Low Carbon Intelligent Operations for Textile Industry in APEC Economies

PROJECT MIDTERM REPORT

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Project Midterm Report

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Taiwan Textile Research Institute (Chinese Taipei) TTRI

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PREFACE

The term "sustainable development" is first used by the World Commission on Environment and Development (United Nations, 1987). The term is then defined by the Brundtland Commission as "the development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Smith & Rees, 1998).

This challenge (i.e., achieving consumption sustainability while reducing ecological impacts and resource intensity) is the key to corporate sustainable competitiveness. In order to overcome this challenge, companies need to maintain their competitiveness advantages through innovation and creativity. As shown in Figure 1, sustainable development ties together environmental sustainability, economic sustainability, and sociopolitical sustainability. Sustainable development has therefore become both a challenge and an opportunity to worldwide corporations--especially in the time of facing continuous and rapid changes in climate change, resources, and economic conditions.

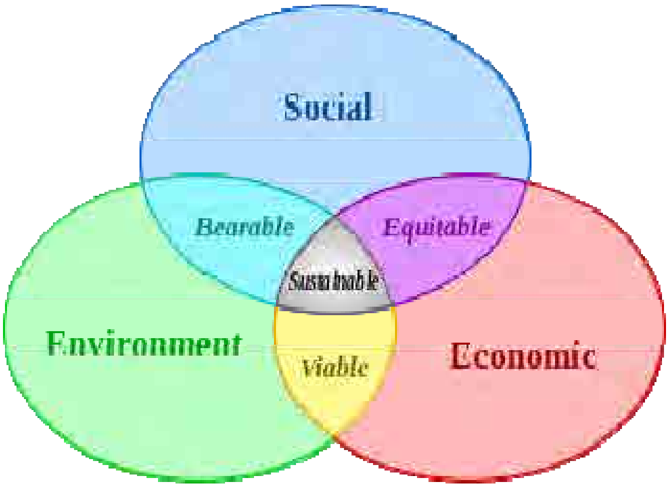

Figure1. Constituent parts of sustainable development

Source: Samuel Mann (2009)

Moreover, both the 2005 Kyoto Protocol and the 2009 Copenhagen Summit are attempts of the United Nations to set binding obligations on industrialized countries to reduce emissions of greenhouse gases. The objectives are to maintain a stabilization of greenhouse gas concentrations at 450 ppm CO_2-equivalent and to achieve a climate target of 2℃ by the year 2100 (Niven Huang, 2012). In order to achieve these objectives, industrialized nations have initiated policies and regulations. How to reduce greenhouse gas emissions has become a global focal point. The 2009 Copenhagen Summit has set up a framework for climate change mitigation beyond 2012. Such framework helps to explore the concept of "low-carbon" development.

The textile industry is one of the biggest GHG emitters on Earth, owing to its huge size and scope. Many processes and products that go into the making of fibers, textiles and apparel products consume significant quantities of fossil fuel. Apparel and textiles account for approximately 10 percent of the total carbon impact. The estimated consumption for an annual global production of 60 billion kilograms of fabrics boggles the mind: 1 trillion kilowatt hours of electricity and up to 9 trillion liters of water (Valerio Zaffalon, 2010).

As a result, the ethical agenda of multinational retail companies has been dominated by environmental issues. Marks & Spencer and Walmart are the two companies that have been setting the pace for the whole textile industry. Along with investments in corporate social responsibility and projects to improve the general living conditions of workers, retail companies are offering environmentally responsible products to their customers by taking the necessary steps to ask their suppliers to reduce carbon emissions from production. Such an action offers a way for companies and individuals to contribute to climate change.

For example, the fashion retail market in the United Kingdom is the first market worldwide to use a carbon footprint label for clothing. This label is issued by a third independent party-the Carbon Trust. Originally, it is estimated that the carbon footprint of a basic men's large 155 gram (g) white T-shirt which is produced in a traditional way without using renewable energy is 6.574 kilogram (kg) of CO_2. But, the same T-shirt made of 100% renewable energy and organic cotton has a footprint of only 671 gram. Accordingly, all relevant stakeholders who produce and sell and buy a basic men's large 155 gram white T-shirt in the UK's fashion retail market contribute to a 90% reduction in CO_2 emissions.

The direct carbon footprint contribution of manufacturing plants from yarn to customer including spinning, knitting, dyeing, finishing, cutting and sewing, plus transportation to the distribution center could reach up to 12.5 kg of CO_2 per kg of fabric. The carbon emissions of T-shirt manufacturing in CO_2 equivalents could be more than 12 times the product weight. Considering that the carbon footprint of steel is about 2 kg of CO_2 equivalents per kg of steel, the pressure coming down from the supply chain to the full industry is understandable: The elephants are among us.

APEC textile manufacturers produce mostly of the textile and clothing. The purchase and use of clothing leads to the release of over 850 Mt CO_2 per year (around 3% of global production CO_2 emissions), including both embodied emissions in the clothing, and emissions arising from clothing use (washing, drying, ironing). Global consumption of clothing results in around 330Mt CO_2 of emissions, with emissions from the use of clothing resulting in an additional 530Mt CO_2 per year (The Carbon Trust, 2011). In 2009, APEC economics exported $118 billion textiles (53.2% of worldwide experts of textile) and $167.8 billion clothing (55.7% of clothing). In 2010, APEC economics exported $158 billion textiles (63% of worldwide experts of textile) and $221.7 billion clothing (63% of clothing). Global warming is more likely to increase the sale of athletic clothes by 3% and maintain a retail margin of 42% (Chen, 2012).

Among APEC economies, Chinese Taipei has strong manufacturing capacities, including textile manufacturing. In order to minimize the impact of the Kyoto Protocol on its industries and to work together with industrialized countries on the global warming issue, the Chinese Taipei government has recently initiated a number of programs which aims to promote carbon footprint labeling. For example, the government announced algorithm specifications for the assessment of the life cycle greenhouse gas emissions of goods and services in March 2010. As of March 2013, there are 77 final products and services which are adopted the algorithm specification and passed the carbon footprint verification. The government has also initiated a carbon footprint management plan since 2010. Under this plan, a carbon-neutral platform is constructed in order to balance a measured amount of carbon released with an equivalent amount offset or to buy enough carbon credits to make up the difference. At the time of the current work, there are 6 products and services which are recorded in the platform's database.

With this in mind, the Taiwan Textile Research Institute (TTRI) has recently started to help the textile manufacturer in Chinese Taipei to tackle high carbon emission in production. Under this project, a Chinese Taipei textile manufacturer, Formosa Taffeta Co., Ltd. (FTC) participates in the case study. (Please refer to Appendices A and B for a brief introduction of TTRI and FTC, respectively). The TTRI conducts an environmental footprint evaluation on the FTC's 24 types of functional textiles. To be more specific, the project team first identifies the needed raw materials as well as calculates both the energy consumption and wastes (in terms of CO_2 emissions being released) in the manufacturing process. Next, the project team locates carbon hotspots and explores optimal solutions based on the amount of CO_2 emissions associated with raw materials, energy consumption, and wastes. In order to facilitate the evaluation process, a tool titled "Life Cycle Inventory Questionnaire (LCIQ)" is designed and used in the project. This tool helps not on the project team to compile a carbon footprint inventory but also the FTC to continuously manage its environmental footprint after the closure of this project. Finally, the experience and lessens gained from the case study are shared to APEC member economies in a workshop.

This project will not be completed without gratitude help from the following individuals and institutions. I express my deep appreciation to the Asia Pacific Economic Cooperation (APEC) and the Chinese Taipei's Ministry of Foreign Affairs for financially support this project.

Special thanks also go to the FORMOSA TAFFETA CO., LTD. for participating in the case study. In particular, Young-Chin CHEN, Bruce H.N. CHUNG, John M.C. LIAG, and Adam F.Y. WANG were kind and helpful in drawing a product's life-cycle map, collecting MSDS information and supporting to offer every activity data. Finally, I wish to acknowledge the support professionals that I worked with on an almost daily basis. Tony Yang Ping SHIH who is project overseer gives me the chance to implement this project, and leads team to take place the upcoming APEC workshop. Tian-pao LIN, and

Huan-yun TU took time to check the integrity of the collected data, analyze the data, and conduct the LCIQ calculation. I couldn't design out the LCIQ Tool without their supports. Wei-chia CHU was great helpers in the workshop preparations and handling. Su-hui CHEN provided visual design of all document's templates. It is hard to imagine that the project would have ever come to completion without the decision and hard work of this fine team of professionals. Furthermore, I wish to thank Kitty WU of ENG-edit Consulting Service provided expert help in turning page after page of words and symbols written in red ink into beautiful copy.

To these individuals, and all the others too numerous to mention, I wish to express my warm thanks and appreciation.

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SUMMARY

This project entitled "Low Carbon Intelligent Operations for Textile Industry in APEC Economics" aims to assist textile manufacturers in creating a low-carbon materials processing procedure according to the publicly available specification of carbon footprint verification (PAS 2050) in APEC economics. This project has two main goals: (1) conduct a case study, and (2) share the experience and lessons learned from the case study in an international workshop. The case study is designed to first identify the needed raw materials and calculate GHG emissions associated with raw materials. Next, it calculates both the energy consumption and the wastes (in terms of carbon emissions being released) during the production process. It then locates carbon hotspots and explores optimal solutions. Finally, the footprint evaluation is verified by a third independent party. Thus, the case study establishes a baseline for low carbon evaluation systems scientifically and credibly.

This midterm report reports only the case study result. It contains Chapters on the introductions of carbon footprint and PAS 2050 Specification, the framework of this project, and the methodologies for measuring textile carbon footprint inventory. In particular, Chapter 5 reports on the case study result. The procedure, methodologies, and results of carbon footprint inventory are delineated in the chapter.

CHAPTER 1.

THE CONCEPT OF CARBON FOOTPRINT

In recent years, the rise of an environmental awareness to save the planet has taken a strong hold across the world. Although, the footprint concept may be very new to textiles manufacturers and consumers, it will not be long before everyone starts to talk about reducing footprint to ward off global warming, save the water, and the natural resources for the future generation. Therefore, it is important to understand the concept of "Footprint". It may come as a surprise to some that, for a dress, its footprint is certainly not the fabric tracks it consumes the energy from the sewing process.

Carbon footprint is the measure of the total greenhouse gas (GHG) emissions caused by product, organization, event, or person. GHGs have been known to cause global warming effects. GHGs are emitted mainly from manufacturing, transportation, heating and electricity generation, as well as agricultural practices. Since there are many types of greenhouse gases, such as carbon dioxide, methane, nitrous oxide, chlorofluorocarbon (CFC), sulfur hexafluoride; carbon footprint is reported in terms of carbon dioxide equivalent. It is calculated by using the Global Warming Potential (GWP) factor of each gas, where GWP of carbon dioxide, the most common gas, is considered to be 1. For example, the GWP of methane is 25, meaning it can cause 25 times more warming than carbon dioxide; the GWP for nitrous oxide is 298 meaning it can cause 298 times more warming than carbon dioxide.

The term "product carbon footprint" refers to using life cycle assessment (LCA) to focus specifically on the quantification of greenhouse gas emissions throughout the product's life cycle. The results of a product carbon footprint are usually presented as a total absolute value of life-cycle carbon dioxide-equivalent (CO_2 e) emissions measured in kilograms or metric tons. Product carbon footprint is based on LCA, which is a method of analysis that seeks to quantify the environmental and human-health impacts associated with products and services. That is, the boundaries of LCA evaluations can encompass a "cradle-to-grave" approach and broadly include the extraction and processing of raw materials, production, consumer-use, and end-of-life scenarios, which may include recycling of materials.

The LCA evaluation result can be used to identify significant impacts on the environment and human health and can inform actions to reduce these impacts. Data and intelligence gathered through this process can also be used to inform strategy and identify design considerations that reduce product cost while also yielding environmental benefits and providing the opportunity to enhance brand value. Many organizations have recognized that carbon footprint provides the ability to evaluate the efficiency with which they produce goods and services using a different set of metrics. The process has enabled companies to improve the environmental performance of their business activities as well as to reduce both manufacturing and supply-chain costs. The process has also enabled companies to identify environmental risks in the supply chain and to position themselves to compete in a carbon-constrained economy.

