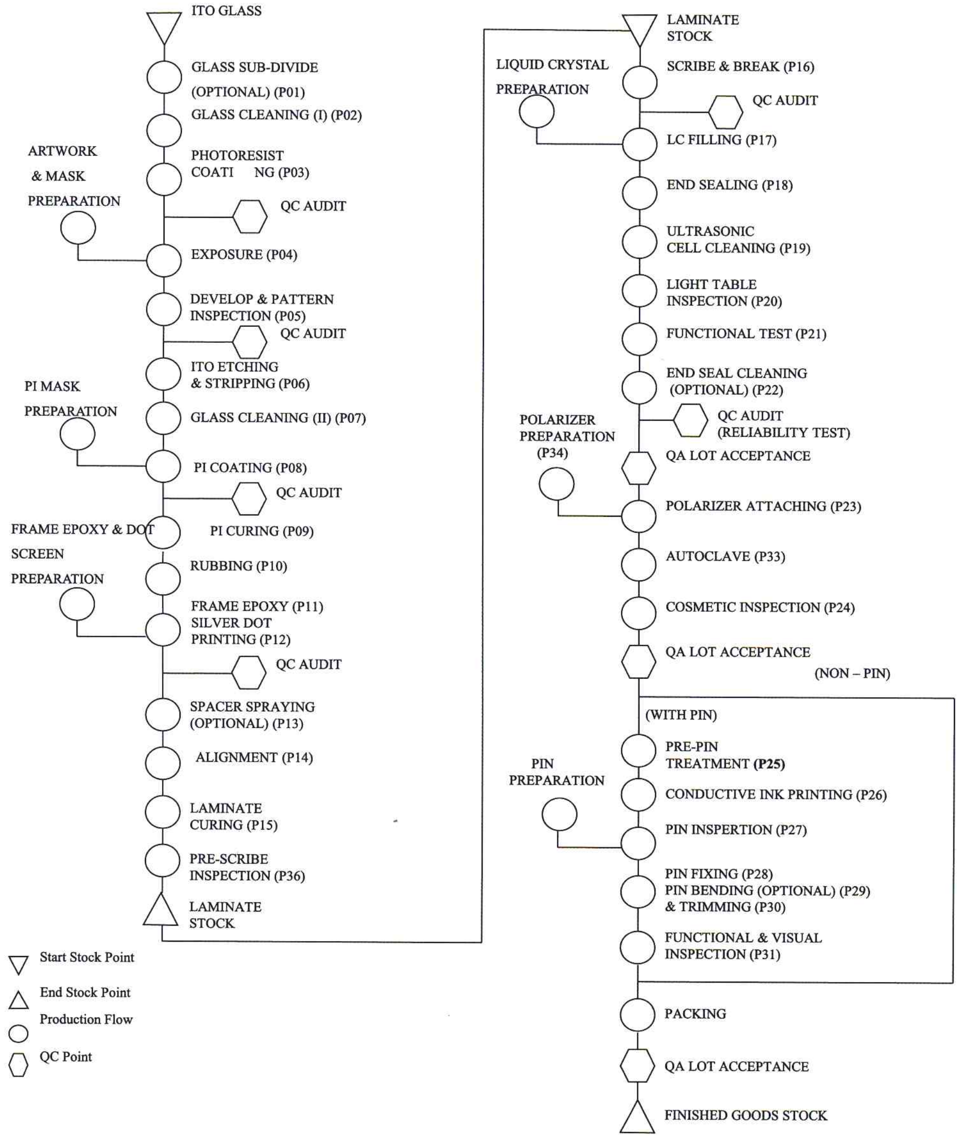


Figure 14. Process flow in the manufacturing stage of Case C: LCD Module

Process flow in manufacturing stage of Case D: Printed Circuit Board (PCB)

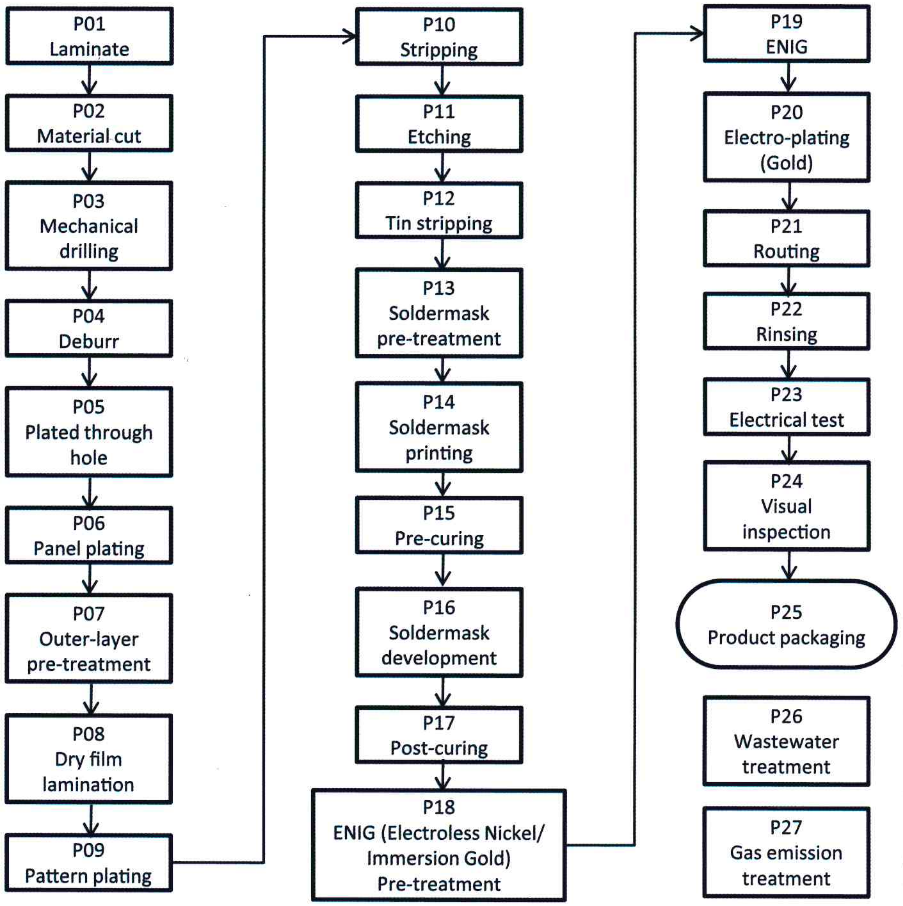


Figure15. Process flow in manufacturing stage of Case D: PCB

c) Primary data collection of processes under the control of reporting manufacturers.

