Developing Low Carbon Supply Networks: Influence, Measurement, and Improvement

by

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Climate change has emerged as one of the most serious challenges faced by human beings. As manufacturing globalisation involves more and more emerging nations, a greater proportion of CO_2 emissions is generated from developing countries. The dilemma between fast industrial development and carbon reduction makes firms in developing nations reluctant to take serious commitment and actions in CO_2 emission reduction in their global manufacturing practices. From a theoretical perspective, low-carbon supply networks research is also still in its infant stage and needs more explorations and development. Therefore this research aims to address the research question: "How can supply networks in developing countries be developed to reduce carbon emission?" Especially it focuses on:

- An influence process to engage companies in developing countries to reduce carbon emission
- A typology of carbon emission assessments in supply networks
- An initial process of implementing carbon-reduction projects in supply network

The research adopts theory building approach based on multiple case studies. The units of analysis are carbon reduction project of focal firms and initiatives of Non-Government Organizations (NGO).

Drawing upon the cases, this research develops a general framework for developing low-carbon supply network, including three parts namely network **influence**, network CO_2 **measurement**, and network CO_2 **improvement** (**IMI**), with the three process models accordingly proposed. In the 'influence' process, based on resource dependence theory (RDT), this research illustrates a categorization of influence choices and a typology of influence pathways, which both underpin the four-step influence procedure proposed later. In the 'measurement' process, this research proposes a goal-oriented carbon footprint measurement guideline. In the "improvement' process, an initial framework to classify carbon reduction projects and implementation process model of these projects are both built based on the analysis of primary case studies and Carbon Disclosure Project (CDP) database which contains corporates' carbon reduction practices.

Overall this research makes contributions in the following aspects: (1) this research advocates **IMI** framework as a pathway to de-carbonize supply networks, contributing to manufacturing system's evolution to sustainable paradigm; (2) It integrates the institutional, stakeholder and network theory in the context of de-carbonization, and extends the research scope of operations management; (3) The research contributes to life cycle assessment (LCA) literature by exploring supply network coordination during the LCA procedure; (4) The research also contributes to green supply chain literature by providing insights from firms' de-carbonization projects in supply network. (5) In practice, the **IMI** three-process models can help practitioners to implement de-carbonization management, serving as a preliminary guideline to follow. The potential audience of this research can be MNCs, NGOs, government bodies, consultants, and any organization or individual who aim to change industrial system in the pursuit of climate change mitigation.

PREFACE

Except for commonly understood terms and accepted ideas, or where specific reference is made, the work reported in this dissertation is my own and includes nothing which is the outcome of work done in collaboration. No part of the dissertation has been previously submitted to any university for any degree, diploma or other qualification.

This dissertation consists of 64899 words, 98 figures and 56 tables.

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Glossary

6Rs	Role, Relationship, Region, Resource, Risk, Reconfiguration
BATs	Best Available Technologies
BOM	Bill of materials
BRUNDTLAND	Brundtland Report promoting sustainable development
BSC	Balanced Score Card
BSI	British Standards Institute's
CCF	Corporate Carbon Footprinting
CCS	Carbon Capture & Storage
CDM	Clean Development Mechanism
CDP	Carbon Disclosure Project
CEO	Chief Executive Officer
CFC	Carbon Footprint of Corporate
CFP	Carbon Footprint of Product
CFT	Cross Function Team
CHP	Combined Heat & Power
CIM	Computer-Integrated-Manufacturing
CQC	Quality Certification Centre
CSC	China Steel Corporation
CSR	Cooperation Social Reports
DEFRA	Department of Environmental, Food & Rural Affairs
eDC	e-Enabling Data Centre
EHS	Environmental, Health & Safety
EICC	Electronic Industry Citizenship Coalition
EIO	Economic Input-Output
EIO-LCA	Economic Input-Output LCA
EPA	Environment Protection Agency
EPD	Environmental Product Declaration
ERP	Enterprise Resource Planning System
ESCO	Energy Service Companies
ESTC	Environmental Science Technology Consultants Corporation
FGR	Flue Gas Recirculation
GDP	Gross Domestic Product
GESI	Global e-Sustainability Initiative
GHA	Global Hectares
GHG	Green House Gases
HVAC	Heating, Ventilation and air-conditioning
ICs	Integrated Circuits
ICT	Information, Communication & Technology
IDB	Industrial Development Bureau
IMP	Industrial Marketing and Purchasing
IPCC	International Panel on Climate Change
ISO	International Standards Organization

ITRI	Industrial Technology Research Institute
JIT	Just-In-Time
JPM	Japanese Production Management
KPIs	Key Performance Indexes
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCMP	Low Carbon Manufacturing Programme
"MEW"	Material, Energy, Waste
MFA	Material Flow Analysis
MILP	Mixed Integer Linear Programming
NYSE	New York Stock Exchange
OEM	Original Equipment Manufacturer
PAS	Publicly Available Specification
PAS2050	Public Available Specification 2050
PCF	Product Carbon Footprinting
PCR	Product Category Rules
P-D-C-A	Plan, Do, Check, Action
PFC	Perfluorinated Compounds
PLM	Product Lifecycle Management System
PMS	Predictive Manufacturing System
PRD	Pearl River Delta
QA	Quality Assurance
RBT	Resource-base-view
RDT	Resource Dependence Theory
SC- SCOR	Supply Chain Operational Reference
SCC	Supply-Chain Council
SR/P2	Source-Reduction/Pollution-Prevention
SSCM	Sustainable Supply Chain Management
TNCs	Trans-National Corporation
TQE	Total Quality Excellence
UNFCCC	United Nations Framework Convention on Climate Change

CHAPTER 1 INTRODUCTION

1.1 Research Background

Climate change is emerging as a major challenge for modern society (Carbon Trust, 2014). Government, business, and wider society all have a shared responsibility to tackle the issue. It is likely that as the change of climate causes higher temperatures that this would increase heat-related stress on crops and livestock; more intense precipitation events resulting in increased floods and soil erosion; and the obvious retreat of mountain glaciers and the shrinking of the arctic ice cap causing sea-levels to rise[1]. The impact of climate change poses a significant risk not only to the earth's ecosystem but also directly to human being's food security (Schmidhuber and Tubiello 2007), safety (extreme weather) (Reichstein et al. 2013), and health (spread of infectious diseases) (McMichael 2003), etc. On the economic side, the widely known Stern Review claimed that, without action, the overall costs of climate change will be equivalent to losing at least 5% of global gross domestic product (GDP) each year, now and forever(Stern, Britain, and Treasury 2006). And Stern further proposed that the investment of 2% of global GDP per annum is required to avoid the worst effects of climate change[2].