Accordingly, the result of a carbon footprint can inform important business decisions and should be used as one of several indicators of product environmental performance. The key to effectively using carbon footprint as a business tool is to balance the complexities of such an analysis with meaningful results that can be applied in a commercial context. Carbon footprint may be considered as a subset of ecological footprint, where only carbon equivalent emission is reported. But, more importantly, carbon footprint focuses on a specific product. For companies, the result of product carbon footprint can help to

(1) reduce costs associated with manufacturing, energy use, waste, and packaging
(2) inform design using a lifecycle approach (Design for Environment)
(3) manage their supply chain to drive greater environmental improvements
(4) quantify the business value of their sustainability initiatives, which can yield immediate returns on investment.

CHAPTER 2.

THE PAS 2050 SPECIFICATION

The international standard which is used in the LCA evaluation for this project is the so-called "PAS 2050 specification." The specification is developed in response to broad community and industry desire for a consistent method for assessing the life cycle GHG emissions of goods and services (see Figure 2). It can be used by organizations of all sizes and types, in any location, to assess the climate change impact of the products they offer. It therefore offers organizations a method to deliver improved understanding of the GHG emissions arising from their supply chains, and to provide a common basis for GHG emission quantification that will inform and enable meaningful GHG emission reduction program.

Figure 2. PAS 2050 (2011 specification)
Source: BSI (2011)

The PAS 2050 specification moreover builds on existing methods established through BS EN ISO 14040 and BS EN ISO 14044 by specifying requirements for the assessment of the life cycle GHG emissions of products. Accordingly, for organizations that supply goods and services, the specification:

- permits an internal assessment of the existing life cycle GHG emissions of goods and services
- facilitates the evaluation of alternative product configurations, sourcing and manufacturing methods, raw material choices, and supplier selection on the basis of the life cycle GHG emissions associated with goods and services

- provides a benchmark for ongoing programs aimed at reducing GHG emissions
- allows for a comparison of goods or services using a common, recognized, and standardized approach to life cycle GHG emissions assessment
- supports reporting on corporate responsibility.

On the other hand, for consumers who purchase goods and services, the PAS 2050 specification:

- provides a common basis from which the results of life cycle GHG emissions assessments can be reported and communicated
- offers an opportunity for greater understanding of life cycle GHG emissions when making purchasing decisions and using goods and services.

CHAPTER 3.

RESEARCH FRAMEWORK

This project aims to address the issues of capacity building enhancing and to experience sharing for low carbon intelligent operations. The project invites one Chinese Taipei manufacturer to participate in the case study in order to measure GHG emissions generated from the whole lifecycle of functional textile products. Based on the publicly available carbon footprint verification specification (PAS 2050), the case study conducts a footprint on 24 types of textile products. In the end of this case study, these products all received the verification statement issued by an independent third party. Under this project, an international workshop is held in Chinese Taipei to share the experience and lessens gained from the case study.

The project's research framework is divided into four phases and is shown schematically in Figure 3.

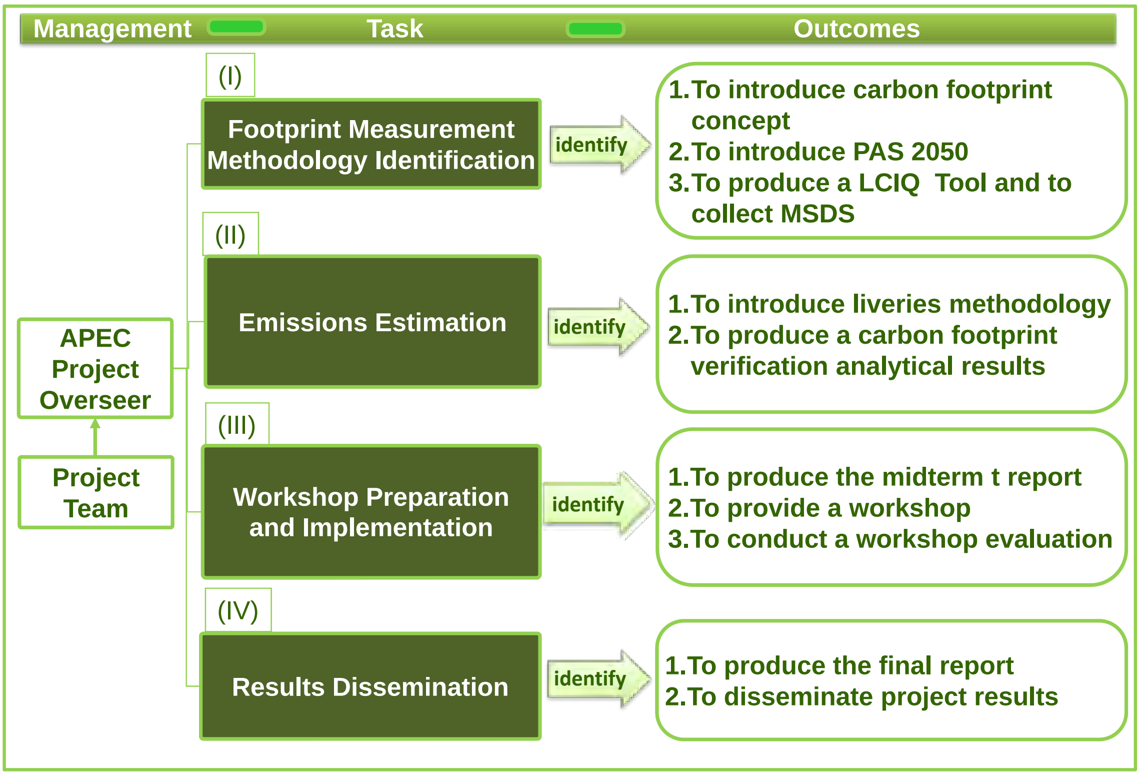


Figure 3. Research Framework

Phase I：Footprint Measurement Methodology Identification

Phase I aims to identify a feasible methodology for conducting the LCA evaluation, i.e., compiling a carbon footprint inventory. This task was carried out between June and August, 2012. The activities conducted by the project team under this phase are described as follows：

1. To design a form for the so-called "product lifecycle inventory method" based on the publicly available specification of carbon footprint verification (PAS 2050). (Please see Chapter 2 for a brief introduction of the PAS 2050 specification.)

2. To construct a methodology for compiling a carbon footprint inventory. This methodology is named "Life Cycle Inventory Questionnaire (LCIQ)." This methodology is designed by the TTRI to calculate all the required data in the PAS 2050 Specification. (Please see Chapter 4 for an introduction of the LCIQ tool.)

3. In order to verify the feasibility of the LCIQ tool, the project team invites a highly qualified Chinese Taipei textile manufacturer (FTC) to participate in the case study.

4. Based on FTC's manufacturing activities, the project team gathers the Materials Safety Data Sheet (MSDS) information for each product under consideration. A total of ten sets of MSDS for functional textile products are completed for the case study. The MSDS is introduced in Chapter 4 while the ten sets of MSDS are reported in Appendix C.

Phase II：Emissions Estimation

After identifying the method for compiling the carbon footprint inventory and locate a textile manufacturer to participate in the case study, the Phase II then estimates the GHG emissions from production processes. This phase was carried out between September and October, 2012. The activities conducted by the project team under this phase are described as follows：

1. To establish a baseline for the LCA evaluation. The project team first reviews previous studies that analyze carbon hotspots in the manufacturing process for functional textiles. Based on the literature review result, the team then establishes a baseline for calculating the GHG emissions from production processes.

2. To estimate the amount of emissions generated from producing functional textiles. The project team first applies the LCIQ tool to calculate production emissions. The team then identifies optimal solutions for reducing emissions.

3. To receive the carbon footprint verification. A carbon footprint report, which delineates the process of measuring, calculating, and declaring the participated manufacturer's direct and indirect GHG emissions, is verified by an independent third party (British Standards Institution). A carbon footprint statement (the highest level for verification) is then issued only under the following two conditions:

   (1) When the carbon footprint report makes the best use of the data available and uses consistent, reasonable practices to apportion data

   (2) The manner in which the carbon footprint is calculated is practical and robust (to the extent it can be given the data available)

In the case study, FTC's 24 types of functional textile products all received the carbon footprint statement. The case study's results are reported in the Chapter 5 of this project midterm report.

Phase III：Workshop Preparation and Implementation

One of this project's goals is to share the experience and lessen gained from the case study. Accordingly, an international workshop titled "2013 Workshop on Low Carbon Intelligent Operations for Textile Industry" is scheduled to be held in Chinese Taipei during April 23-24, 2013. Also, the project team believes that an international workshop will help to raise awareness and interests among workshop participants in how the green benefits can be gained from the use of a low carbon materials processing procedure, and to encourage wider application as well as trade and investment in low carbon intelligent operations for the textile industry in APEC economies.

The target audience for the workshop are - APEC economies' presenters, including professors and experienced manufacturers delivering specific low carbon textile operation workshop to government officials of Chinese Taipei, academic scholars, industry experts as well as PPSTI members and experts, government officials of the APEC economies, including the policymakers in the area of environmental protection, employees of the Environmental Affairs' office and (patent) law enforcement bodies. It is expected that more than 30 delegates from APEC economies, academia, and industries will participate in the workshop.

The preparation work for the workshop has begun since October 2012. The preparation work contains the following activities:

1. To invite highly qualified experts and textile manufactures to be workshop presenters.
2. To distribute invitation letters by e-mail to the expected participants of the workshop;
3. To ensure visa support;
4. To create the arrive-departure schedule of workshop participants;

5. Support in determination of location and dates for the workshop, working out of proposals on the accommodation, catering and transportation services for the workshop participants;
6. To distribute circular information (Administrative Circular) on organizational issues of holding workshop for participants and APEC Secretariat;
7. Support in organization of workshop mock-up design development, fabrication and\or purchase of equipment and materials;
8. Fitting-out of rooms for holding workshop (furniture, equipment and materials, including sound amplifying systems (mikes, consoles, amplifiers, acoustic systems) and a set of video projection equipment (screens, video projectors, notebooks), required for workshop;
9. To ensure technical support throughout the workshop according to APEC standards and rules;
10. To work out scenario of the official opening ceremony;
11. To organize photo session and audio record of all presentations and reports;
12. To develop a workshop participant input form, which will be distributed to participants during the workshop
13. Finally, after the workshop, an analysis of participants' experiences about low carbon textile operations and their feedback regarding the workshop will be prepared by the project team.

Phase III effort, that is, all tasks in the preparation and the implementation of workshop, will be shown in both the workshop proceedings and the workshop evaluation report.

Phase IV：Results Dissemination

In order to communicate to the widest possible audience, all project deliverables—the project midterm report (the case study result), the workshop proceedings, and the workshop evaluation report—will be distributed on CD-ROM and electronically. It is expected that 30 copies workshop proceedings CD-ROM will be sent to APEC Secretariat.

The project deliverables will also be disseminated to the non-APEC economies, whose assistance was received within project implementation.

CHAPTER 4.

METHODS FOR CARBON INVENTORY ESTIMATION

All activities along the full life cycle of individual fabric, from raw material acquisition through disposal, use energy in the manufacturing process. Carbon emissions result from energy use. But we haven't seen a study discussing a feasible methodology or tool for compiling a carbon footprint inventory. This chapter introduces the tool for compiling a carbon footprint inventory.

The process of carrying out a carbon footprint inventory requires evaluation of product lifecycles, estimation of required main raw materials, auxiliary materials and packaging materials, and quantities of greenhouse gas emissions created during manufacturing and shipping of output products. The process thus requires a great deal of information and calculation.

Before we conduct the footprint inventory calculation, we need to decide which product carbon footprint standard to choose because the footprint standard provides requirements and guidelines on the decisions to be made when conducting a carbon footprint study. In response to the need for transparency in the greenhouse gas (GHG) emissions of products, several standards have been developed or are still under development. There are three main Product Carbon Footprint standards that are or will be applied worldwide: PAS 2050, GHG Protocol and ISO 14067. In addition to these three standards, also numerous other initiatives were initiated by either public or private organizations at the regional and local level. So how can a company decide which carbon footprint standard best supports its sustainability strategy? This study uses PAS 2050 because it has already been applied by many companies worldwide, including Chinese Taipei. Also the ISO DS 14067, which is derived from PAS 2050, is under development.

As shown in Figure 4, PAS 2050 allows for two standard types of assessment: Cradle-to-Gate and Cradle-to-Grave assessments. These two types of assessments are often used for different purposes. Cradle-to-Gate assessments are commonly used where a buyer has asked a supplier to provide information on the carbon footprint of the product they supply. In this kind of case, it makes sense to report emissions that occur only up to the point at which the product is transferred to the buyer. It also enables footprints to be incrementally calculated and reported across a supply chain. For cradle-to-gate carbon footprints it is particularly important that adequate records on removals of carbon and carbon content are provided to downstream companies using cradle-to-gate information in their carbon footprint assessments.