Calculate CFP of the product's manufacturing process. Primary data may consist of the following:

• Quantity of energy used in the whole process

• Quantity of raw material used (raw material, auxiliary material)

• Greenhouse gases emission from chemical reactions in the process

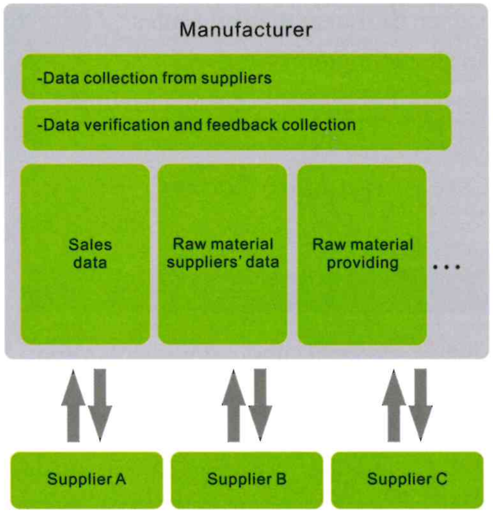


Figure 16. Data collection for CFP program

d) Primary and secondary data collection

Collect primary and secondary data from upstream and downstream activities. The following data are examples of the secondary data.

• Process energy usage from the database.

• Process energy usage of similar product to the subject product process.

• Industry average emission of greenhouse gases from the chemical reactions involved in the process.

• Country and industry average material inputs in the processes.

Data and data quality of Case A: Electronic Scale

Table2. Data and data quality of Case A: Electronic Scale

Life cycle stage	Type of data	Data
Raw material stage	Primary data (site specific)	Amount of materials and components used
	Secondary data	Emission factors of material and components
Manufacturing stage	Primary data (site specific)	Electricity consumption of manufacturing process
	Secondary data	Emission factors of electricity
Transportation stage	Primary data	Distance of transportation routes
		Transportation tools used
	Secondary data	Emission factors of transportation route
Use stage	Scenario	Resource consumption in use
	Secondary data	Emission factors of resources used
End of life stage	Scenario	Distance of transportation routes
		Transportation tools used
	Secondary data	Emission factors of disposal activities

Data and data quality of Case B: Induction Cooker

Table2. Data and data quality of Case B: Induction Cooker

Life cycle stage	Type of data	Data
Raw material	Primary data (site specific)	Amount of materials and components used
	Secondary data	Emission factors of material and components
Manufacturing	Primary data (site specific)	Electricity consumption of manufacturing processes
	Secondary data	Emission factors of electricity
Transportation (for reference)	Primary data	Transportation tools used
	Secondary data	Emission factors of transportation routes
		Distance of transportation routes

Data and data quality of Case C: LCD Module

Table 4. Data and data quality of Case C: LCD Module

Life cycle stage	Type of data	Data
Raw material stage	Primary data (site specific)	Amount of materials and components used
	Secondary data	Emission factors of materials and components
Manufacturing stage	Primary data (site specific)	Electricity consumption of manufacturing processes
	Secondary data	Emission factors of electricity
Transportation stage (for reference)	Primary data (site specific)	Transportation tools used
	Secondary data	Emission factors of transportation route
		Distance of transportation routes

Data and data quality of Case D: Printed Circuit Board (PCB)

Table5. Data and data quality of Case D: PCB

Life cycle stage	Type of data	Data
Raw material stage	Primary data (site specific)	Amount of materials and components used
	Secondary data	Emission factors of materials and components
Manufacturing stage	Primary data (site specific)	Electricity and water consumption, amount of waste generated in the manufacturing processes
	Secondary data	Emission factors of electricity and water usage
Transportation stage (for reference)	Primary data (site specific)	Transportation tools used
	Secondary data	Emission factors of transportation route
		Distance of transportation routes

e) Data quality assessment and improvement

A check on data validity is required to confirm and provide evidence that the data collected have met the quality requirements (6.3.5 in ISO/TS 14067). Solution to data gaps analyzed and low data quality

- Sources of low quality data should be identified
- New data should be collected to improve quality data
- Quality analysis of new data collected
- Update and adjustment of data sources
- Refine the system boundaries

After collection of the raw data, the CFP team needs to process the inputs/outputs in each process. The matrix should process names in a row and inputs/outputs parameter in a column. Table 6 is an example of a matrix used in data modification and management. Under the row for the manufacturing processes (example: procedure 1, 2, 3) place relevant inputs/outputs of the processes. If data modification is simplified in a row, the whole manufacturing process should be entered and the sum of input/output values of the whole manufacturing processes can be obtained.

Table 6. Example of input/output data table

Parameter	Material			Manufacturing			Distribution	Use	Disposal		Sum
	Component 1	Component 2	Component 3	Procedure 1	Procedure 2	Procedure 3			Disposal method 1	Disposal method 2	
Electricity											
Aluminum											
PP											
PC											
PCB											
Screws											
Motor											
Output											
Plastic straps											
Total											

Step 4 - Product life cycle impact assessment

In this step, the main task is to calculate inventory results. Multiply global warming potentials (GWPs) and emission factors with processes/procedures and input/output data from the table to convert the value to the product carbon footprint and display in the form of g CO_2 eq. /product. If the collected data is not directly emitted, 6 major Greenhouse gases emission factors are used. Normally in most cases, the emission factor is used to calculate the product carbon footprint calculation.

CFP calculation:

CFP (kg CO_2 eq.) = input/output (unit) data × emission factor (kg GHG/unit) × GWP (kg CO_2 eq. /kg GHG).
If the unit of the emission factor is CO2 eq. /unit, the GWP value should not be multiplied by the emission factor.

Example of raw material:

Carbon footprint of 2 kg plastic ABS in the used material = 2 kg ABS × 2.97 kgCO_2 eq. /kg (emission factor of ABS) = 5.84 kg CO_2 eq. /kg

If the emission factors are not available, data supplementation can be estimated by using external data and/or similar data.

In order to reduce the workload and difficulties in the calculation procedures, the activity data can be inputted into an online CFP analyzer (the G-BOM Analyzer) developed by The Hong Kong Polytechnic University. A detailed introduction (Section 4) and guidelines (Insert) are provided along with this advisory kit.

Step 5 - Life cycle assessment interpretation

In this step, manufacturers should identify inputs/outputs and processes/procedures that contribute significant greenhouse gas emissions by using contribution analysis. For more accurate CFP calculation values, sensitivity, consistency and uncertainty analysis are needed.

a) Identify significant issues or contributors

After calculation of cabon footprint, a detail analysis of product carbon emission results can begenerated by firstly identify the most significant issues or contributors among the selected product life stages.