Despite there being disputes on the dominant reasons that cause climate change (Goertzel 2010), IPCC (International Panel on Climate Change) has affirmed by its scientific findings that the largest driver of global warming is carbon dioxide (CO_2), including emissions from fossil fuel combustion, cement production, and land use changes such as deforestation. "It is extremely likely (95-100%) that human influence has been the dominant cause of the observed warming since the mid-20th century." (Stocker and Qin 2013). In fact, Climate change is only one of many conflicts between environmental protection and human being's industrial development.

The Conflict between Environment and Industrial Development

The first industrial revolution started in Britain from about 1760 to the early 19th century, by the invention and use of machine and steam power engines. The large-scale utilization of energy and materials, which was enabled by machine invention, marked the beginning of traditional industrialization, and also opened the new page in the human drilling of the earth resources and the

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[1] Cited from IPCC Third Assessment, Climate Change 2001, Report on Impacts, Adaptation and Vulnerability (Policymakers Summary).

[2] Jowit, Juliette; Wintour, Patrick (26 June 2008). "Cost of tackling global climate change has doubled, warns Stern". The Guardian (London).

resulting destruction of the environment. The traditional British-way of industrial development is not wrong in itself but had proceeded with the assumption that the environment had an infinite ability to support the pollution that manufacturing caused and that there would be infinite supplies of natural resources to sustain it. As early as 1920s the neoclassical economists have recognized the insufficiencies associated with the technical externalities generated by industrial production (Pigou 1924). But it was not until 1962 with the publication of Carson's book 'Silent Spring' (Carson 1962)that environmental protection issues became widely recognized. The new wave of concerns to consider sustainable development started afterwards, including several seminal milestones—the 'Limits to Growth' from the Club of Rome discussion (Meadows, Goldsmith, and Meadow 1972), Brundtland Report promoting sustainable development (BRUNDTLAND 1987), and the 1st Earth Summit in1992. The climate change issue was firstly tackled from 1992 at an international level. The United Nations Framework Convention on Climate Change (UNFCCC) was formed to provide a framework for negotiating specific international treaties to set national-level binding limits on GHG. The most successful treaty was the Kyoto Protocol on 1997, which concluded and established legally binding obligations for major developed countries (except U.S) to reduce their GHG emissions. The following Figure 1.1 shows some of the landmarks of environmental and climate change events.

The UK is one of leading powers in promoting the tackling of the climate change issue. In its 2008 Climate Change Act UK established the world's first legally binding climate change target, aiming to reduce the UK's greenhouse gas (GHG) emissions by at least 80% (from the 1990 baseline) by 2050. Such legislation tools empower governments to engage with society and industries to take action in mitigating climate change. Similar legislation frameworks have been introduced in EU countries and other developed countries (Hitchcock 2012). Under multiple pressures from government legislation and society, companies have to embrace low carbon management(Weinhofer and Hoffmann 2010; Busch and Pinkse 2012; Okereke and Russel 2010).