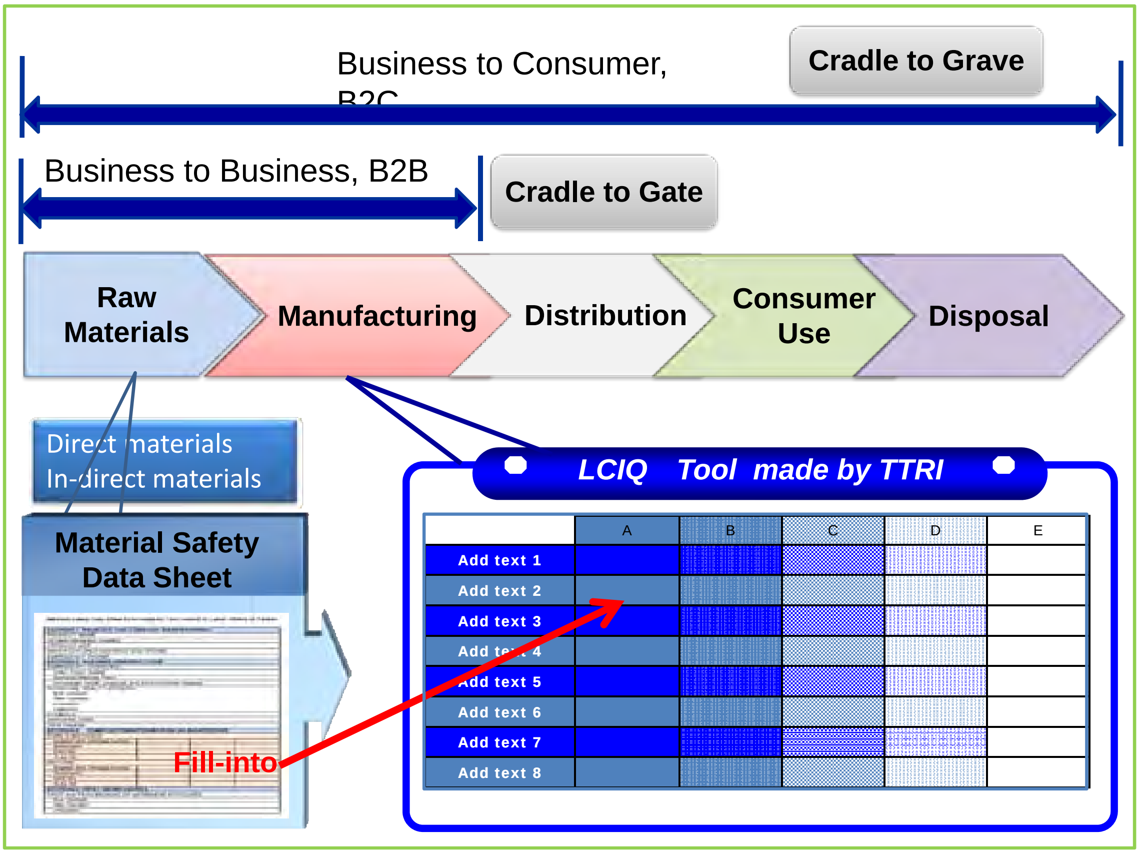


Figure 4. The assessment phase of the product life cycle

In our case study, FTC purchases raw materials (e.g., yarns, dyes, chemicals, and package materials) from its upstream suppliers and converts them into fabrics. FTC then sells fabrics to its downstream firms (e.g., large multinational retail companies). Finally, clothing are made of fabrics by retail companies. Accordingly, we carry out a cradle-to-gate assessment in the case study. And, such an assessment includes the following two main calculation processes:

(1) to calculate the amount of carbon emissions generated from raw materials

(2) to calculate the amount of emissions generated from the energy used in converting raw materials to a fabric

FTC purchases raw materials (e.g., yarns, dyes, chemicals, and package materials) from its upstream suppliers and converts raw materials into fabrics. FTC then sells fabrics to its downstream firms (e.g., large multinational retail companies). These firms turn fabrics into clothing. Accordingly, FTC asked their up-stream suppliers to provide information on the carbon footprint of the product they supply. This provided information is such as Materials Safety Data Sheet (MSDS) of chemicals, Energy Consumption etc. MSDS goes to page 30 for details. The PAS 2050 Guide suggests four footprint process steps (See Figure 5). Among four steps, the Step 2 is perhaps the most difficult step. It requires collecting primary activity data (e.g., the amounts and types of raw material consumed in manufacturing a fabric) for a period of 12 months. Thus, the project team needs to collect such data from electricity billing statement or account.

Also, in order to compile the carbon footprint inventory, the project team designs a method called "Life Cycle Inventory Questionnaire (LCIQ). Based on the concept of cradle-to-gate and uses the materials safety data sheet (MSDS), the LCIQ method can be applied to collect the necessary data required in Step 2. The LCIQ method not only can be applied to the cradle-to-gate assessment but also can be expanded to the cradle-to-cradle assessment (a full product life cycle assessment).

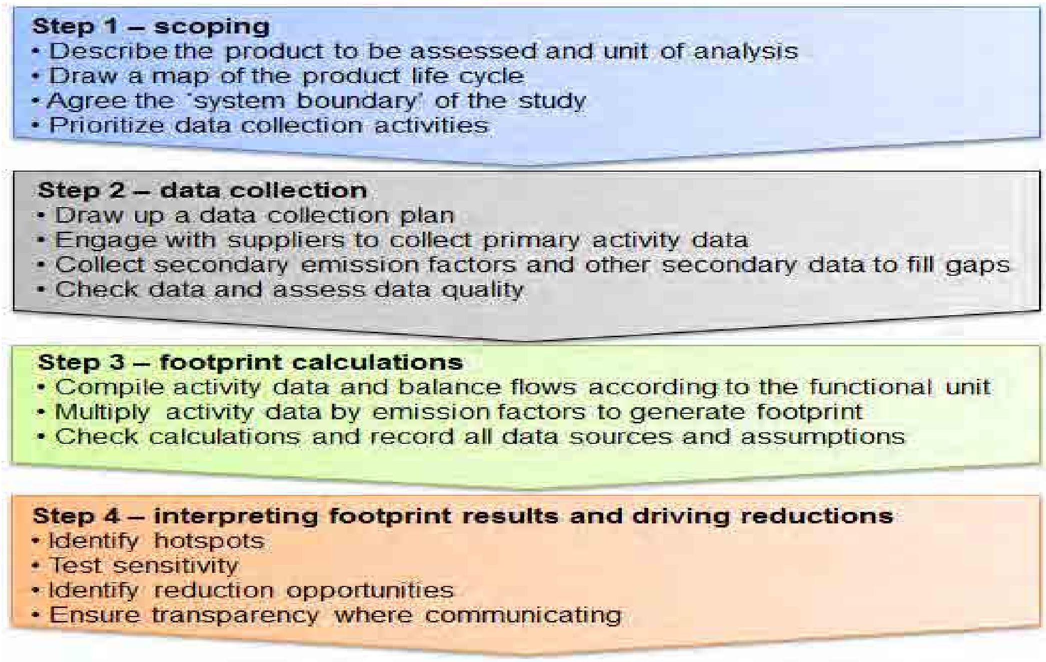


Figure 5. The stepwise footprint process

Source: The Guide to PAS 2050:2011, (BSI, 2011), p4

The following sub-sections briefly introduce the four stepwise footprint processes, MSDS, and LCIQ.

4.1 The Four Stepwise Footprint Process

The PAS 2050 is a publicly available specification that provides a method for assessing the life cycle greenhouse gas (GHG) emissions of products. It can be used by organizations of all sizes and types, in any location, to assess the climate change impact of the products they offer. For businesses, carbon footprint information that has been calculated in accordance with PAS 2050 provides a common basis for understanding the life cycle GHG emissions of products.

While PAS 2050 continues to drive consistency through greater prescription, there are instances in which the one-size-fits-all approach has limitations for some sectors or products. An important addition to PAS 2050 was the introduction of principles promoting the development and use of 'supplementary requirements' for different products or sectors. Supplementary requirements could provide further clarification on only one, or a small number, of aspects of the calculation process. The concept of supplementary requirements is akin to 'Product Category Rules', PCR (i.e. developed through ISO 14025[1]) and 'Product rules' (GHG Protocol Product Standard) and may include either of these (if consistent with PAS 2050). Before begin to carry out the assessment, look to see if there are supplementary requirements that may help to assess the emissions associated with product. Where they exist they should always be used. If there are no supplementary requirements for your sector, check to see whether other rules or guidance may be applicable[2].) If not, may even want to consider starting to develop supplementary requirements within the industry.

A provision of this part (i.e., supplementary requirements) of PAS 2050 moreover derives a four stepwise footprint process. The process starts from scoping, data collection, emission calculation, emission result reduction (see Figure 5). These steps are sequential and cannot be carried out in isolation.

4.1.1 Step 1-Scoping

Scoping is the most important step when undertaking any product carbon footprint inventory. It ensures that the right amount of effort is spent in getting the right data from the right places to achieve robust results in the most efficient manner possible. There are four main stages to scoping, and they are best undertaken sequentially.

- **Describe the product to be assessed and the unit of analysis**

It is vital that the product to be assessed is clearly defined at the outset. For its carbon footprint, the product must be defined in terms of a 'functional unit'. The functional unit defines the function of the product that will be assessed and the quantity of product to which all of the data collected will relate. By defining the product to be assessed as a quantified functional unit, it provides a reference to which all of the studied inputs and outputs across a product system are related, which helps to ensure the consistency and comparability of results.

- **Draw a map of the product life-cycle**

The process-mapping stage is an initial brainstorm exercise to map all of the 'flows' of materials and energy in and out of the product system as they are used to make and distribute the product. Since an assessment should focus on the most important aspects and avoid unnecessary detail, a process map can be as simple or as detailed as is deemed necessary or as time permits. Additionally, even if only a cradle-to-gate assessment is performed, it is always useful for the map to include the assessed product's whole life cycle in order to make sure that the 'downstream' of all activities, such as recyclability at end-of-life or potential to influence use phase emissions, are not overlooked.

1 ISO 14025:2006 *Environmental labels and declarations – Type III environmental declarations – Principles and procedures.*

2 For example, see the PCR library at http://pcr-library.edf.org.tw/ about/index.asp.

- **Agree and record the system boundary of the study**

Once the process map is complete, it can be used to help identify which parts of the overall system will, and will not, be included in the assessment. As an output from this scoping stage, It should clearly document and record the 'system boundary' in terms of:

- a list of all included life cycle stages (e.g. raw materials, production, use, end-of-life)
- a list of all included activities and processes within each life cycle stage
- a list of all excluded activities and processes, and the steps taken to determine their exclusion.

- **Prioritize data collection activities**

Having defined a system boundary, the next step in the scoping stage is to prioritize data collection activities. Data collection is the most time-consuming and resource intensive step in a carbon footprint assessment. It is usually not worth spending significant time and effort getting precise and accurate data for a life cycle stage that have very little impact on the overall footprint. Efforts should focus on important purposes of assessment.

4.1.2 Step 2-Data collection

The data needed to carry out a product carbon footprint calculation fall into two categories: activity data and emission factors. Collecting primary activity data for specific activities across the supply chain can be time consuming, and so often dictates the amount of resource needed for a footprint study. But the use of primary data generally increases the accuracy of the carbon footprint calculated, as the numbers used in the calculation relate directly to the real-life production or provision of the product or service assessed. Secondary data are usually less accurate, as they will relate to processes only similar to the one that actually takes place, or an industry average for that process.

- **Draw up a data collection plan**

Having prioritized the needed data in the scoping step, the next stage is to develop a plan of collecting data. Such a plan is used in order to focus efforts as well as provide a reference for the inventory estimation. The data collection plan should outline top targets for primary data collection, and highlight areas where secondary data will be sought instead, recognizing where primary data collection may not be feasible. It does not have to be too detailed, or formal, but should cover all of the data you will need for the carbon footprint assessment.

- **Engaging suppliers to collect primary data**

Engaging suppliers in the carbon footprint process helps to collect specific primary activity data and to gain greater insights into emission sources in the supply chain. It can also encourage future cooperation in reducing emissions for the supply chain. Nonetheless, it is a difficult task for up-stream suppliers, especially chemical producers, to provide specific information about their products. Suppliers can also be reluctant to provide carbon footprint data or their product information.