Carbon footprint result and analysis of Case A: Electronic Scale

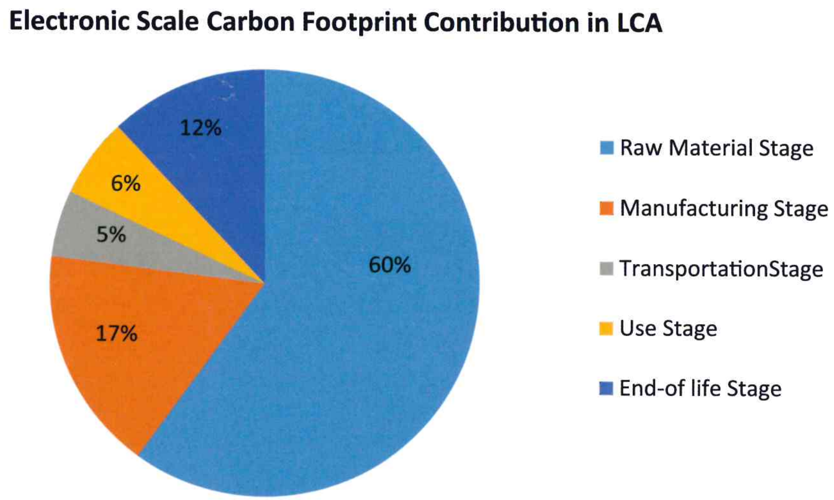


Figure 17. Carbon footprint result of Case A: Electronic Scale

The "Raw Materials" stage is the most significant life cycle stage, and contributes to a significant amount of carbon emission (60%) in the whole life cycle.

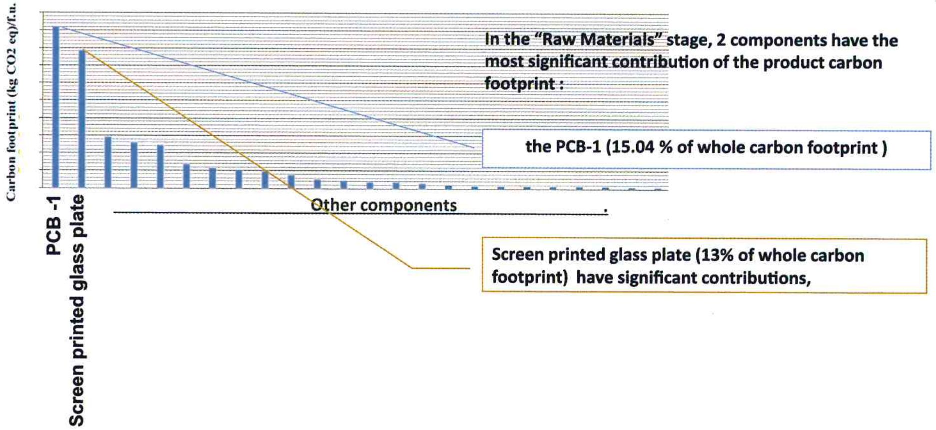


Figure 18. Significant contributor identification of Case A: Electronic Scale

Data and data quality of Case B: Induction Cooker

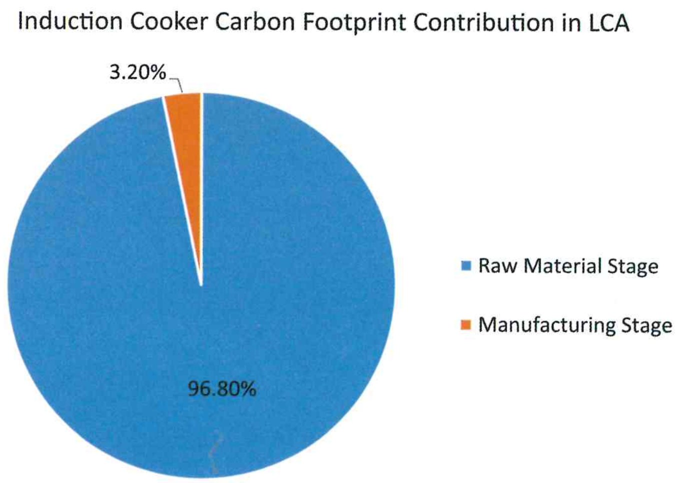


Figure 19. Carbon footprint result of Case B: Induction Cooker

The "Raw Materials" stage is the most significant life cycle stage, and contributes to a significant amount of carbon emission (>90%) in the whole life cycle.

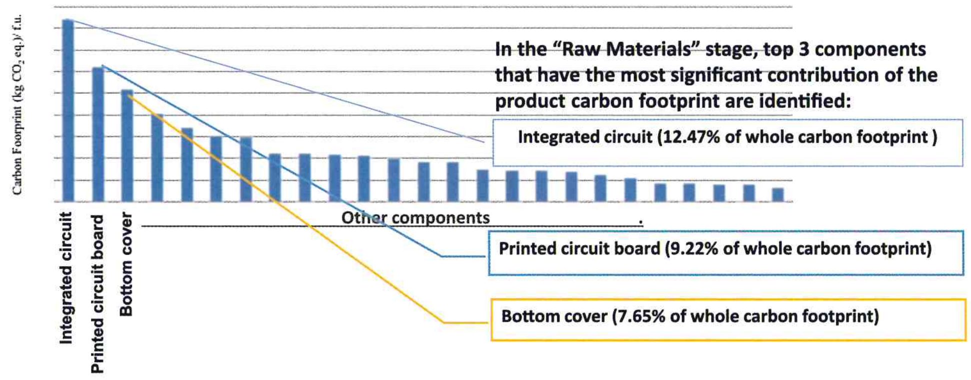


Figure 20. Significant contributor identification of Case B: Induction Cooker

Carbon footprint result and analysis of Case C: LCD

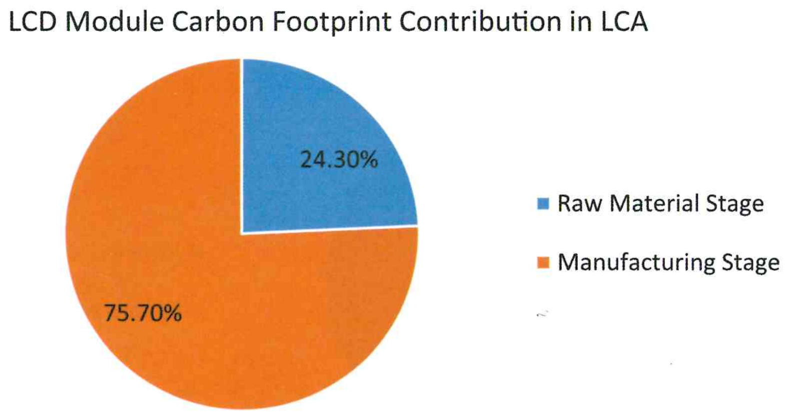


Figure 21. Carbon footprint result of Case C: LCD Module

The "Manufacturing" stage is the most significant life cycle stage, and contributes to a significant amount of carbon emission (75.66%) in the whole life cycle.