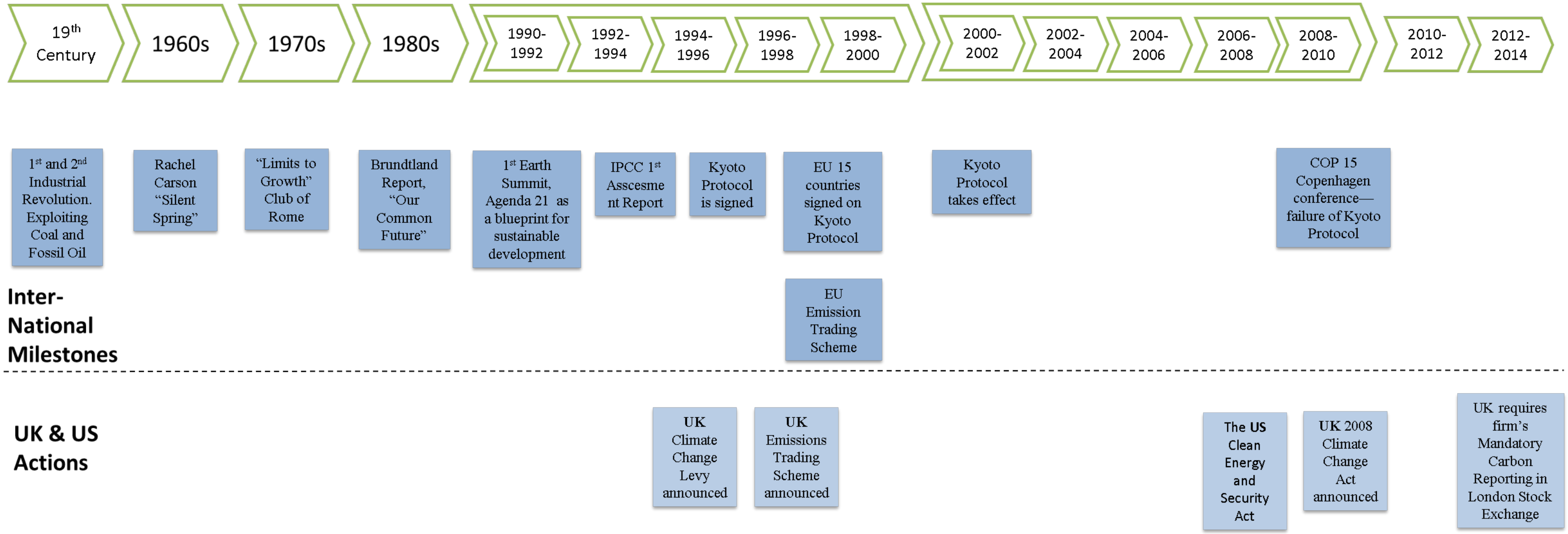


Figure 1.1 Milestones of Environmental Protection & Global Warming Events

Higher Conflicts in Emerging Economies

It has been shown that emerging economies suffer more conflicts between environmental protection and economic development due to their relatively larger population and lower technology industrial level. Developing countries population equals 80% of the world population (World Population Data Sheet 2013), and if the life style of the U.S. people was adopted by the world population, then about 5 Earths would be needed to sustain it, and for European countries it would be 3 ("Living Planet Report 2012" , 2012). Moderate UN scenarios have suggested that if current population and consumption trends continue, by the 2030s, the equivalent of two Earths is needed to support demand.

For the firms in emerging economics, copying the traditional industrial development 'route' is a relative simple way, but it is not sustainable under the climate change issue. And they face more difficulties to conduct the de-carbonization due to lack of supporting infrastructure (Jeswani, Wehrmeyer, and Mulugetta 2008), sufficient technology and knowledge (Binh and Khang 2014), and last but not least, their regional legislation pressure (Dahlmann, Brammer, and International Association for Business and Society 2013). All these issues make the engaging of firms in developing economies complicated.

Operations Management Research Responses to Climate Change Issue

From the 1990s research has begun to explore the 'Green Wave'—environmentally responsible requirement of the manufacturing system(Abend 1994; Hitomi 1996). Serkis's (2001) first systematically reviewed the sustainable research trend in manufacturing research. Until 2000s the focus of the global warming problem has driven the researchers' attention from the broad arena of the 'Green' issue into a more specific 'low carbon' stream, that is considering the issues of risks (Austin et al. 2004), measurement (Petersen and Solberg 2002), mitigation (Lema and Ruby 2006) in the different industries (Subak and Craighill 1999; Floros and Vlachou 2005; Huntzinger and Eatmon 2009; Chaudhary, Bhagat, and Gulrajani 2009; Song and Lee 2010). As enterprises with a formidable knowledge, cutting-edge technology, and global reach, TNCs (Trans-National Corporation) are necessarily among the primary actors in the global effort to reduce greenhouse gas emissions and a shift towards a low-carbon economy (UNCTAD 2010 Report).

The trend to de-carbonization, however, is bringing about some fundamental transformation in the logic of designing the manufacturing system and supply network concepts and patterns, from pursuing low cost, high flexibility, strong robustness adding the low carbon consideration. The firm that successfully manages the low carbon transition obtains a competitive advantage on multiple aspects: entry to the market of environmentally concerned customers, gaining legitimacy from the external environment, and achieving a better supply network management, etc. "businesses that ignore the debate over climate change do so at their peril" (Crane 2004). Hoffman (2004) explored the potential voluntary carbon reduction benefits for firms by dividing them into 7 categories: operational improvement, anticipating and influencing climate change regulations, accessing new sources of capital, improving risk management, elevating corporate reputation, identifying new market opportunities and enhancing human resource management.

The above-mentioned practical and research requirements raise many new questions:

- *What are the economical and non-economical drivers and motivations for manufacturing firms to manage carbon emission performance?*
- *What are the stakeholders' pressures and institutional pressures interplaying to stimulate the firms in the carbon emission reduction transition?*
- *How can firms in developing economies be led to proactive climate change mitigation actioners rather than reactive obstructers?*
- *How can manufacturing system as a whole evolve to a sustainable developing paradigm?*
- *What are the procedures and steps taken to enable firms to start carbon emission management in their supply network?*
- *What is the internal and external support that firms need in order to routinize the emission mapping?*
- *How can firms rationalise their operations on site and their supply network to balance economic constraints and carbon constraints?*
- *How many options do firms have to effectively configure the operational systems and satisfy carbon reduction improvement requirements?*
- *What are the suitable processes for firms to systematically conduct de-carbonization actions?*

Since the carbon issue is relatively new to the arena, extant research has not yet extensively covered these above issues, which are crucial for the firm's strategic decisions and their design of supply network transition to a low carbon status (Gunasekaran and Spalanzani 2012; Cordero 2013). As shown in Figure 1.1, PAS2050 and ISO14067 are both protocols that measure the carbon emission of products. These protocols make the carbon reduction pressure naturally diffuse along the supply network because life cycle assessment, which involves both the upstream and downstream supply network, is the underpinning method of these protocols. The above issues are filling serious 'gaps' in the carbon management strategy of a firm's operation in the supply network.

The carbon concerned characteristics of manufacturing systems involve many new and wider perspectives covering network design, operation and improvement. These new perspectives require new understanding about the nature of manufacturing networks and the mechanisms involving actors in the network. This research work should benefit not only supply network but also the manufacturing system research generally.

1.2 Research Aims and Priorities

1.2.1 Aims of the Research

This research seeks to extend the understanding to a supply network concept under the new requirement of a low carbon transition, including exploring the linkages, coordination and continuous improvement activities. It also aims to gain better understanding about the network's internal structure, behaviour and characteristics, which can help the development of tools and processes to assist organizations or individuals to involve firms to conduct low carbon action and assist managers to improve their strategy, and decisions about the supply network de-carbonization. The aims of this research are to:

- Develop understanding about supply network linkages, coordination and improvement under de-carbonization pressure;
- Develop a process to enable supply network de-carbonization transition

The focus of the work is on the supply network of the firm, alongside the extended participants of the network including government, consultancy, NGO, rivals, suppliers and customers, etc.