- **Collecting and using secondary data**

Secondary data are typically used in footprint studies as a source of:

- ✧ emission factors – which convert primary activity data (material/energy/process inputs and outputs) into GHG emissions (in kg CO_2e)
- ✧ information to fill gaps in primary activity data
- ✧ information to calculate the impact of 'downstream' life cycle stages.

- **Collecting data for downstream' activities**

Downstream activities refer to activities which occur during the product distribution process, in retail operations, in use, and at the end-of-life. Generally only the primary activity data for distribution is needed for performing inventory estimation. But if the retail operation is part of business activities, the estimation will require including data from both distribution activities and retail operations.

- **Assessing and recording data quality**

The accuracy or 'quality' of product carbon footprint result is ultimately dependent on the quality of the data used to calculate it. It is critical that we consider the quality of the primary and secondary data we have used, and demonstrate that they appropriately represent the footprint product. The best-quality data should always be sought in an assessment, but is of particular importance where external communication is an ultimate goal of the study.

4.1.3 Step 3-Footprint calculations

- General calculation process

The first task in the calculation process is to map all of the 'flows' occurring and calculate the quantities associated with each flow. Flows should be able to show all of the inputs, outputs, distances, and other activities at each stage of production. Because these activity data are often collected in many different formats and relating to different units, the next task is to balance the production process flows so that all inputs and outputs reflect the provision of the functional unit/reference flow defined in Step 1. This is an important task, and perhaps the most difficult part of the calculation process. Nonetheless, there are three golden rules to follow when balancing flows and they are:

- ✧ always consider waste in the process
- ✧ make calculations as transparent as possible, so they can be traced backwards
- ✧ record all assumptions and data concerns.

Once all production process flows are balanced to reflect the functional unit, the remaining work in the footprint calculation process stage is simple. A footprint is calculated simply by multiplying the activity data by the emission factor for each production process flow. The formula is provided in the following. The footprint of each flow is then summed to give total footprint against each life cycle stage, and for the total system.

Carbon footprint = activity data (kg/litres/kWh/tkm, etc.) × emission factor (kg CO2e per kg/litre/kWh/tkm,etc.)

- **Calculations for specific aspects of the footprint**

The 2011 version of PAS 2050 contains a number of revised clauses with regard to the accounting procedures for biogenic carbon emissions/removals/potential storage within a product system. New provisions require that emissions resulting from all energy use, both energy produced off-site and energy produced on site, must be taken into account in the calculation of a carbon footprint. And, based on publicly available secondary emissions factors, one can account for the most common types of energy using. This is because emission factors for fuel and electricity are normally well-described and available country-by-country. For example, in Chinese Taipei, emissions factors for grid electricity and common fuel types are provided by Taiwan Power Company and can be accessed on the internet (http://www.taipower.com.tw/quickLink/co2.htm)

Refrigeration/ Sulfur hexafluoride (SF6)

Refrigeration and climate control systems commonly contain substances such as hydrochloro fluorocarbons (HCFCs, e.g. R-22) and hydrofluorocarbons (HFCs, e.g. R-134a). These are highly intensive to produce, and when emitted to the atmosphere have a global warming potential often in excess of 1,000 times that of carbon dioxide. This is why, even in very small quantities, refrigerant leakages can be an important source of emissions.

In calculating the footprint, we need to identify the type of refrigerant used to produce a product. We also need to figure out the annual level of gas replacement (system top-ups) from maintenance records. These data are system inputs and are assumed to reflect the amount of refrigerant that has leaked from the system over the studied period. Thus, we need an emission factor for both the production of the refrigerant and for the release of the gas.

Transportation emissions

Transportation plays an important role in production and distribution. On the one hand, it carries raw materials and labor to the place where they are needed. On the other hand, it transports intermediate products to other producers for subsequent use in their production process or ships finished goods to customers. Thus it is always necessary to calculate the amount of emissions from transportation. Emission factors for transportation are widely available, and the most common unit used for measuring transportation emissions is: tonne-kilometre (tkm).

1 tkm refers to transporting 1 tonne of material a distance of 1 km.

4.1.4 Step 4-Interpreting footprint results and driving reductions

- **Understanding carbon footprint results**

The footprint calculation result is a 'total' footprint value for the agreed functional unit. The result is broken down according to the contributions in each material, process, and life cycle stage. Footprint results contain powerful information because they can be used to identify emission hotspot areas where implementing change would have the most impact. In addition, the granularity of the footprint result is affected by the amount and type of inventory data used. To identify the main contributors in each process or activity, we can only dig down into the result as far as the data will allow.

- **How certain can be about the footprint and hotspots?**

When we apply the PAS 2050 specification to conduct a product carbon footprint, we can only regard the footprint result as an estimate. So, the process to compile a carbon footprint inventory is an estimation process. Inevitably, there are some inaccuracies in standardized emission factors and in data collection. There are also some knowledge gaps and misconceptions that are filled by assumptions and global warming potentials used to calculate the CO2 equivalence of GHG. It is therefore important for analysts and users to understand uncertainties associated with the footprint result as well as to identify which aspects of the assessment leading to these uncertainties. By doing so, we can ensure that the resulting estimation is as accurate as possible. This is important when making decisions on carbon hotspot prioritization, raw material acquisition, etc.

- **Footprint verification**

The final stage in the step 4 is to verify the footprint result by an independent third party. By gaining third-party assurance, footprint claims can be bullet proofed. Such an assurance provides stakeholders with the confidence that claims are robust and well founded. Typically, assurance involves the following:

- ✧ reviewing and testing data collection and calculation procedures to confirm these are sound and that activity data are of the appropriate quality
- ✧ reviewing the reported footprint claims to ensure that these reflect what has been undertaken and delivered in the given reporting period.

Moreover, there are three different levels of assurance (self-verification, other third-party verification, independent third-party certification) issued by the third party. And, the PAS 250 specification requires that claims of conformity state the level of assurance.

By gaining third-party assurance, footprint claims can be ‘bullet-proofed’, and provide stakeholders with the confidence that claims are robust and well founded. Typically, assurance involves:

- ✧ reviewing and testing data collection and calculation procedures to confirm these are sound and that activity data are of the appropriate quality
- ✧ reviewing the reported footprint claims to ensure that these reflect what has been undertaken and delivered in the given reporting period.

It is important to remember that there are different levels of assurance (i.e.

self-verification, other third-party verification or independent third-party certification), and it is a requirement of PAS 2050 that claims of conformity state the level of assurance.

4.2. Materials Safety Data Sheet (MSDS)

The United Nations Environment Programmer (UNEP) has actively promoted hazardous chemical use reduction. According to a newest report, there are over 140,000 chemicals on the marketing, but only a few has been studied if they are hazard to both human and environmental health. The OECD also points out that both chemical compounds (e.g., ammonia, hydrogen sulfide and sulfuric acid) and organic chemical compounds (e.g., phenyl ethylene and methanol) generate the most emissions to the air when they are used in the production process. In order to reduce the use of hazardous chemicals, it urgently needs a good collaboration between governments and businesses on the regulation of chemical use.

With this in mind, material safety data sheet (MSDS) is an important component of product stewardship and occupational safety and health. MSDS is designed to provide workers and emergency personnel with procedures for handling or working with that substance in a safe manner. MSDS includes information such as physical data (melting point, boiling point, flash point, etc.), toxicity, health effects, first aid, reactivity, storage, disposal, protective equipment, and spill-handling procedures. It is widely used for cataloging information on chemicals, chemical compounds, and chemical mixtures. According to ISO 11014-1, there are four categories of information that must be presented on an MSDS, and they are:

A. Information for Emergency Response
  - Product and company identification (Sec. 1)
  - Hazards identification (Sec. 2)
  - Composition/Information on ingredients (Sec. 3)

B. Standard Operation Procedure for Emergency
  - First and measures (Sec. 4)
  - Fire fighting measures (Sec. 5)
  - Accidental release measures (Sec. 6)

C. Hazard-Prevention Information
  - Handling and storage (Sec. 7)
  - Exposure controls/Personal protection (Sec. 8)
  - Physical and chemical properties (Sec. 9)
  - Stability and reactivity (Sec. 10)

D. Other information

- Toxicological information (Sec. 11)
- Ecological information (Sec. 12)
- Disposal considerations (Sec. 13)
- Transportation information (Sec. 14)
- Regulatory information (Sec. 15)
- Other information (Sec. 16)

Moreover, the Chinese Taipei government agencies (i.e. Environmental Protection Agency, Council of Labor Affairs, Ministry of Transportation and Communications) have implemented Regulations Respecting Controlled Products. These regulations mandate the MSDS information to be made public available. The MSDS format used in Chinese Taipei is provided in Table 1.

Table 1: Material Safety Data Sheet form made by The Council of Labor Affairs of Taiwan

Material Safety Data Sheet

SECTION 1: PRODUCT AND COMPANY IDENTIFICATION			
PRODUCT NAME			
OTHER/GENERIC NAMES			
PRODUCT USE			
MANUFACTURER ADDRESS AND PHONE			
EMERGENCY PHONE			
SECTION 2: HAZARDS IDENTIFICATION			
EMERGENCY OVERVIEW			
Odor, Color, Grade			
General Physical Form			
Immediate health, physical, and environmental hazards			
POTENTIAL HEALTH EFFECTS Eye Contact Skin Contact Inhalation Ingestion			
SYMBOLS			
WARMING SIGN			
Other hazards			
SECTION 3: COMPOSITION/INFORMATION ON INGREDIENTS			
PURE SUBSTANCE			
English and Chinese names			
Synonyms			
CAS No			
% by Wt			
MIXTURE			
English and Chinese names			
Synonyms			
CAS No.			
% by Wt			
SECTION 4: FIRST AID MEASURES			
FIRST AID PROCEDURES OF DIFFERENT EXPOSURE			
Eye Contact			
Skin Contact			
Inhalation			
Ingestion			
The most important symptoms and hazardous effects			

Advice to physician
SECTION 5: FIRE FIGHTING MEASURES
EXTINGUISHING MEDIA
Special hazards that may be encountered when extinguishing
Unusual Fire and Explosion Hazards
Special protective equipment for fire-fighters
SECTION 6: ACCIDENTAL RELEASE MEASURES
ENVIRONIRONMENTAL CONSIDERATION
METHIDS FOR CLEANING UP
SECTION 7: HANDLING AND STORAGE
HANDLING
STORAGE
SECTION 8: EXPOSURE CONTROLS/PERSONAL PROTECTION
ENGINEERING CONTROLS
CONTROL PARAMETERS

TWA	STEL	CEILING	BEIs

PERSONAL PROTECTIVE EQUIPMENT (PPE)
Prevention of Swallowing
Respiratory Protection
Eye/Face Protection
Skin Protection
EXPOSURE GUIDELINES
SECTION 9: PHYSICAL AND CHEMICAL PROPERTIES

General Physical Form	Odor, Color, Grade
Olfactory threshold	Melting point
pH	Boiling point
Flammable Limits - LEL	Flash Point
Flammable Limits - UEL	
Auto ignition temperature	Evaporation rate
Vapor Pressure	Vapor Density
Density	solubility in Water
Specific Gravity	Viscosity

SECTION 10: STABILITY AND REACTIVITY
STABILITY
HAZARDOUS POLYMERIZATION
INCOMPATABILIES
MATERIALS AND CONDITIONS TO AVOID
HAZARDOUS DECOMPOSITION
SECTION 11: TOXICOLOGICAL INFORMATION
IMMEDIATE(ACUTE) EFFECT

SYMPTOMS		
ACUTE TOXICITY		
LD50		
CHRONIC OR LONG-TERM TOXICITY		
ROUTE OF EXPOSURE		
SECTION 12: ECOLOGICAL INFORMATION		
ECOTOXICOLOGICAL INFORMATION		
SECTION 13: DISPOSAL CONSIDERATIONS		
Waste Disposal Method		
SECTION 14:TRANSPORT INFORMATION		
US DOT HAZARD CLASS		
US DOT ID NUMBER		
HAZARD CLASS OF TRANSPOR		
PACKAGING CATEGORY		
MARINE POLLUTANT （Y /N）		
SPECIAL DELIVERY METHODS AND PRECAUTIONS		
SECTION 15: REGULATORY INFORMATION		
APPLICABLE REGULATIONS		
SECTION 16: OTHER INFORMATION		
REFERENCES		
MSDS-MAKER'S COMPANY	Company Name	
	Address / Phone	
MAKER	Titles	Name (Signature)
DATE		
NOTE		

Globally, Material Safety data sheets (MSDS) should provide comprehensive information about a substance or mixture for use in workplace chemical control regulatory frameworks (ECHA, 2011). Both employers and workers use it as a source of information about hazards, including environmental hazards, and to obtain advice on safety precautions. The information acts as a reference source for the management of hazardous chemicals in the workplace (OSHA, 2004).