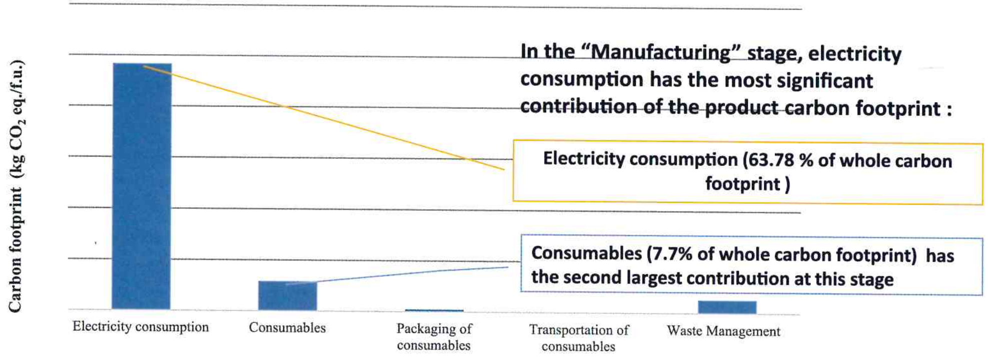


Figure 22. Significant contributor identification of Case C: LCD Module

Carbon footprint result and analysis of Case D: Printed Circuit Board (PCB)

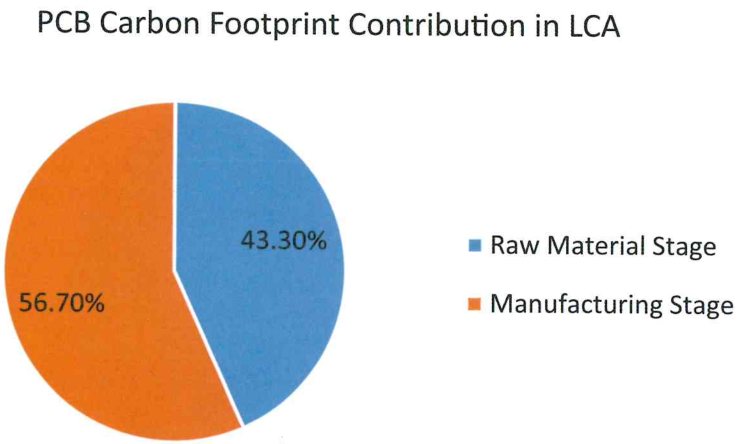


Figure 23. Carbon footprint result of Case D: PCB

The "Manufacturing" stage is the most significant life cycle stage, and contributes to a significant amount of carbon emission (56.74%) in the whole life cycle.

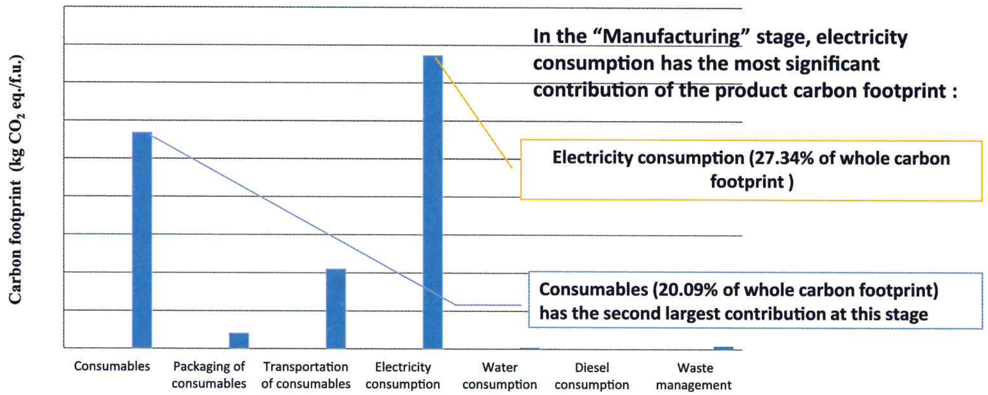


Figure 24. Significant contributor identification of Case D: PCB

b) Evaluate the completeness, sensitivity, and consistency of the assessment

There are certain factors that affects the result of CFP. Figure 25 below lists three most common parameters.

c) Conclusions, limitations, and recommendations

Draw conclusions, point out the limitations of the CFP study, and generate recommendations according to the analysis of the results.

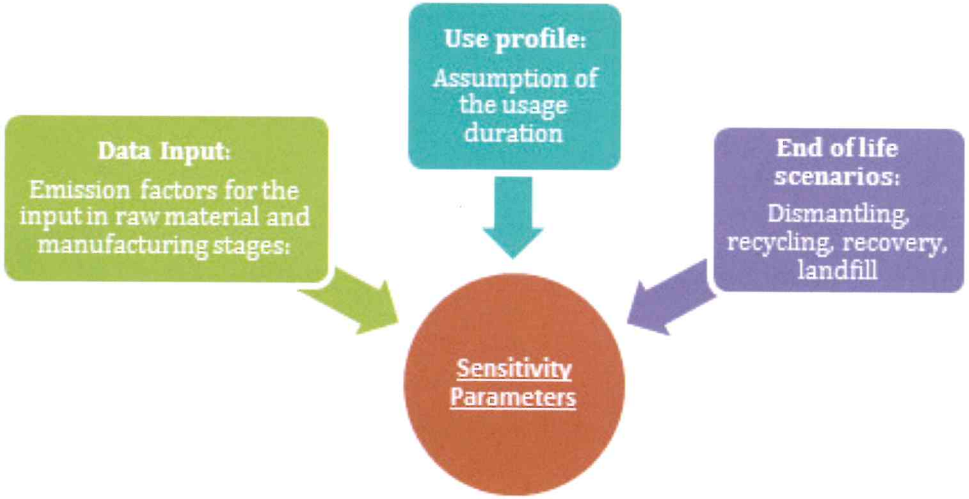


Figure 25. Eamples of sensitivity parameters

Step 6 - CFP study reporting

A checklist of reporting segments is shown as below. The reporting body should include the following information in the CFP report without bias, in order to conform to ISO/TS 14067.