According to the research aims mentioned above, the objectives of this research are:

- Review and synthesise the theories in the fields of a sustainable supply network, de-carbonization and firms' behaviour in the supply network;
- Develop a robust research framework for understanding the purposes, processes and strategies of firms' de-carbonization practices in the supply network;
- Conduct an appropriate research design and apply a sufficient data collection, and data analysis to answer the following questions:
    - **How** can firms in emerging economies be influenced to take carbon reduction action in the supply network context?

    - **How** can firms measure the carbon emission performance in the supply network?
    - **What** could firms do to improve their carbon emission performance in the supply network?
- Conclude the research contribution to related theories in the sustainable supply network and illustrate the potential implication to practices.

1.2.2 Research Approach and Process

By adopting the research strategy of theory building from multiple-case studies, this research is intended to capture the good practices from low carbon supply network system change practices, and to contribute to the theory-building from the supply chain management, manufacturing, and sustainability literature. Meanwhile, it aims to provide strategic insights that can be used by managers in supply network planning and reconfiguration.

The research process follows two stages.

Stage One: a series of preliminary case companies are studied and some basic understanding of low carbon practices. The outputs are initial observation and understanding about the industry issues, network structure, links, projects of de-carbonization, and industry protocols. A focused research agenda, and conceptual network model is generated as well.

Stage Two: major cases are used to develop a process approach to develop the content within the conceptual framework. Moreover, cases are used to populate and validate emerging patterns of network linkages, behaviours, and a coordination mechanism.

1.3 Overview of the Dissertation

This dissertation consists of two main parts introducing the research preparation and low carbon supply network processes. The first chapter gives an introduction to the overall background, practical needs for low carbon supply network study, and structure of the dissertation, the exploration of current up-to-date literature is reviewed in Chapter 2, which covers the manufacturing system needs, sustainability concepts, principles, decarbonisation in supply chain, and organizational behaviour in business network. Research methodology and design are illustrated in Chapter 3 as well as the criteria to select case study companies and relevant data. An overview of all the company cases is also demonstrated in this Chapter, and the demonstration of each case data is arranged in the following three chapters to support data analysis in network influence, carbon footprint measurement and carbon emission improvement. In Chapter 4 the research is focus on the pressure and influence from external business environment towards the firm, and different influence strategies are explained. Carbon footprint measurement methods and strategies are the key topic for discussion with a three-type footprint measurement process is given. Following the measurement result, carbon emission improvement in supply network level is further explored in Chapter 6 using case studies in multiple industries. In Chapter 7 discussion in stakeholder-institutional business network, performance measurement theories, green supply network and the relevant theoretical contribution are discussed, followed with the discussion into future research direction. The overall structure of this thesis is shown in Figure 1.2.