An MSDS should be produced for all substances and mixtures which meet the harmonized criteria for physical, health or environmental hazards under the GHS and for all mixtures which contain ingredients that meet the criteria for carcinogenic, toxic to reproduction or specific target organ toxicity in concentrations exceeding the cut-off limits for MSDS specified by the criteria for mixtures.

The Globally Harmonized System of Classification and Labeling of Chemicals (GHS) are a globally harmonized hazard classification and compatible labeling system, including material safety data sheets and easily understandable symbols. The GHS covers all hazardous chemicals. The mode of application of the hazard communication elements of the GHS (e.g. labels, safety data sheets) may vary by product category or stage in the life cycle. Target audiences for the GHS include consumers, workers, transport workers, and emergency responders. The GHS is designed to permit self-classification (UNECE, 2011).

Material Safety Data Sheets and Labeling are provided as a convenience to general users. The 2009 Chemical Dialogue (CD) meeting agreed that the Council of Labor Affairs of Chinese Taipei would help to set up a website which provides information on GHS:

- GHS Reference Exchange and Tool (G.R.E.A.T.) - a Standard Element Clearinghouse

The goal of this GHS clearinghouse website (named the “GHS Reference Exchange and Tool, G.R.E.A.T.”) is to collect and provide GHS information by collaboration with focal point(s) of member economies. This “G.R.E.A.T.” website covers the GHS labeling elements in local languages including (1) hazard class and category, (2) pictogram (Symbol), (3) signal word, (4) hazard statement, and (5) precautionary Statement. Chinese Taipei encourages member economies GHS focal point(s) to provide the GHS labeling elements in different languages or update status (APEC, 2009).

In order to calculate the carbon emissions generated from producing and to conduct carbon footprint inventory, we obtain MSDS information from FTC's upstream suppliers. In particular, the information on the column of hazard compounds (in %) in the MSDS helps us to obtain secondary data from the LCA software. Once we have the MSDS information, they are incorporated into the LCIQ calculate in order to obtain the carbon emissions generated from producing raw materials.

In this chapter, we introduce MSDS and discuss what kind of information should be included in the MSDS. Due to the large size of MSDS, we attached some copies of MSDS conducted for the case study in the Appendix C.

4.3 Life Cycle Inventory Questionnaire (LCIQ Tool)

In the case study, the project team designs a tool (the LCIQ tool) for compiling a carbon footprint inventory. This chapter introduces this tool. We first collect information on company and evaluated products. We draw a product life-cycle map and set the inventory boundary. We also calculate the carbon emissions generated from producing both direct and in-direct raw materials. Based on the obtained raw material emissions, we calculate the emissions from suing SF6 gas/refrigerant/ energy in the production process. Finally, we calculate the waste emissions to the air, water, and the land. When we perform the LCIQ calculation, we perform the Step 3 in Figure 5. After this step, we will be able to locate carbon hotspots and find emission reduction policies.

Each step in the LCIQ calculation is introduced in the following:

(1) LCIQ Introduction
This is an introduction of the LCIQ tool, which include architecture description, purpose, instruction, and recommended attachment. These are the inventory list.


Life cycle inventory questionnaire (LICQ)version: 1.0

Created by：Taiwan Textile Research Institute

Architecture Description

1. This life cycle inventory questionnaire is established according to ISO14040: 2006 and ISO14044: 2006 standard, comply the spirit and procedures of life cycle inventory and assessment which could assist industry doing life cycle inventory of products.
2.Term explained:
a.ISO14040:2006--Environmental management-Life cycle assessment-Principles and framework
b.ISO14044:2006--Environmental management-Life cycle assessment-Requirements and guidelines

Purpose

1.Article 11 (Requirements for components and sub-assemblies) of EuP Directive mentions that implementing measures may require manufacturers or their authorised representatives placing components and subassemblies on the market and/or putting them into service to provide the manufacturer of an EuP covered by implementing measures with relevant information on the material composition and the consumption of energy, materials and/or resources of the components or sub-assemblies. For the purpose of making the Eco-profile of the products, please assist in filing this LCI questionaire
2.Application of LCI&LCA:
a.Identification of signiggcant environment issues
b.Environmental information disclosure, such as Environmental product declaration(EPD), Ecological profile, carbon footprint , and European Union Eco-labelling program, etc.
c.Decide the environmental performance indicators and their measurement technology selection.

Instruction

1.The questionnaire contains 11 sheets: profile, flowchart, the make-up of the component, auxiliary material, energy & resource consumption, electricity consumption by equipments, emission to the air, emission to the water andwastes. Please fill out the sheets from left to right.
2.DQI(Data Quality Indicator) mentioned in the questionnaire includes three types of value：
a.Measurement：can be obtained by measure equipment directly.
b.Calculation：can be obtained by calculating via using standard formula, such as energy consumption of equipment.

(2) Company Profile
This requires information on company profile, including company name, company address, capital of plant, employee number, contact person, contact person title, phone number, fax number, e-mail address, company homepage, company introduction, product name & model, product picture, product specification, function unit of product, environmental regulation compliance, and inventory period. Since this information must be written into the inventory report for the third party verification, it is good to know or identify correctly from the beginning.

◎ Company profile

Company name	
Factory Address	
Capital of plant	
Employee no.	
Contact person	
Title	
Phone no.	
Fax No.	
E-mail	
Company website	
Company introduction	
Product name & model	
Product Picture	
Product specification	
Function unit of product	Kg /yard
Environmental regulation complied	

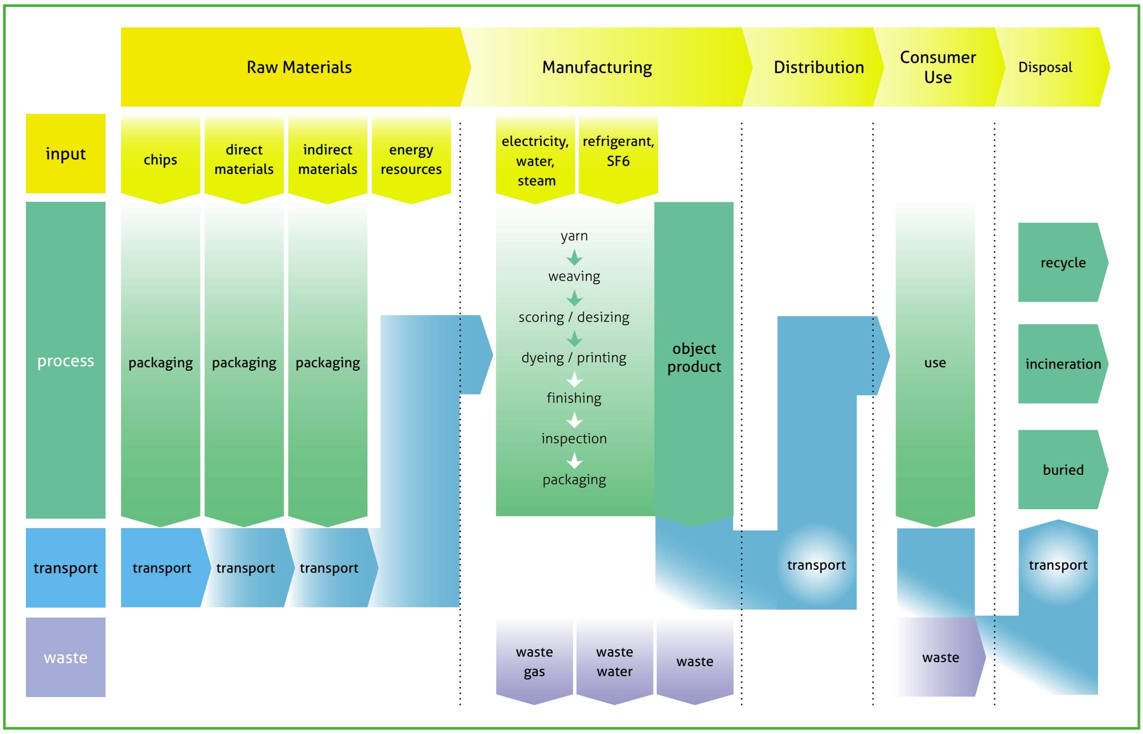
◎ Investigation information

Filling date	
Inventory period	20XX/ 1/1~20XX/12/31

(3) Draw a product life-cycle Map

As we mentioned earlier, the PAS 2050 Guide suggests four footprint process steps. The first step is to draw a product life-cycle process map. And, the important thing about drawing the map is to help us to set the inventorying boundary and list out each production stage.

In the case study, as shown in this step, we first identify inputs and outputs (i.e. from raw materials to disposal, including transportation) according to the concept of a product's life-cycle. In our case, the whole manufacturing process of converting raw materials to a fabric takes place in one single factory. This simplifies the emission calculation process. We then set both raw materials and manufacturing as the boundaries for conducting carbon footprint inventorying.



(4) Emissions of Direct Materials

After we draw the map, we start to apply the LCIQ tool to calculate carbon emissions from production processes. We first calculate the amount of carbon emissions generated from producing raw materials. And, as in the production process map, we identify the types of raw materials that are used in the production process. These raw materials are considered as direct materials in the production process.

In order to perform the LCIQ calculation process, we obtain the MSDS information for each raw material from suppliers and incorporate the information (i.e. components and percentages) into the calculation process. We also incorporate the database in the LCA software into the calculation to obtain the amount of carbon emissions generated from producing each raw material. And, our calculation includes emissions for shipping of each raw material.

Processing Stage	Raw Material Items			Raw Material Consumption (Annual)	Chemical Characteristics (Raw Materials)		Data Quality Attributes
					Composition		
	No.	Supplier	Name	Quantity	Name	Ratio	
Gray Fabric	N9999	A	Nylon or Polyester fabric	100541.000 kg	nylon	100.0%	Measurement
Desizing	AA112	B	Desizing agent	195.000 g	Sodium persulfate	>98.0%	Measurement
Dying	AB225	C	Scouring agent	720.800 kg	Naphthalenes ulfonic acid	3.0%	Measurement
					Sodium sulfate	47.0%	
					Thiourea dioxide	50.0%	

Note: Data for chemical characteristics are taken directly from the Material Safety Data Sheet (MSDS).

(5) Emissions of In-direct Materials
We then continue to calculate the amount of emissions generated from producing in-direct materials. The calculation process is the same as that of direct materials.

If suppliers are not able to provide the needed MSDS information for some of the in-direct materials, we ask them to give us the amount of energy used in producing these indirect materials. We then estimate emissions from energy use.

Processing Stage	Raw Material Items			Raw Material Consumption (Annual)	Chemical Characteristics (Raw Materials)		Data Quality Attributes
					Composition		
	No.	Supplier	Name	Quantity	Name	Ratio	
Gray Fabric	P50010	C	Industrial SP sewing thread (white)	100.000 kg	polyester	100.0%	Measurement
Packaging	T60010	E	1.25"*2.2*45" paper tube	720.800 kg	fiber	90.0%	Measurement
					polyvinyl acetate	5.0%	
					water	5.0%	

Note: Data for chemical characteristics are taken directly from the Material Safety Data Sheet (MSDS).

(6) Emissions of SF6 gas Consumption
In order to obtain the amount of Sulfur Hexafluoride (SF6) gas used in producing a product, we first estimate the total amount of gas consumed from its servicing equipments. We then estimate the total amount of gas consumed according to the ratio of gas escape or the proportion of filling material(s). With

these information, we can calculate the amount of Sulfur Hexafluoride (SF6) gas used in producing a product.

Location	Power Circuit Breaker	Brand Name	Type	Equipment No.	Production Year	Last Filling Date	SF6 Filling Volume (kg)	SF6 Annual Added Volume (kg)	Allocated Amount (kg)
Q	GCB	FUJI	HU 1220N-06MF-C	FM67076/1.3	1992	2010/1/6	1.96	4.52	
s	VCB	Mitsubishi	C-Mitsubishi VCB	FK68499/1-10	1994	2007/6/8	2.56		

(7) Emissions of Refrigerants Consumption
The way to calculate the amount of each refrigerant (R11, R12, R134, R134a, R22 etc) used in producing a product is the same as that of SF6 gas.