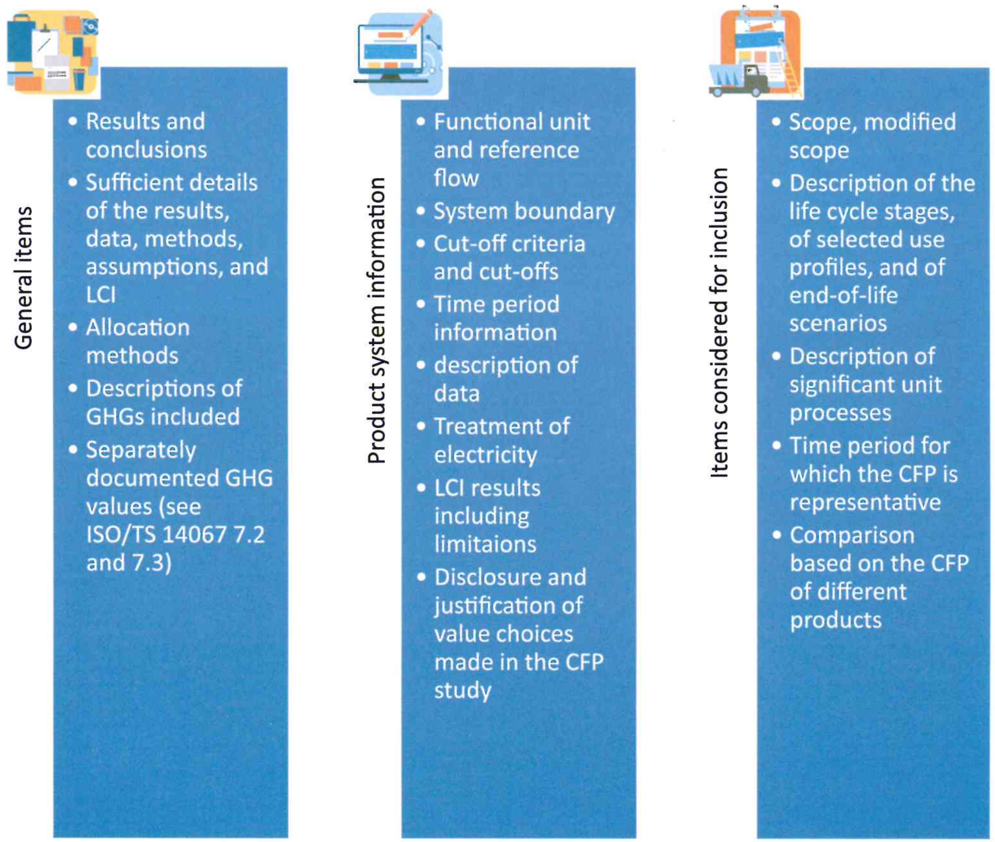


Figure 26. A checklist of reporting segments

The following figure demonstrates CFP study reports of four showcases (electronic scale, induction cooker, LCD module, and PCB).

Figure 27. CFP reports of different products

Step 7- Develop reduction strategy

Based on the CFP results and recommendations, the CFP team and other stakeholders can establish corresponding carbon emission reduction strategies for the selected product. Some of the suggestions that can be implemented are listed as below:

List of Suggestions for Carbon-Reduction in Product Design:

1. Raw Material Stage:
   - Look for alternatives of material choice that has lower impact in terms of cabon emission;
   - Increase the usage of recycled/reused materials; etc.
2. Manufacturing Stage:
   - Replace traditional energy souce with renewable energy;
   - Improve the efficiency of material and energy use;
   - Recycle/reuse materials (for example, packaing materials)
   - Chhose alternatives of consumables that emit less carbon dioxide;
3. Distribution Stage:
   - Choose proper transportation tools for lower carbon emission;
4. Use Stage:
   - Better product design for higher energy efficiency in use stage;
5. End-of-life Stage:
   - Design effective recycle policies for product.

Strategies for carbon footprint reduction are not limied to the items above.

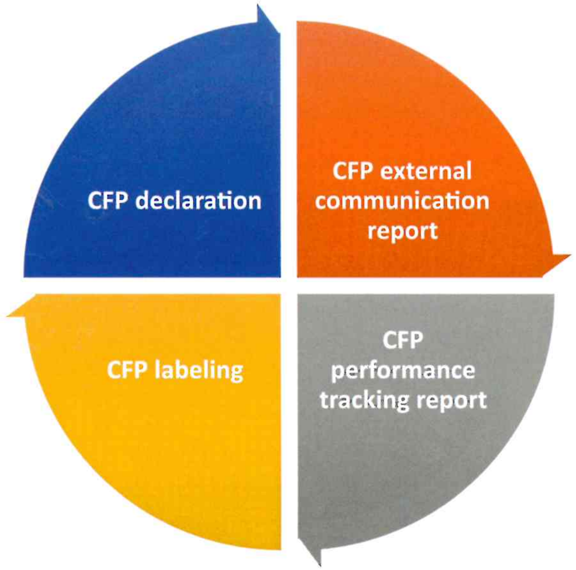


Figure 28. CFP communication options of ISO14067

Step 8- CFP communication

After identifying the major parameters of the product, the manufacturer should communicate the CFP result to the market according to the options provided by ISO 14067, as follows:

a) CFP external communication report
b) CFP performance tracking report
c) CFP labeling
d) CFP declaration

Decisions on the communication methods and format should be made according to the CFP study objectives, product system, involved activities, and target audiences.

Once a communication plan is decided on, the reporting entity prepares the necessary processes, such as establishing a CFP communication programme, conducting verification from a certified third party, etc. Samples for verification activity preparation documents are attached to this advisory kit (Appendix I- work flow of site-audit, Appendix II- checklist of materials for verification).