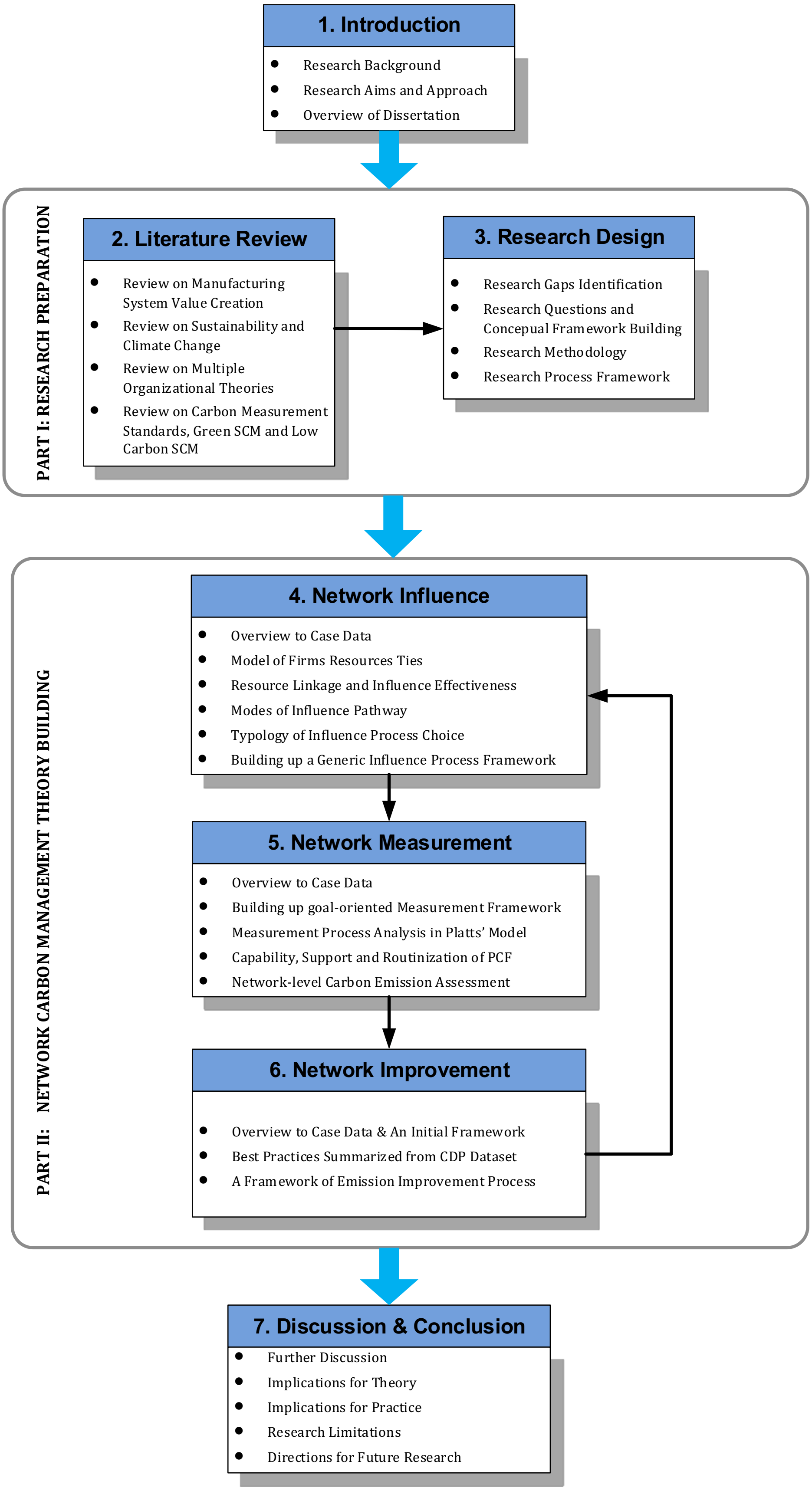


Figure 1.2. Dissertation Structure

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

The UK was the origin of the first industrial revolution, which helped the transition of human society from being an agricultural society to an industrial society. This revolution then spread to other modern countries such as US, Germany, etc. During these industrial revolutions, the production model focused on making products through low cost and high volume, and ignored the value of the external natural environment. This model presumes that there is an infinite supply of natural resources, which can suit small amounts of people, but as the population of the earth increases, the environment cannot sustain the needs of such a large group of human beings to live the same way. Although some improvements have been practiced e.g. lean production, it is necessary to introduce a more systematic and more holistic thinking to the industrial system and the value creation mind set. So this chapter reviews the revolution of manufacturing research since Taylor's scientific management, and then the basics of supply network management. Origins of sustainability issue and green supply chain management, especially the low carbon issues are covered afterward. The embedded theories of influencing a firm's behaviour, including stakeholder theory, institutional theory, resource dependent theory, and drivers for de-carbonization are then reviewed. Following the basic logic of "things measured get managed", the basics of life cycle assessment and carbon footprint measurement protocols are introduced.

2.2 Manufacturing Systems-Industrialization for Developments

2.2.1. Industrial System and the Modern Industrialization

Modern industrialization history is the history of pursuing productivity via new technology and management theory. The first industrial revolution started in Britain from about 1760 to the early 19th century, by the invention and using of textiles machine, steam power engines and iron making. The utilization of large scale energy and materials, which was enabled by machine invention, marked the beginning of industrialization in human history. These machines greatly increased the productivity of manufacturing.

The electricity generator and petrol engine started the second phase of industrialization, coming together with a thriving steel making industry, and petro-related chemical, and transportation industry from 1860s. The leap from using coke to petrol turns a new page in the human's drilling of the resources from the earth, while again increasing the productivity again significantly.

The technology revolution starts with the invention of the silicon-based computer, nuclear power generators and bio-technology. Although researchers have argued about the differences between the technology revolution and the industrialization revolution, the consensus is that productivity is again greatly boosted. The significant result is that there is a wider range of exploitation from the earth's natural resources and a huge demand for energy in the form of petroleum products and electricity. (Rifkin 2011)

Along with the technology development, the modern management research stems from manufacturing industry, and is the recognized start of modern operations management in late 19th century, or named Scientific Management at the time, Taylor's introduction to relate scientific method to production is seminal to management research.(Kanigel 2005; Sprague 2007). His book "The principles of Scientific Management, Engineering and Management" (Taylor 1914) has invented the term 'management' as all the researchers study nowadays, and not only manufacturing management (Drucker 1994), but he also changed the focus of study—from the study of machinery to the study of workers, their work and management. The essence of Taylor's theory is measuring, documenting, standardization of each action, segregating the planning of work from its execution, excelling workers' performance—simply speaking, enabling workers to achieve best work practices for each job(Kanigel 2005). Its main objective was improving labour productivity.

Henry Ford's automobile assembly line is an icon of manufacturing industry(Sprague 2007) representing the first example of mass production. He described his contribution as being "…to keep everything in motion and take the work to the man and not the man to the work"(Henry and Samuel

1926). Consistent to Taylor's principles(Sprague 2007), Ford introduced the standardization of semi-products/components, and expanded the utilization of assembly lines (the assembly lines application can date back to Qin Dynasty in ancient China and Venice in Italy). The objective of Ford's method of manufacturing is the same as Taylor's Scientific Manufacturing—boosting productivity—"We want to use material to its utmost in order that the time of men may not be lost. Materials cost nothing", stated in Ford's book, reflecting the majority view concerning material resources at that time.

After World War II, the 'HMMS' model has been developed, the core of which is a linear-quadratic model of aggregate production planning (Singhal and Singhal 2007). From 1960s Elwood Spencer Buffa Buffa published a textbook "*Modern Production Management*", consolidating knowledge from various streams of production management, including the early adoption of computer technologies to production management (K. Singhal, Singhal, and Starr 2007).

Japanese production management (JPM) became a dominant influence in the field of operations management when, in the early 1980s, knowledge of its main elements became known beyond Japan(Schonberger 1982, 2007). Schonberger identifies five generations of JPM which later dovetailed and was enhanced by western companies.

Table 2.1. Five generations of Japanese Production Management

(Source: Schonberger, 2007)

1st Generation	Quality Circle, Quality Management Movement, JIT(Just-In-Time)
2nd Generation	Cost of Quality, Design for Manufacturing and Assembly
3rd Generation	Western modifications and enhancements
4th Generation	Lost decade
5th Generation	Global best practices anchored by an enduring Japanese core

The key logic of JIT/TPS (Toyota Production System) which is different from western automobile manufactures is to reduce cost by eliminating waste, not wasting any material or machine time (Holweg 2007). The JIT is the precursor of lean manufacturing, the latter got the term after John Krafcik's 1988 article was published "Triumph of the Lean Production System"(Krafcik 1988). Both of these concepts focus on waste reduction. The waste are transport (moving products that are not actually required to perform the processing), inventory (all components, work in process and finished product not being processed), motion (people or equipment moving or walking more than is required to perform the processing), waiting (waiting for the next production step, interruptions of production during shift change), overproduction (production ahead of demand), over processing (resulting from poor tool or product design creating activity), defects (the effort involved in inspecting for and fixing defects) (Womack and Jones 2010). Principles and tools such as found in the Kanban system, Just-in-time inventory, levelling out the workload, standardization of tasks were invented and implemented.