Location	Refrigerant	Type	Quantity	R11, R12, R123, R134a, R22	Original Filling	Quantity * Original Filling	Refrigerant Emission Factor	Annual Emissions	Total Emissions	Allocated Amount
					(tone)	(tone)	(kg/kg)	(tone)	(kg)	(kg)
S	TRANE	440_RT	2	R11	0.4631	0.9262	20%	0.19524	0.96704	
IO	CARRIER	800RT	5	R123	0.6810	3.4050	20%	0.6810		
U	MC_QUAY	650_RT	1	R134a	0.4540	0.4540	20%	0.09080		

(8) Energy Emissions
In order to calculate the amount of carbon emissions generated from the energy used in converting raw materials to a fabric, we first identify all types of energy (electricity, coal, fuel oils, etc.) used in the production process. We then collect the amount of energy used each month for a period of 12 months. Finally, we calculate energy emissions based on the portions of the individuals consumed in production.

With the calculated energy emissions, companies can establish a new baseline or correct existing baseline for energy consumption in the production process.

	Purchased Electricity					Coal		Fuel Oil	LPG	Nature Gas	Diesel	Bio-diesel	Underground Water	Tap Water	Steam		Nitrogen	Sold Electricity		Own Generating Electricity Capacity
	Peak	Half Peak	Off Peak	Half Peak on Sat.	Total	Calorific Value	Amount								Purchased	Sold		Peak Time	Half Peak Time	
	kWh					kcal/kg	ton	kL	kg	m3	L	L	ton	ton	ton		kg	kWh		
Last Dec.																				
1																				
2																				
~																				
11																				
12																				
Next Jan.																				
Total																				

(9) Waste Emissions to the Air

In Chinese Taipei, hazardous wastes released in the air, water or on land are regulated by governments. Information on facility compliance with water, air, and hazardous waste requirements provides a good source for calculating waste emissions.

So, we first collected the needed data from the emission control database and checked the data quality. From the data, we then calculated the amount of volatile organic compounds (VOCs) and methane consumed from production processes.

Location	Monthly or Quarterly	SO_x	NO_x	VOC	Allocated Amount of This Product	Data Quality Attributes
		kg				
Finishing 1	Last Dec.					I: Measurement
	Q1					II: Calculation
	Q2					III: Estimation
	Q3					
	Q4					
	Next Jan.					
Total						

Note: Data are taken directly from the air pollution fee declaration

(10) Waste Emissions to the Water

From the government's emission control database, we collect the amount of water used each month for a period of 12 months. We then calculate wastewater emissions released into the environment.

Location	Monthly or Quarterly	Waste Water	COD	SS	Total COD	Total SS	Output	Allocation Proportion	Allocated Amount	Data Quality Attributes
		m^3/month	mg/L	mg/L	kg	kg	kg	%	kg	
Q	Last Dec.									I: Measurement
	1									I: Measurement
	2									I: Measurement
	12									I: Measurement
	Next Jan.									I: Measurement
Total										II: Calculation

Note: Data are taken directly from daily or monthly operation records, and are checked with the waste water treatment fee declaration.

(11) Waste Emissions to the Soil

From the government's emission control database, we collect the amount of wastes (other than air and wastewater) generated each month for a period of 12 months. We then calculate waste emissions released into the soil. With the calculated waste emissions, companies can establish a new baseline or correct existing baseline for wastes released from production process.

Location		No.	Item Name	Official Code	Output	Allocation Proportion	Allocated Amount	Data Quality Attributes
					kg	%	kg	
	Last Dec.	1	Plastic Buckets	D-0299				I: Measurement
		2	Drum					I: Measurement
		3	Paper Tube					I: Measurement
		4	Waste Fabric					I: Measurement
		5	Garbage					I: Measurement
		6	Textile Sludge					I: Measurement
Total								II: Calculation

Notes: 1. Data are taken directly from daily or monthly operation records, and are checked with the Waste pollution declaration.

2. The "Total" amount is calculated by Last Dec. Q1, Q2, Q3, Q4 and next Jan.

When we conduct environmental footprint using the LCIQ tool, we need to apply the following equation, which is the equation used to calculate emissions in the PAS 2050.

Before we perform the calculation using the equation, we need to calculate activity data. And we can calculate activity data when we complete the aforementioned 11 data sheets. Also, we can obtain emission factors from LCA database or other references. After we obtain both activity data and emission factors, we incorporate them into the equation and calculate carbon emissions for environmental footprint.

A = B × C

where

A：Carbon footprint of a given activity

B：Activity data (mass/volume/kWh/km)

C：Emission factor (CO_2e per unit)

CHAPTER 5

THE CASE STUDY

The most famous and biggest textile manufacturing company in Chinese Taipei -FORMOSA TAFFETA CO., LTD. (FTC) participated in the case study. We performed environmental footprint for their 24 types of functional textile products. FTC would like to understand the carbon emissions generated from producing a functional textile. With such information, FTC will be able to set baselines for both energy consumption and carbon emissions in the production process. Such baselines help FTC not only to reduce energy consumption (and hence production costs) but also to find emission reduction plans. Moreover, "environmental impact reduction" is becoming a marketing tool. Carbon footprint labeling (like the Nutrition labeling) provides information on product's environmental performance. This is definitely an extra buying selection criteria to customers, and also helps FTC's downstream firms to evaluation information on their own. With these in mind, FCT forms a taskforce for carrying out this environmental footprint study.

In the case study, we perform the environmental footprint on FTC's 24 types of functional textile products. The profile of these products is provided as follows:

Item	Function	Use purpose
-Nylon /polyester dyeing & setting process for woven fabrics	Dyeing & setting	lining, cloth cover
-Nylon /polyester dyeing & wicking finishing process for woven fabrics	Moisture absorbing & quick drying	athletic clothes, jackets, golf clothing
-Nylon/polyester dyeing & water repellent process for woven fabrics	Antifouling, waterproof	Cloth cover, tent, athletic clothes, jackets
-Nylon/polyester dyeing & water repellent & calendaring process for woven fabrics	waterproof, handling soft	Tank top, trench coat, down jacket, athletic jacket, fashion clothing
-Nylon/polyester dyeing & PU coating process for woven fabrics	Waterproof, windproof, coloring	trench coat, rain coat, athletic jacket, fashion clothing, anorak
-Nylon dyeing & acrylic coating process for woven fabrics	Waterproof, windproof	umbrella, tent, athletic jacket, fashion clothing
-Nylon/polyester dyeing & laminating process for woven fabrics	Breathable and waterproof, warm & windproof	trench coat, rain coat, athletic jacket, fashion clothing, anorak
-Nylon/polyester printing & water repellent process for woven fabrics	Printing, Antifouling, Breathable and waterproof	umbrella, cloth cover, athletic jacket, fashion clothing, beach shorts
-Nylon/polyester printing & water repellent & calendaring process for woven fabrics	waterproof, handling soft	lining, cloth cover, trench coat, anorak, athletic jacket, fashion clothing
-Nylon/polyester printing & PU coating process for woven fabrics	breathable and waterproof, windproof, coloring	trench coat, rain coat, athletic jacket, fashion clothing, anorak

-Nylon printing & acrylic coating process for woven fabrics	breathable and waterproof, windproof	umbrella, tent, athletic jacket, fashion clothing
-Nylon/polyester printing & laminating process for woven fabrics	breathable and waterproof, warm & windproof	trench coat, rain coat, athletic jacket, fashion clothing, anorak

This chapter reports the case study results according to both the 4 stepwise processes in Section 4.1 and the LCIQ calculation process.

In short, we will need to check it complies with the principles in clause 4.3 of PAS 2050. In particular, we should check that it (as follows) in order to know whether if a supplementary requirement or other product rules/PCR is applicable:

- ✧ does not conflict with the provisions of PAS 2050 unless this has been explicitly allowed for within a PAS 2050 provision (e.g. if justified, the time period for assessment may be different in supplementary requirements to the 100 year period identified in PAS 2050)
- ✧ has been developed through a consensus-based process and well recognized (i.e. within our sector and/or internationally)
- ✧ has a scope that is applicable to our industry/ stakeholders and it is comprehensive.

Because there is no available document of supplementary requirement or PCR worldwide to be able to use in the report of assessment, the system boundary for the assessment is defined in PCF inventory report. In the following sub-sections, we will details how the project team proceeds the environmental footprint process according to the 4 stepwise footprint process in Figure 5.

5.1 Step 1-Scoping

FTC first identifies which textile products they would like to do environmental footprint. The company identifies a total of 24 types of functional textiles including polyester and nylon, and they are listed as follows：

- Dyeing & setting process for woven fabrics
- Dyeing & wicking finishing process for woven fabrics
- Dyeing & water repellent process for woven fabrics
- Dyeing & water repellent & calendaring process for woven fabrics
- Dyeing & PU coating process for woven fabrics
- Dyeing & acrylic coating process for woven fabrics
- Dyeing & laminating process for woven fabrics
- Printing & water repellent process for woven fabrics
- Printing & water repellent & calendaring process for woven fabrics
- Printing & PU coating process for woven fabrics
- Printing & acrylic coating process for woven fabrics
- Printing & laminating process for woven fabrics

- **Describe the product to be assessed and the unit of analysis**

In general, the weaving and dyeing segment is the most important product processes of functional textile business unit. In the textile supply chain operations, the weaving and dyeing processes produce fabrics differently in thickness and lengths. Therefore, fabrics are generally cut and sold by the yard. But, in order to uniform the unit measurement in the emission calculation process, we use "1kg of woven fabric" as the declared unit。The appropriate functional unite is then driven by how the product is typically consumed, therefore, the functional unit of FTC products are defined such as 1kg Nylon dyeing & setting process for woven fabrics, 1kg Polyester dyeing & wicking finishing process for woven fabrics, 1kg Polyester printing & laminating process for woven fabrics etc.

- **Draw a product life-cycle map**

In the case study, the LCIQ tool is applied to conduct the cradle-to-gate assessment. We need to calculate:

(1) the amount of carbon emissions generated from producing raw materials (yarns, dyes, chemicals, and package materials), and
(2) the amount of emissions generated from the energy used in converting raw materials to a fabric.

So, we need to first draw a product life cycle map and set the inventory boundary. As shown in Figure 6, we first identify inputs and outputs (i.e. from raw materials to disposal, including transportation) according to the concept of a product's life-cycle. In our case, the whole manufacturing process of converting raw materials to a fabric takes place in one single factory. This simplifies the emission calculation process. We then set both raw materials and manufacturing as the boundaries for conducting carbon footprint inventorying.

After we draw the map, we start to apply the LCIQ tool to calculate carbon emissions from production processes. We first calculate the amount of carbon emissions generated from producing raw materials. And, as in the production process map, we identify the type of raw materials that are used in the production process. These raw materials are considered as direct materials in the production process.

In order to perform the LCIQ calculation process, we obtain the MSDS information for each raw material from suppliers and incorporate the information (i.e. components and percentages) into the calculation process. We also incorporate the database in the LCA software into the calculation to obtain the amount of carbon emissions generated from producing each raw material. And, our calculation includes emissions for shipping of each raw material.

We then continue to calculate the amount of emissions generated from producing in-direct materials. The calculation process is the same as that of direct materials. If suppliers are not able to provide the needed MSDS information for some of the in-direct materials, we ask them to give us the amount of energy used in producing these indirect materials. We then estimate emissions from energy use.