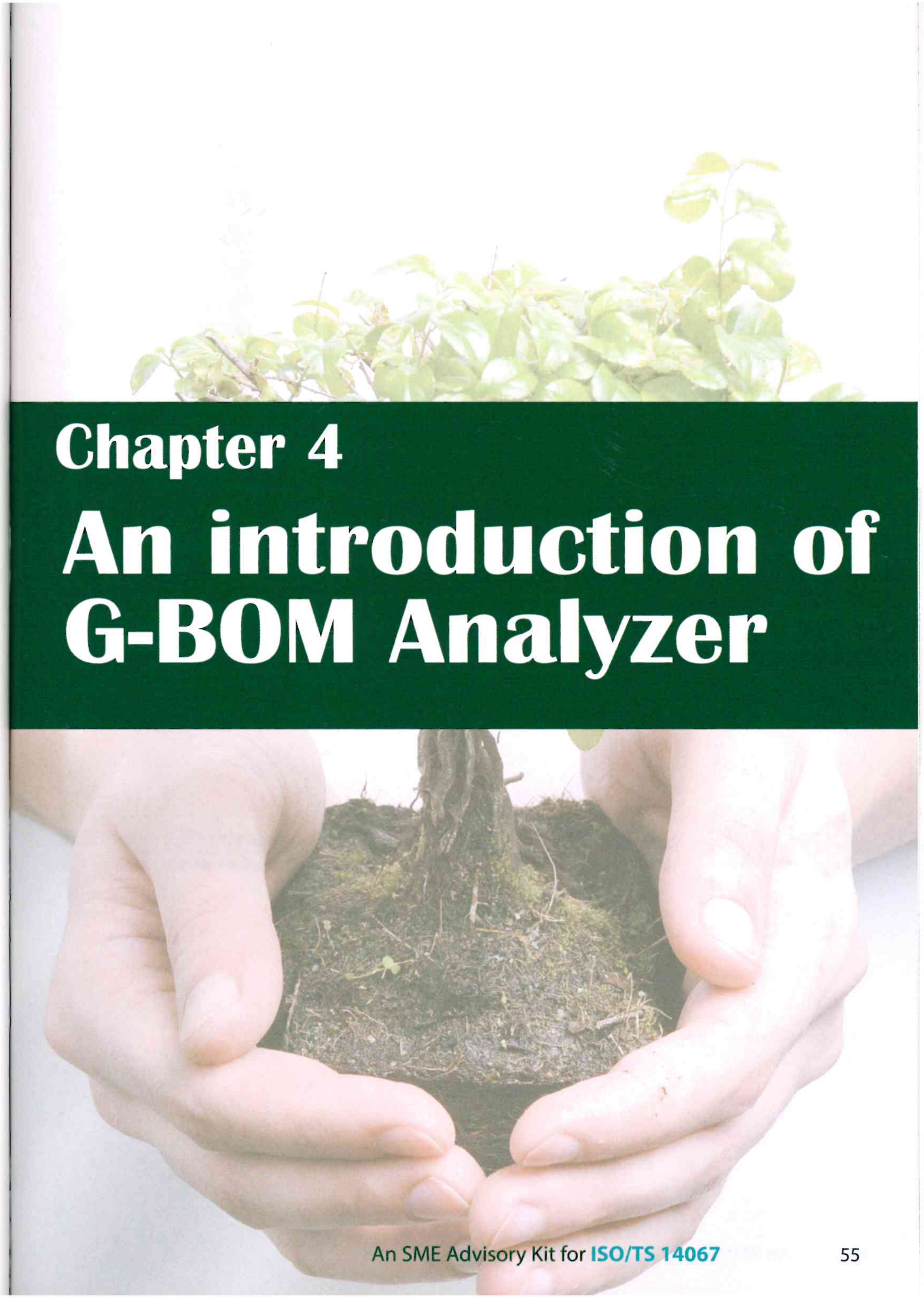
A detailed description can be found in Section 2.5 of the advisory kit.

3.3 An evaluation of CFP study with reference to ISO/TS 14067

The following table is a self-checking list for reporting entities to evaluate their CFP study with the reference to ISO/TS 14067 requirements.

CFP Study Steps	Corresponding reqirements in ISO/TS 14067
Step 1- CFP project team establishment	N.A.
Step 2- Define life cycle inventory settings	a) Item *6.1 Methodology for CFP quantification-General;* *b) Item 6.3 Goal and Scope of the CFP Quantification*
Step 3- Life cycle inventory for CFP	Item *6.4 Life cycle Inventory analysis for the CFP*
Step4- Product life cycle impact assessment	Item *6.5 Life Cycle Impact Assessment*
Step 5- Life cycle assessment interpretation	Item *6.6 Life Cycle Interpretation*
Step 6- CFP study reporting	Item *7 CFP Study Report*
Step 7- Set reduction strategy	N.A.
Step 8- CFP communication	a) Item *8 Preparation for Publicly available CFP Communication;* *b) Item 9 CFP Communication*

Figure 29. A self-checking list for CFP study



Chapter 4

An introduction of G-BOM Analyzer

The Green Bill of Materials (G-BOM) analyzer is an online PCF software based on the structure of the bill of materials developed by The Hong Kong Polytechnic University.

The activity data collected from each unit process is inputted into the G-BOM Analyzer and computed, as in [5]. The working principle, the methodology behind the software and access can be found in the following link:

http://www.pctech.ise.polyu.edu.hk/ecodesign/gbom_analyzer.html

The G-BOM analyzer allows manufacturers to input their product information/data according to the product life cycle, which includes the raw materials, manufacturing, distribution, usage, and end-of-life stages, and simply calculates the product carbon footprint using the greenhouse gas (GHG) emissions on the basis of the database provided. Users can define the material names, emission factors, and quantities according to their life cycle inventory. The GHG emission database is pre-grouped into five life cycle stages. The emission factor can be selected manually in the life cycle groups or by a keyword search engine.