The waste reduction logic in lean manufacturing focuses on time, labour, inventory, overproduction etc., but the negative environmental impact is not part of the focus.

After the lean manufacturing stream, many new models of the manufacturing system emerged. Enabled by the IT system, agile manufacturing was promoted, with emphasis for a quick response to customer needs, via modular product design, shared demand information across a supply chain, and virtual alliance partnership with other companies. Computer-Integrated-Manufacturing (CIM) system links all functional units in firms including the design, analysis, planning, purchasing, cost accounting, inventory control, and distribution with the factory floor manufacturing processes, materials handling and management, via computers(Kalpakjian 2001; Waldner, Waldner, and Waldner 1992). It promotes direct control and monitoring of all the operations on the shop floor. Other new advanced manufacturing systems include Bionic manufacturing(Okino 1993), fractal manufacturing (Tharumarajah 1996), disperse network manufacturing(Noori and Lee 2006), etc. Stepping into the 21st century, new types of manufacturing system emerge as different innovative technologies are applied to the production process. With the advent of smart sensors such as RFID technologies collecting data in equipment and manufacturing process has become a simple exercise, contributing to a ‘big data’ environment. Therefore a new paradigm—predictive manufacturing system (PMS) emerged so that the system is programmed with certain type of intelligence to enable machine and systems with “self-aware” capabilities. The system “allows assets to estimate their own condition, detect the presence of a fault or an anomaly, infer future fault events and even diagnose the potential root cause of the problem.”(J. Lee et al. 2013). The advantage of this new system is the data transparency available to achieve overall enterprise control and optimization. The management group are able to access the appropriate information (such as actual condition and state of machines, not just cycle times) to determine factory-wide overall equipment effectiveness, such as better just-in-time planning. This transparency can benefit a multiple management system e.g. enterprise resource planning system (ERP), and product lifecycle management system (PLM).

The development of stereolithographic technology brings in fundamental change to manufacturing process. It is a milestone of allowing direct digital manufacturing from CAD to physical parts, making rapid prototyping techniques leap to rapid manufacturing (Hon 2007). The addictive manufacturing technology is completely changing the manufacturing landscape especially in small-bulk, customized production.

A report summarising the future of UK manufacturing (“Future of Manufacturing: A New Era of Opportunity and Challenge for the UK - Publications - GOV.UK” 2014) summarized the technologies changing the manufacturing system paradigm (Figure 2.1).

PERVASIVE TECHNOLOGY	LIKELY FUTURE IMPACTS
Information and communications technology (ICT)	Modelling and simulation integrated into all design processes, together with virtual reality tools will allow complex products and processes to be assessed and optimised, with analysis of new data streams.
Sensors	The integration of sensors into networks of technology, such as products connected to the internet, will revolutionise manufacturing. New data streams from products will become available to support new services, enable self-checking inventories and products which self diagnose faults before failure, and reduced energy usage.
Advanced & functional materials	New materials, in which the UK has strong capabilities, will penetrate the mass market and will include reactive nanoparticles, lightweight composites, self-healing materials, carbon nanotubes, biomaterials and 'intelligent' materials providing user feedback.
Biotechnology	The range of biotechnology products is likely to increase, with greater use of fields of biology by industry. There is potential for new disease treatment strategies, bedside manufacturing of personalised drugs, personalised organ fabrication, wide availability of engineered leather and meat, and sustainable production of fuel and chemicals.
Sustainable / green technologies	These will be used to reduce the resources used in production including energy and water, produce clean energy technologies, and deliver improved environmental performance of products. Minimising the use of hazardous substances.
SECONDARY TECHNOLOGY	
Big data and knowledge based automation	These will be important in the on-going automation of many tasks that formerly required people. In addition, the volume and detail of information captured by businesses and the rise of multimedia, social medial and the internet of things will fuel future increases in data, allowing firms to understand customer preferences and personalise products.
Internet of things	There is potential for major impacts in terms of business optimisation, resource management, energy minimisation, and remote healthcare. In factory and process environments, virtually everything is expected to be connected via central networks. Increasingly, new products will have embedded sensors and become autonomous.
Advanced and autonomous robotics	Advances are likely to make many routine manufacturing operations obsolete, including: healthcare and surgery, food preparation and cleaning activities. Autonomous and near-autonomous vehicles will boost the development of computer vision, sensors including radar and GPS, and remote control algorithms. 3D measurement and vision will be able to adapt to conditions, and track human gestures.
Additive manufacturing (also known as 3D printing)	This is expected to have a profound impact on the way manufacturers make almost any product. It will become an essential 'tool' allowing designs to be optimised to reduce waste; products to be made as light as possible; inventories of spare parts to be reduced; greater flexibility in the location of manufacturing; products to be personalised to consumers; consumers to make some of their own products; and products to be made with new graded composition and bespoke properties.
Cloud computing	Computerised manufacturing execution systems (MES) will work increasingly in real time to enable the control of multiple elements of the production process. Opportunities will be created for enhanced productivity, supply chain management, resource and material planning and customer relationship management.
Mobile internet	Smart phones and similar devices are positioned to become ubiquitous, general purpose tools for managing supply chains, assets, maintenance and production. They will allow functions such as directed advertising, remote healthcare and personalisation of products. Linked technologies include battery technology, low energy displays, user interfaces, nano-miniaturisation of electronics, and plastic electronics.