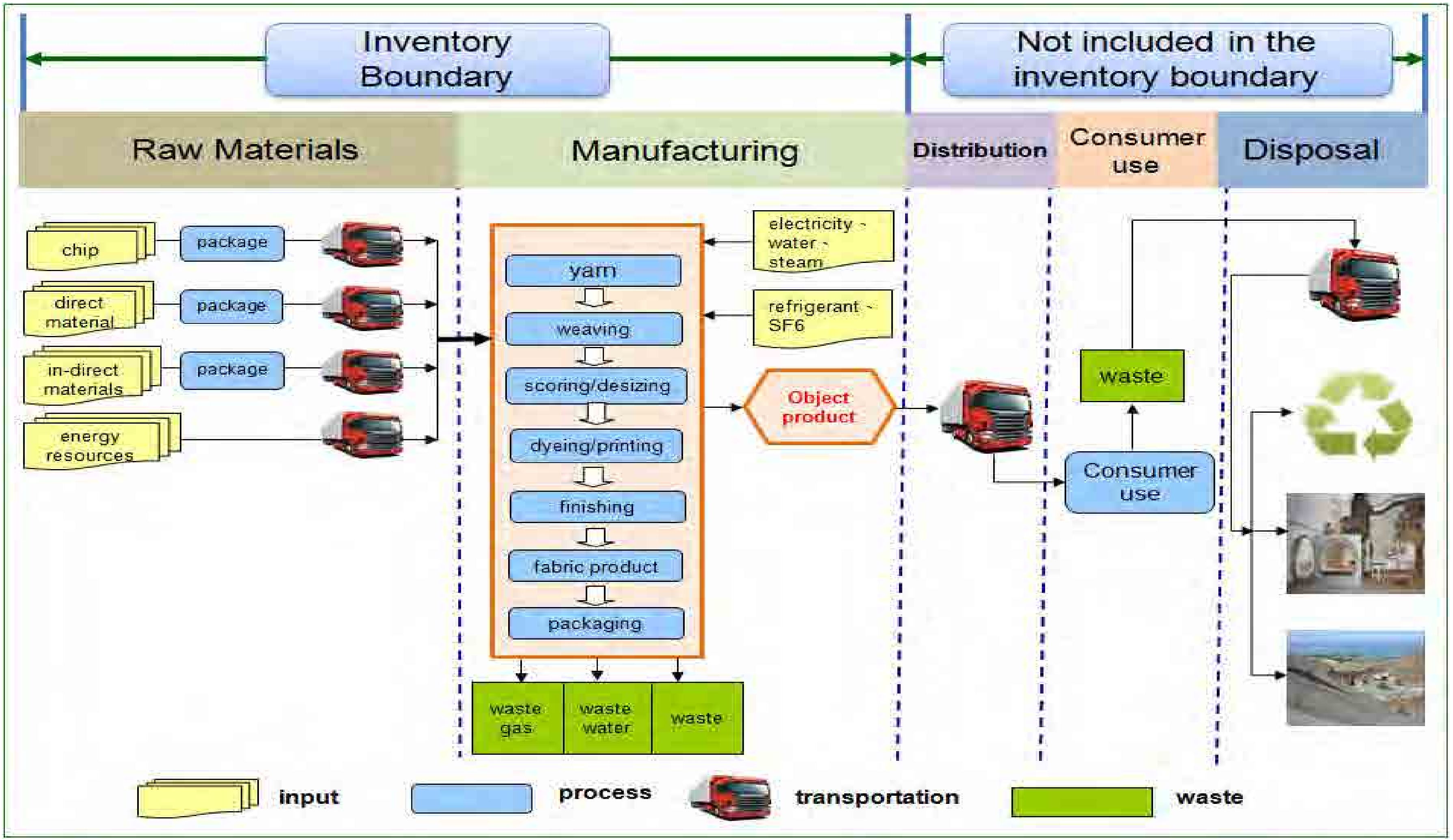


Figure 6: The process-map of the weaving fabric from a functional textile manufacturing

- **Agree and record the system boundary of the study**

After we draw the product life-cycle map and finish aforementioned estimation, we are able to obtain the following information:

- a list of all direct materials of chemicals and dye ; a list of all in-direct materials of paper tubs and threads ; a list of all fabric production activities.
- a list of all included activities and processes within each produced stage
- a list of all excluded activities and processes, and the steps taken to determine their exclusion.

- **Prioritize data collection activities**

A good initial check is to look for any previous carbon footprint or life cycle assessment (LCA) studies that have been carried out on the product system (or a similar product system) to be studied. A quick internet search, using typical search engines can help with this.

- Raw materials are commonly a hotspot for the carbon footprint of a product. By using a bill of materials and/or the process map, it is possible to do some quick, 'back of the envelope' calculations to identify areas where the impact is likely to be high, and therefore primary data collection should be prioritized.
- Processing energy is also often a large contributor to emissions. By looking at the process map it is possible to identify potential processes that are likely to use a lot of energy. Even if a rough amount for energy consumption is known (e.g. from industry guidance), it is possible to do the same 'back of the envelope' calculations to ascertain where in the life cycle specific information is likely to be needed.

5.2 Step 2-Data collection

The data needed to carry out a product carbon footprint calculation fall into the following categories:

- Activity data: referring to quantities of inputs and outputs (materials, energy, gaseous emissions, solid/liquid wastes, co-products, etc.) for a process – typically described for a unit of production for a specified year of production (e.g. kg CO_2e per kg of for woven fabrics in 2011). This also includes details of any transportation of incoming materials, wastes or distribution of the final product (distances travelled, vehicles used, etc.).

Activity data can be from either:

- primary sources – first-hand information, specific to the activity in question (e.g. chemicals/dyestuff amount using at dyeing process), collected internally or from the supply chain or
- secondary sources – average, or typical, information about a general activity (e.g. components of chemicals, fuel consumption of truck engines) from a published study or other source.

✧ Emission factors: values that convert activity data quantities into GHG emissions – based on the 'embodied' emissions associated with producing materials/fuels/energy, operating transport carriers, treating wastes, etc. These are usually expressed in units of 'kg CO_2e' (e.g. kg CO_2e per kg of for woven fabrics, per liter of diesel, per km of transport or per kg of waste to landfill), and are most often from secondary sources.

● Draw up a data collection plan

The data collection plan outline top targets for primary data collection, and highlight areas where secondary data will be sought instead, recognizing where primary data collection may not be feasible. For FTC case, the input and output flows in the main phases is shown as Figure 7, and the data collection outline follows each item of the inputs, manufacturing and outputs.

FTC has a highly effective Enterprise resource planning (ERP) system, and its taskforce members are familiar with the system. These are keys to the success of this ecological footprint project.

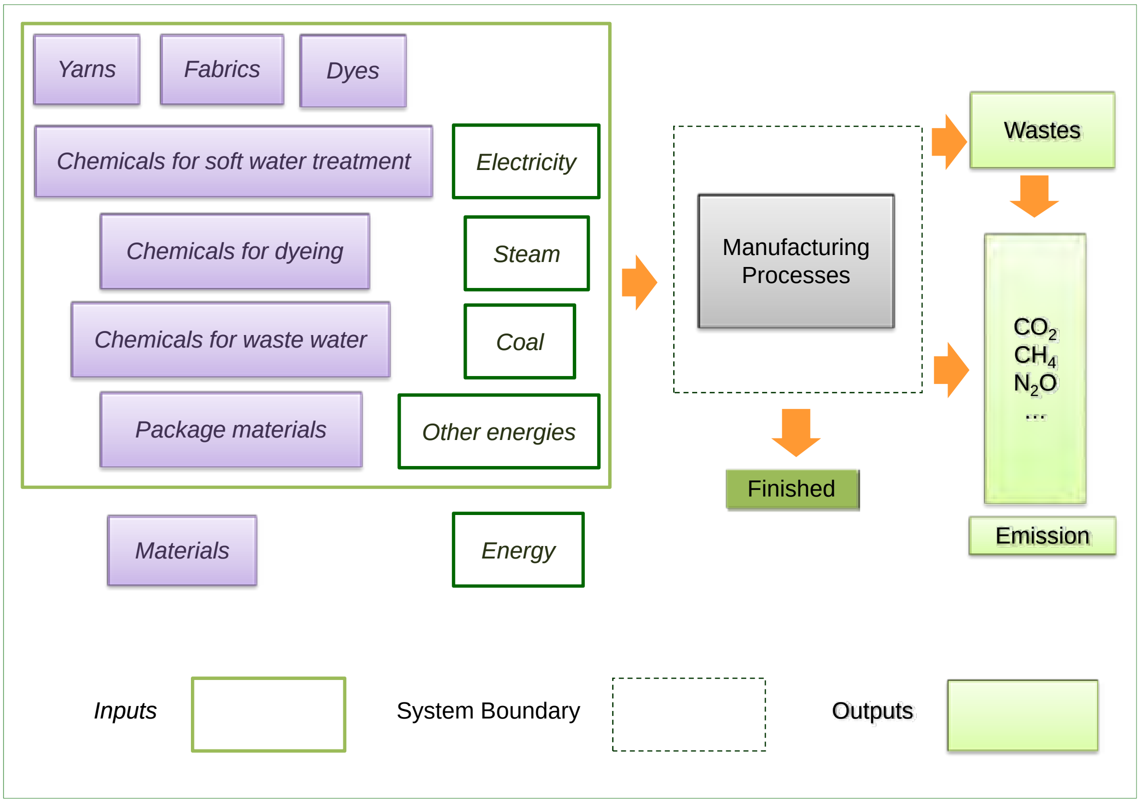


Figure 7: Data collection plan for the functional textile manufactory

- **Engaging suppliers to collect primary data**

It seems that not much supply is willing to offer carbon footprint data or information in textile industry supplier chain until today, It is really hard to collect the primary data from up-stream supplier, especially the chemicals' supplier. That is the reason why have to ask them to offer the MSDS to instead of the secondary data.

- **Collecting and using secondary data**

For FTC case, the secondary data we used were shown as follows：

- ✧ emission factors – which convert primary activity data (material/energy/process inputs and outputs) into GHG emissions (in kg CO_2e), e.g. some of chemicals, dyes, biodiesel etc.
- ✧ information to fill gaps in primary activity data： For overall inventory data, there were NO data gaps because all data was assessed along the whole supply chain with cradle – to – gate approaches. Cut off are materials below 5% contribution.

- **Collecting data for downstream' activities**

'Downstream' activities refer to processes that occur during product distribution, retail, use and end-of-life. For FTC case is no necessary to collect because it is the cradle-to-gate assessment.

- **Assessing and recording data quality**

When performing the LCIQ calculation process, it is important to validate the collected data. The data can be obtained internally (from corporate) and externally (from literature or other references). In particular, the internal data generally cannot be collected from one single department; therefore, it is important to have a good communication channel or mechanism for collecting such data. FTC has an ERP system which provides a good mechanism to collect data from various departments.

All installations relate to the products are covered in the verification, and the main emissions are from：

- ✧ Energy use (including energy sources, such as electricity) Combustion processes
- ✧ Refrigerant loss and other fugitive gases
- ✧ Operations
- ✧ Waste
- ✧ Service provision and delivery are not applicable for the assessment of cradle to gate

All sources of emissions anticipated to make a material contribution to the life cycle GHG emissions of the functional. At least 95% of the anticipated life cycle GHG emissions of the functional unit. The each LCA stage in the assessment less than amount 5% GHG emissions to total product life cycle GHG emissions can be cut-off. However there is no any item is omitted in the report of assessment.

About the Data quality, the company provided data on：

(1) Distances from agents or suppliers of ingredients to the Company factory,
(2) Quantities and types of ingredients for the manufacturing of the product,
(3) Quantity and type of materials used in packaging the finished product,
(4) Quantity and type of waste arising from manufacture and its treatment,
(5) Distances and loads of raw material transported.

The quality of these data is good and required no clarifications. An assessment of the quality of data received from Formosa Taffeta Co., Ltd. can be seen below in table below. To determine the quality of data received, completeness, validity, consistency and accuracy were evaluated subjectively by Formosa Taffeta Co., Ltd. In its PCF report, the data has been assessed as different quality level shown as below Figure 8：

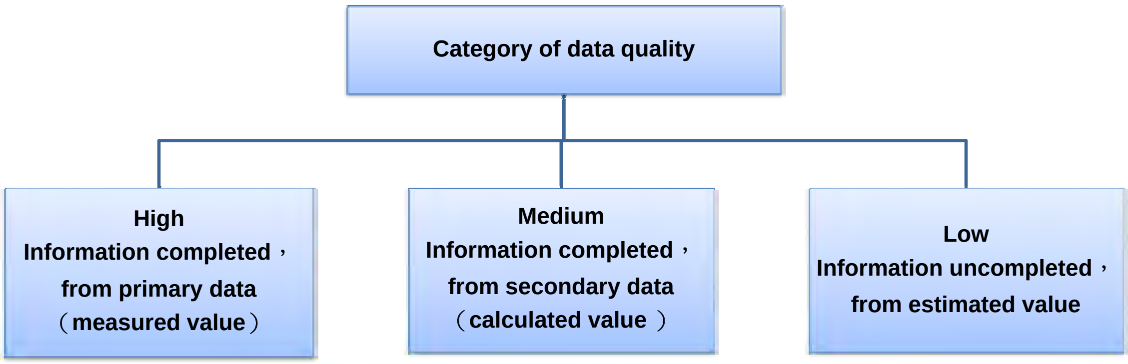


Figure 8. Category of data quality in the case study

Meanwhile, assessment of product life cycle GHG emissions should use data that will reduce bias and uncertainty as far as practicable by using the best quality data achievable. The company quantifies most of their emission data from public sources in order to reduce uncertainty.