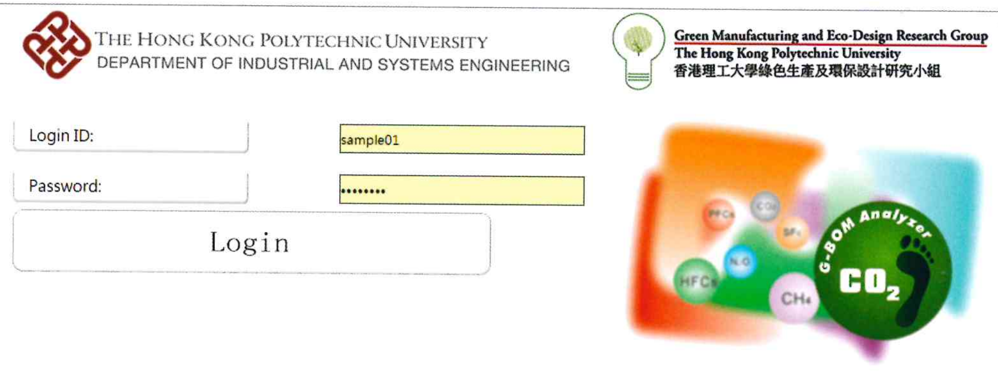


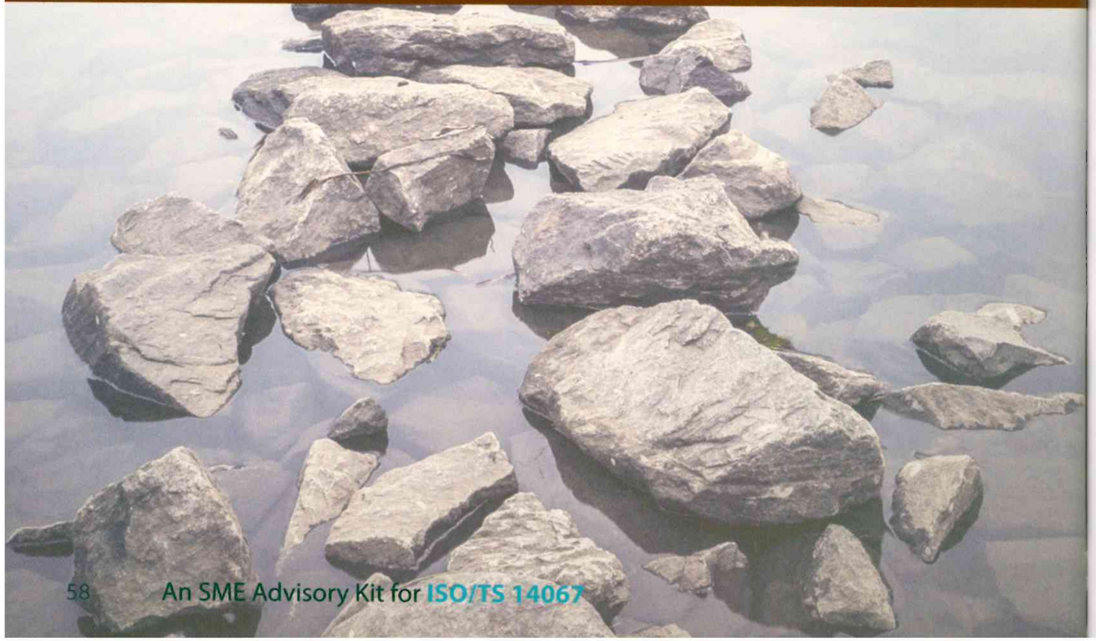
Figure 30. Screen capture of G-BOM Analyzer log-in page

A more detailed and step-by-step manuscript of the G-BOM analyzer application is available in a separate "guideline" attached with this advisory kit. The "guideline" has the title:

"Application Guideline for Embedded GHG Emissions Database and G-BOM Analyzer"

Chapter 5

Recommenations



The procedures of undertaking a carbon footprint project can be complicated and time-consuming. In order to carry out the study of carbon footprint of products more effectively, this section introduces some helpful recommendations from project experiences.

1. Reporting companies should bear in mind that, at the beginning, it is better to choose a simpler product for CFP start up. After getting familiar with the processes, a more sophisticated product can be selected for study.

2. It is important to keep track of the measurement evidence.

3. The CFP team should include personnel from different backgrounds. For example, an engineer with knowledge of manufacturing processes, a person familiar with purchasing issues that can help in the collection of information, an administrative representative who has ready access to the documents needed, and a contact person, etc.

4. During the quantification process, it is recommended to highlight the process flow at every stage in order to make sure no input/output is left out and also to avoid double-counting.

5. Data collection methods vary from case to case. It is necessary to consider different ways to collect data in order to get the most accurate outcome.

6. There are many parameters that might increase the uncertainty, and geographical and time factors should be taken into consideration when collecting the data.

7. Companies should choose communication methods based on their CFP objectives and business activity attributes.

8. Assumptions made and their justification should be documented and clearly stated in the report.

9. If there is no exact corresponding emission factor for a certain material in the database, a careful examination of alternatives should be carried out to reduce the uncertainty. The justification and reference source should be documented and stated.

10. The CFP, in accordance with ISO/TS 14067, only covers a single impact of climate change, which is presented as CO_2 eq.. The reporting body should also take social impacts, environmental impacts from other aspects caused by the production or the by the reduction itself into account when establishing the carbon reduction, as part of the sustainable development strategy.

Glossary [3] [11] [12]

Allocation
The partitioning of emissions and removals from a common process between the studied product's life cycle and the life cycle of the co-product(s).

Carbon dioxide equivalents
A measure of the global warming potential of a particular GHG compared to that of carbon dioxide

Carbon footprint of a product (CFP)
Sum of greenhouse gas emissions and removals in a product system, expressed as CO_2 equivalents and based on a life cycle assessment using the single impact category of climate change.

Carbon footprint of a product- product category rules (CFP-PCR)
Set of specific rules, requirements and guidelines for quantification of and communication on the CFP for one or more product categories.

CFP communication programme
Programme for the development and use of CFP communication based on a set of operating rules.

CFP disclosure report
Report required for publicly available CFP communication without third-party CFP verification.

CFP external communication report
Report on the CFP that is based on the CFP study report and intended to be communicated externally.

CFP performance tracking report
Report comparing the CFP of one specific product of the same organization over time.

CFP label
Mark on a product identifying its CFP within a particular product category according to the requirements of a CFP communication programme.

CFP verification
Confirmation, through provision of evidence, that specified requirements related to a CFP study and a CFP communication have been fulfilled.

Cradle-to-gate inventory
A partial life cycle of an intermediate product, from material acquisition through to when the product leaves the reporting company's gate.

Cradle-to-grave inventory
Removals and emissions of a studied product from material acquisition through to end-of-life.

Functional unit
Quantified performance of a product system for use as a reference unit.

Global warming potential (GWP)
Characterization factor describing the radiative forcing impact of one mass-based unit of a given greenhouse gas relative to that of carbon dioxide over a given period of time.

Greenhouse gas (GHG)
Gaseous constituent of the atmosphere, both natural and anthropogenic, that absorbs and emits radiation at specific wavelengths within the spectrum of infrared radiation emitted by the earth's surface, the atmosphere, and clouds.

Greenhouse gas emission (GHG emission)
Mass of a greenhouse gas released to the atmosphere.

Greenhouse gas removal (GHG removal)
Mass of a greenhouse gas removed from the atmosphere.

Greenhouse gas emission factor (GHG emission factor)
Mass of a greenhouse gas emitted relative to an input or an output of a unit process or a combination of unit processes.

Impact category
Class representing environmental issues of concern to which life cycle inventory analysis results may be assigned.

Life cycle
Consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal.

Life cycle assessment (LCA)
Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.

Life cycle impact assessment (LCIA)
Phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product.

Life cycle interpretation
Phase of life cycle assessment in which the findings of either the life cycle inventory analysis or the life cycle impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations.