Figure 2.1. Important technologies for future manufacturing activities (UK Government Office for Science, 2013)

In the following Table 2.2. the evolution of manufacturing models and their objectives are summarized:

Table 2.2. Evolution of Main-Stream Manufacturing Models

Main Stream of Manufacturing Models	Objectives
Scientific Manufacturing	Scale Driven
Ford's Method	Scale Driven
Just-in-time/Lean Manufacturing	Cost Driven, Quality Driven
Agile Manufacturing	Response-rate / Flexibility Driven
Bionic manufacturing, fractal manufacturing, CIMS, etc.	Flexibility Driven, Technology Innovation Driven
Predictive Manufacturing	Information transparency for optimization

Similar to these objectives evolution, Hon (2005) proposed a manufacturing system performance measurement framework based on 5 metrics and 5 levels. The five major metrics are time, cost, quality, flexibility and productivity, and the five levels cover machine, cell, line, factory, and network level.

2.2.2 The Awareness of Environmental Issues

From the review of the last section, it can be found that it is not until recent decades that the 'Sustainability/Green' issues have come to be main-stream concerns of industrial development. This section reveals some of the milestones of awareness made to environmental problems along with industrial evolution in both society and in the academic field.

The evolution of awareness to environmental issues

Long ago the neoclassical economists have (as early as 1920s) recognized the insufficiencies associated with the technical externalities generated by production and suggested that governments tax polluters an amount equivalent to the social cost of pollution that would harm the whole community (Pigou 1924). But the severity of these negative externalities of human activities was not made aware to public until the book 'Silent Spring' and following a motion drafted in 1960(Carson 2002).

Carson's book has had the largest impact of its kind to raise public awareness about the issues of pesticides and also the ecological systems of earth, encouraging society to re-examine human being's relationship to the natural world. The book's impact directly resulted in greater restrictions being made on the use of chemicals and the banning of DDT. The US Environment Protection Agency (EPA) was established in 1970 partially due to this environmental movement. The Table 2.3 summarized some kind milestones in environmental protection after Carson's calling.

Table 2.3. Milestones in Environmental Protection

(Source: Worldwatch Institute and Environmental History Timeline[3])

1962	Carson's remarkable book '**Silent Spring**', calling attention to the threat of toxic chemicals to people and the environment.
1970	Forming of US Environmental Protection Agency (**EPA**)
1972	**The Club of Rome**, a group of economists, scientists, and business leaders from 25 countries, publishes The Limits to Growth, which predicts that the Earth's limits will be reached in 100 years at current rates of population growth, resource depletion, and pollution generation.
1974	**OZONE LAYER** problem-Chemists Sherwood Rowland and Mario Molina publish their landmark findings that chlorofluorocarbons (CFCs) can destroy ozone molecules and may threaten to erode the Earth's protective ozone layer.
1987	**The Brundtland Report**--The World Commission on Environment and Development publishes Our Common Future (The Brundtland Report), which concludes that preserving the environment, addressing global inequities, and fighting poverty could fuel—not hinder—economic growth by promoting sustainable development.
1992	The Convention on Climate Change sets non-binding carbon dioxide reduction goals for industrial countries (to 1990 levels by 2000). The final treaty calls for avoiding human alteration of the climate, but falls far short of expectations, largely due to lack of support from the United States
1992	1st **Earth Summit**-Most countries and 117 heads of state participate in the groundbreaking UN Conference on Environment and Development (Earth Summit), in Rio de Janeiro, Brazil. Participants adopt Agenda 21, a voluminous blueprint for sustainable development that calls for improving the quality of life on Earth.
1997	**Kyoto Protocol**--The Kyoto Protocol strengthens the 1992 Climate Change Convention by mandating that industrial countries cut their carbon dioxide emissions by 6 to 8 percent from 1990 levels by 2008-2012. But the protocol's controversial emissions-trading scheme, as well as debates over the role of developing countries, cloud its future.
2001	U.S. President George W. Bush announces that the United States will not ratify the Kyoto Protocol, saying that the country cannot afford to reduce carbon dioxide emissions.
2003	1st **Emission Trading Law in Europe**--Europe adopts first climate emissions trading law, giving carbon dioxide a market value across the EU when trading begins in 2005.
2005	With a majority of the world's nations ratifying, the Kyoto Protocol officially goes into force without the U.S. Countries signing the treaty agree to cut back emissions of heat-trapping gases to levels 5.2% below their 1990 emissions levels.
2006	**The Stern Review**, a report on scientific evidence of global warming— is published.
2007	European Union agrees to cut CO_2 emissions by 20% by 2020, compared to 1990 levels. Under the Kyoto protocol, the EU was already committed to an 8% decrease
2009	US EPA announces new **Clean Air Act** regulations to reduce greenhouse gas emissions from electric power plants. And India and China agree on a joint approach to climate talks "that promotes the interests of developing countries"
2009	**Copenhagen Fail**. Collapse of climate negotiations in Copenhagen. Representatives from 193 countries failed to reach a consensus on replacement for the 1997 Kyoto Protocol emissions treaty, set to expire in 2012.
2010	France sets a carbon tax of 17 Euros per ton on all fossil fuels, following similar but much higher taxes in Sweden (imposed as early as 1991), Denmark, Finland, Norway and Switzerland
2013	The city of Beijing struggles through months of life-threatening toxic smog in the winter of 2012 and spring of 2013.
2013	Intergovernmental Panel on Climate Change (IPCC), fifth assessment, says climate scientists are 95 percent certain that "human influence has been the dominant cause" of global warming.

The conflict between industrial development and environmental protection

For a long time, the traditional stream of operation management aims to improve performance on quality, speed, dependability, flexibility, and cost (Slack, Chambers, and Johnston 2010; Slack, Lewis, and Bates 2004), or basically similar objectives, or namely competitive priorities by Skinner's manufacturing strategy paper, which are cost, quality, dependability, flexibility, innovation (Skinner 1969). Pursuing the optimum of these goals are not wrong, but the background assumption that underpins all these objectives are the infinite ability of environment to support pollution from manufacturing and the infinite supply of natural resources. Not only the damage of production activity to the environment is not sustainable, but also the speed of consumption to natural resources in modern industrialization is beyond the capability of the earth's environment. In a small scope of a company's operating environment, firms have constraints imposed by the biophysical (natural) environment (Hart 1995; Brown, Kane, and Roodman 1994; Meadows, Meadows, and Randers 1992).