5.3 Step 3-Footprint calculations

FTC has selected and used the combination of calculation based on product life cycle GHG activities primary data multiplied by related GHG emission factor/mass balance approach and measurement. With the help of EPR system, we collected the needed data for performing the LCIQ calculation.

Also, the emission factors from the LCA database are applied as for most secondary data sources in its PCF report. As a result of carrying out the product life cycle greenhouse gas emissions, it is shown as follows:

Item	$kgCO_2eq$
Nylon dyeing & setting process for woven fabrics	27.718
Nylon dyeing & wicking finishing process for woven fabrics	35.156
Nylon dyeing & water repellent process for woven fabrics	28.270
Nylon dyeing & water repellent & calendaring process for woven fabrics	29.946
Nylon dyeing & PU coating process for woven fabrics	38.799
Nylon dyeing & acrylic coating process for woven fabrics	29.409
Nylon dyeing & laminating process for woven fabrics	70.455
Nylon printing & water repellent process for woven fabrics	28.648
Nylon printing & water repellent & calendaring process for woven fabrics	32.520
Nylon printing & PU coating process for woven fabrics	48.451
Nylon printing & acrylic coating process for woven fabrics	29.009
Nylon printing & laminating process for woven fabrics	86.644
Polyester dyeing & setting process for woven fabrics	25.394
Polyester dyeing & wicking finishing process for woven fabrics	28.346
Polyester dyeing & water repellent process for woven fabrics	26.300
Polyester dyeing & water repellent & calendaring process for woven fabrics	28.316
Polyester dyeing & PU coating process for woven fabrics	36.513
Polyester dyeing & acrylic coating process for woven fabrics	27.914
Polyester dyeing & laminating process for woven fabrics	39.077
Polyester printing & water repellent process for woven fabrics	24.036
Polyester printing & water repellent & calendaring process for woven fabrics	28.415
Polyester printing & PU coating process for woven fabrics	39.309
Polyester printing & acrylic coating process for woven fabrics	33.640
Polyester printing & laminating process for woven fabrics	36.430

Note: unit = 1kg fabric

5.4 Step 4-Interpreting footprint results and driving reductions

As a result of carrying out the third-party verification of product life cycle greenhouse gas emissions, it is the opinion of BSI with reasonable assurance, and it is also a requirement of PAS 2050 that claims of conformity state the level of assurance. One product verification statement is shown as an example in the following:


Opinion Statement
Product Carbon Footprint
Verification Opinion Statement

Figure 9: Product Carbon Footprint Verification Opinion Statement

After we perform the LCIQ calculation, the project team identifies carbon hotspots in the production process for driving emission reduction. Based on the identified hotspots, as shown in the blue highlighted area of Figure 10, FTC has initiated the following four reduction plans.

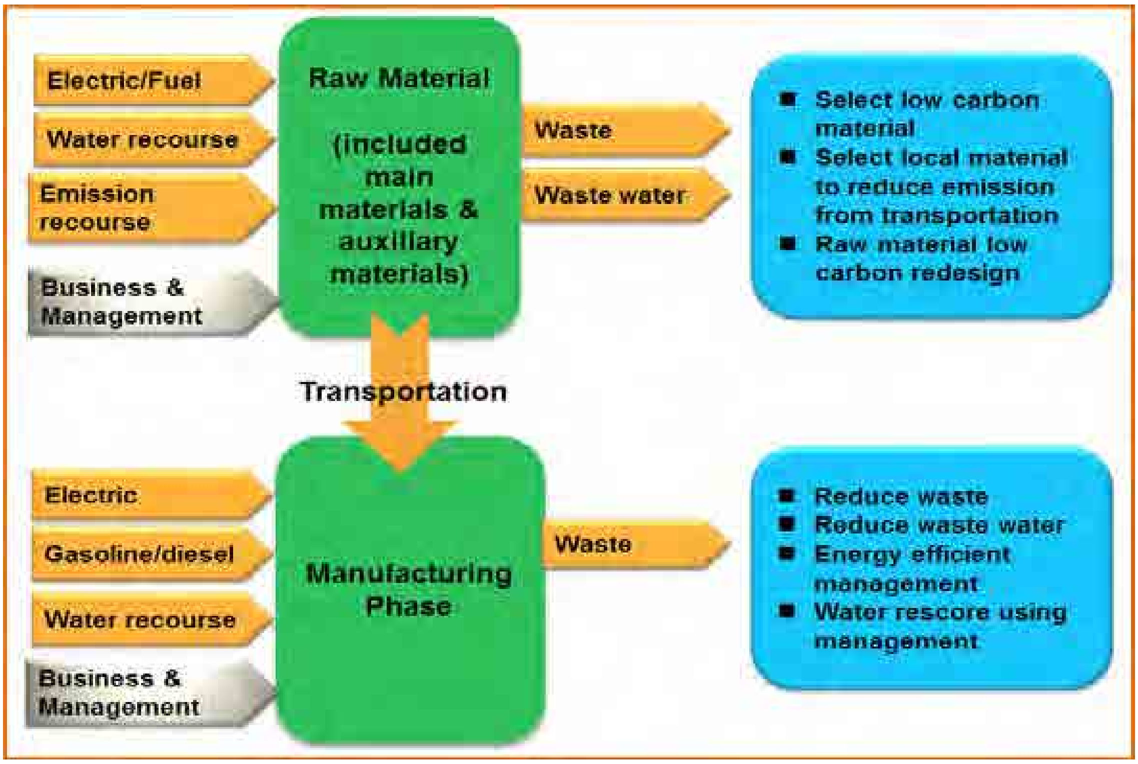


Figure 10. From LCA process to find out the Hot Spots

1. To reduce water consumption in textile processes. For example, install a condensed steam water recycling system and use more recycled water in both weaving and dyeing processes.

2. To lower electricity consumption in textile processes. For example, improve lighting and air-conditioning systems in facilities. Another example, adjusting product production combinations so that machines can be used to produce more the same products for a longer time and hence, FTC will be better in the control of electricity consumption.

3. To implement a low pressure steam saving plan. For example, FTC will implement a focus production so that fewer machines will need to be turn on and wait for the equipment to reach a certain temperature. FTC will also recycle water heat from dyeing machines, forming machines, and desizing wastewater. These recycled heats will be used in the production processes.

4. To reduce fuel consumption. For example, FTC will implement a focus production strategy in order to improve overall equipment effectiveness.

5.5 Cost Estimation

Generally, the costs of conducting an environmental footprint study include the carbon footprint inventorying fee and the third party verification fee. The third party verification fee is charged based on the number of auditors per day. ISO19011: 2002/14064-3: 2006 has clearly specified a total of auditors and auditing days that are needed for a normal environmental footprint case.

The product carbon footprint verification of Formosa Taffeta Co., Ltd was based upon the client's product carbon footprint management system & inventory report. The verification process included one off-site document review and two stages on-site verification which prepared in accordance with ISO19011: 2002/14064-3: 2006. The Initial Stage 1 verification was expected to take 10 verification man days and 2 verification man-days for Stage 2 verification. The service charge for conducting a footprint inventory is according to the number of evaluated products, the number of chemicals used in the production process, types of textile processes, and the number of production facilities used in producing evaluated products.

5.6Summary

Environmental footprint is a new concept, and we definitely need to do it for our environmental sake. When we conduct an environmental footprint, we want to know the amount of carbon emissions generated from production processes. But which methodology or tool we should use to calculate emissions? We haven't seen a study discussing a feasible tool for compiling a carbon footprint inventory. In the APEC project, we designed the LCIQ tool and tested its feasibility in a case study. This tool is used in the data collection process, which is schematically shown in Figure 11. We really appreciate that the FTC participated in this case study. We are also happy that this tool helped FTC's 24 types of functional textiles to receive the Carbon Footprint Verification, the highest level for this verification.

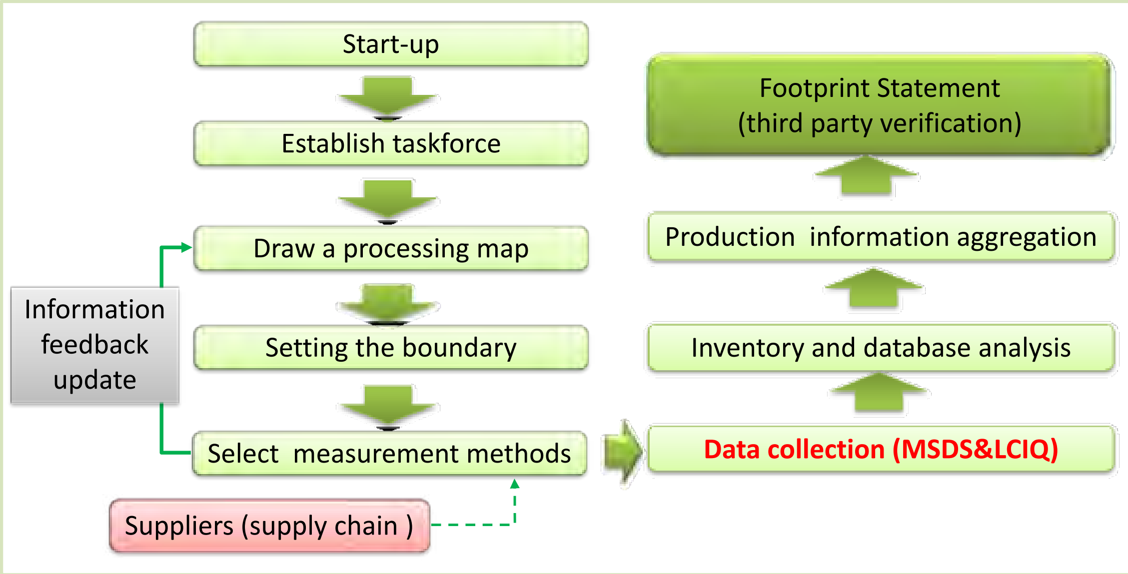


Figure 11. Product carbon footprint inventory process

We have learnt many valuable lessons from conducting this case study. And we believe that the followings are keys to the success of environmental footprint:

(1) a commitment to environmental footprint;

(2) organize an effective taskforce;

(3) have a good ERP system so that we can easily get the data or information requested in the PAS 2050; and

(4) Good assistance in obtaining the MSDS information from raw material suppliers.

CHAPTER 6.

CONCLUSIONS

Carbon footprint inventory can provide an opportunity to adjust the textile supply chain operations.
Product carbon footprint is a useful tool for understanding the climate impacts of bringing products and services to market. The insight it can offer into a product's supply chain and its efficiency of production can be used to improve product environmental performance and identify cost savings, often yielding a significant return on investment. Provided with this level of insight, companies can align their business practices to minimize risk and maximize competitive advantage, especially in sectors where life-cycle climate impacts are used for product differentiation.

When we conduct a carbon footprint verification, we want to know the amount of direct and indirect carbon emissions generated from production processes. But which methodology or tool we should use to calculate emissions? So, in the APEC project, we introduce a measurement tool which we call it "LCIQ" -- standards for Life Cycle Inventory Questionnaire.

Companies can also use the results of product carbon footprint to provide consumers with information that helps them make informed decisions. In particular, the use of product carbon labels is expected to increase as a means of communicating life-cycle GHG emission impacts to consumers and others who purchase and use goods and services. The goal and scope definition includes defining the system boundaries and the functional unit of analysis.

Although a good ERP system plays an important role in the success of carbon footprint inventory in the case study, both the concept of footprint inventory and the LCIQ calculation process can be applied to any environmental footprint case. The textile industry output is about 60 billion kg of fabric annually around the globe. And according to a report from the United Nations Industrial Development Organization, in 2004, the textile industry used 26% of global energy use and produced 18.5% of CO_2 emissions. Of course, the manufacturing technology has improved with time. But, we are still heavily polluting the place we are living in. So, we definitely need to do it for our environmental sake.

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ABBREVIATIONS AND ACRONYMS

APEC = Asia-Pacific Economic Cooperation

BSI = British Standards Institution
FTC = Formosa Taffeta Co., Ltd
GHG = Greenhouse gas

GWP = Global warming potential

ISTWG = Industrial Science and Technology Working Group

KG = Kilogram

LCA = Life-cycle analysis

LCIQ = Life-cycle inventory questionnaire
MSDS = Materials safety data sheet
OECD = Organization for Economic Co-operation and Development
TKM = Tonne-kilometre
TTRI = Taiwan Textile Research Institute

UNEP = United Nations Environment Programmer

Appendix A to C can be viewed at http://publications.apec.org/publication-detail.php?pub_id=1443