Life cycle inventory analysis (LCI)
Phase of life cycle assessment involving the compilation and quantification of inputs and outputs of a product throughout its life cycle.

Primary data
Data obtained from a direct measurement or a calculation based on direct measurement at its original source within the product system.

Product
Any good or service.

Product category rules (PCR)
Set of specific rules, requirements and guidelines for developing Type III environmental declarations for one or more product categories.

Product system
Collection of unit processes with elementary flows and product flows, performing one or more definedfunctions and which models the life cycle of a product.

Reference flow
Measure of the outputs from processes in a given product system required to fulfil the function expressed by the functional unit.

Secondary data
Data obtained from sources other than a direct measurement or a calculation based on direct measurements at the original source.

Sensitivity analysis
Systematic procedures for estimating the effects of the choices made regarding methods and data on the outcome of a CFP study.

System boundary
Set of criteria specifying which unit processes are part of a product system.

Uncertainty
Parameter associated with the result of quantification which characterizes the dispersion of the values that could be reasonably attributed to the quantified amount.

Unit process
Smallest element considered in the life cycle inventory analysis for which input and output data are quantified.

References

1. IPCC, Summary for Policymakers, In: Climate Change 2014, Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2014.

2. International Organization of Standardization, 2010. GHG schemes addressing climate change- How ISO standards help. ISBN 978-92-67-10543-7.

3. International Organization of Standardization, 2013. ISO/TS 14067:2013, Greenhouse gases- Carbon footprint of products- Requirements and guidelines for quantification and communication. The British Standards Institute, BSI standards Limited 2013. ISBN 978-0-580-75109-7.

4. International Organization of Standardization, 2006. ISO 14044:2006, Life Cycle Assessment: Requirements and Guidelines.

5. International Organization of Standardization, 2006. ISO 14025:2006, Environmental Labels and declarations-Type III environmental declarations-Principles and procedures.

6. European Commission, 2011. Analysis of Existing Environmental Footprint Methodologies for Products and Organizations: Recommendations, Rationale, and Alignment.

7. Joe Wang and Rachel Wu, 2014. Technical report on carbon footprint analysis of electronic scale. Green Manufacturing and Eco-Design Research Group of Department of Industrial and Systems Engineering, The Hong Kong Polytechnic University. ISBN 978-988-18959-7-4.

8. Connie Chan and Jane Zhang, 2014. Technical report on carbon footprint analysis of induction cooker. Green Manufacturing and Eco-Design Research Group of Department of Industrial and Systems Engineering, The Hong Kong Polytechnic University. ISBN 978-988-18959-4-3.

9. Connie Chan, Jane Zhang, and Rachel Wu, 2014. Technical report on carbon footprint analysis of liquid crystal display (LCD) panel. Green Manufacturing and Eco-Design Research Group of Department of Industrial and Systems Engineering, The Hong Kong Polytechnic University. ISBN 978-988-18959-5-0.

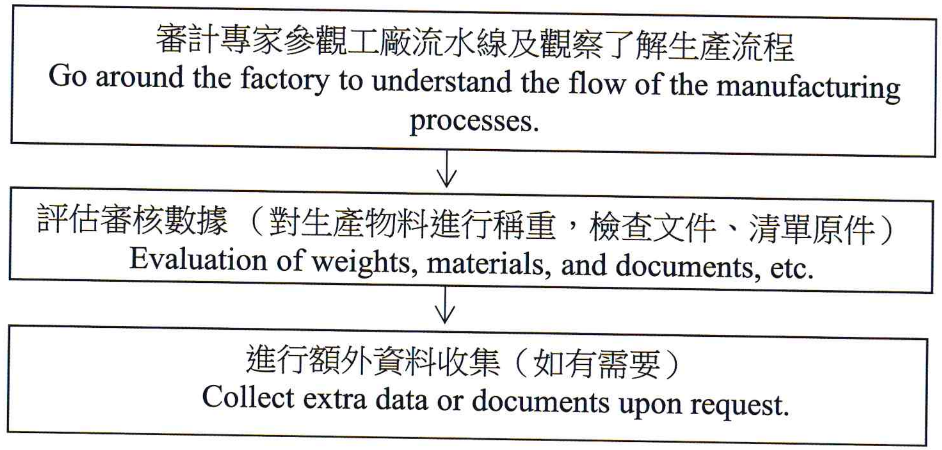
10. Connie Chan and Jane Zhang, 2014. Technical report on carbon footprint analysis of printed circuit board (PCB). Green Manufacturing and Eco-Design Research Group of Department of Industrial and Systems Engineering, The Hong Kong Polytechnic University. ISBN 978-988-18959-6-7.

11. British Standards Institute (BSI), 2011. PAS 2050:2011 Specification for the assessment of the life cycle greenhouse gas emission of goods and services.

12. World Resources Institute (WRI) and World Business Council for Sustainable Development, 2011. Product Life Cycle Accounting and Reporting Standard. ISBN 978-1-56973-773-6.

Appendix I

Figure 1. Work flow of site-audit:



Appendix II

Table 1. Suggest Checklist of Materials and Documents for Audit

序號 No.	分類 Category	物料 Item
1	產品 Product	成品樣品 Product sample
2		所有零部件 Product components
3		生產中消耗品樣品（如化学试剂等）Consumables
4	包裝材料 Packaging materials	產品包裝材料 Finish goods packaging
5		零部件及消耗品包裝材料 Packaging of all materials
6		原料及成品包裝的包裝 Packaging materials of packaging
7	文件 Documents	電費單 Electricity bill
8		生產記錄（總生產及選定型号相关记录）Production record (total production and selected model's record)
9		出貨資料（如订单、UPS快递单据） Order information for transportation
10		物料來源信息 Materials sources information
12	其它 Others	電子秤、計算器、文具等 Scale, calculator, stationery, etc.
13		會議室或者獨立房間一間 A meeting room

Disclaimer

Any opinions, findings, conclusions or recommendations expressed in this material/event (or by members of the Project team) do not reflect the views of the Government of the Hong Kong Special Administrative Region, Trade and Industry Department or the Vetting Committee for the SME Development Fund and the Dedicated Fund on Branding, Upgrading and Domestic Sales (Organisation Support Programme).

This provided material/event is for information purpose only.Whilst every effort has been made to ensure the accuracy of the information supplied herein, the publisher of this material and the associated organizations in this Programme cannot be held responsible for any damage or claim resulting from use of the informaion.

This project is organised by The Hong Kong Polytechnic University, and funded by the SME Development Fund of the Trade and Industry Department, HKSAR Government.

Published: January 2015