[3] Worldwatch Institute--https://www.worldwatch.org/brain/features/timeline/timeline.htm; Environmental history timeline--http://66.147.244.135/~enviror4/21st-century/20-teens/

In broad scope, human society as whole, also have constraints from the biological ecosystem of earth. Two decades ago, it was expected that is would be necessary to increase economic activity of that time five- to tenfold to provide the basic amenities needed to a population of 10 billion(MacNeill 1989; Hart 1995). The concept of an ecological footprint(Rees 1992) was created to measure human demands on the Earth's ecosystems. It is a standardized measure of demand for natural capital that may be contrasted with the planet's ecological capacity to regenerate it. According to WWF's Living Planet Report 2012, the average biologically productive area per person worldwide is approximately 1.8 global hectares (gha) per capita. The U.S. footprint per capita is 9.0 gha, which means that if the life style of U.S. people was adopted by the world population, about 5 Earths would be needed to sustain it("Living Planet Report 2012" 2013). Moderate UN scenarios suggest that if current population and consumption trends continue, by the 2030s, the equivalent of two Earths is needed to support demand. Although manufacturing industry is not the only industry that utilizes the planet's resources, but there are other sectors, including farming in modern times, that are also linked with the products of manufacturing industry. And the industry as a whole (including manufacturing industry, construction, agriculture, etc.) consumes 28% of the total world energy use according to IEA(ENCY 2013). So manufacturing industry has to play a key role in tackling the environmental issues. Although as early as the late 19th century research discussed issues about the creation of pollution waste in manufacturing process (Wallace 1885), but there was little reference in the manufacturing literature that was considering environmental issues(Corbett and Van Wassenhove 1991) before 1990s. It was not until 1996 that the term 'Green Manufacturing' appeared and saw the first bloom of related research, by the journal paper with this term that was published by the Society of Manufacturing Engineers(R. T. Smith and Melnyk 1996). The green manufacturing goes along with the effort of human society for sustainable development. As the field of manufacturing research expands to study the supply network, the green manufacturing expands to network level as well. The green supply network research and especially low carbon supply network review will be introduced in the Section 2.3.

As a basis, the next section 2.2.3 reviews the traditional supply chain and supply network management review.

2.2.3 Value Creation In Traditional Manufacturing System and Supply Networks Basics

In Porter's milestone work--"Competitive Advantage: Creating and Sustaining Superior Performance" (Porter 1985) in 1985, the concept of the value chain is defined as "A value chain is a chain of activities that a firm operating in a specific industry performs in order to deliver a valuable product or service for the market". Porter's value chain consisted of a chain of primary activities (inbound logistics, operations/productions, outbound logistics, marketing & sales, services) and support activities (firm's infrastructure, human resources management, technology development, and procurement) as Figure 2.2.

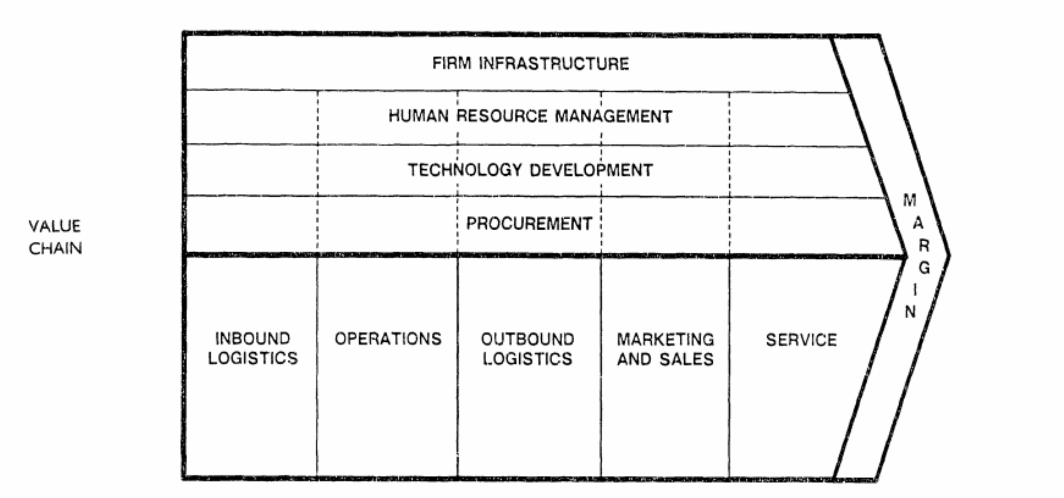


Figure 2.2. Value chain model

(Source: Porter, 1998)

Porter also stated that a firm's value chain forms part of a larger stream of activities, which Porter calls a *value system*. A value system, or an industry value chain, includes the suppliers that provide the inputs necessary to the firm along with their value chains. After the firm creates products, these products pass through the value chains of distributors (which also have their own value chains), all the way to the customers. All parts of these chains are included in the value system. To achieve and sustain a competitive advantage, and to support that advantage with information technologies, a firm must understand every component of this value system.

But in the term 'value chain' the definition of value is not specially discussed and is limited at its early stage: it mainly refers to the economic value to customers. Resource-base-view (RBT) researchers have argued that a resource has also been defined as valuable if it either enables customer needs to be better satisfied (Bogner and Thomas,1994 ;Verdin and Williamson,1994), or if it enables a firm to satisfy needs at lower costs than its competitors (Barney,1986a; Peteraf,1993). Resources are thought to have value in relation to their ability to meet customers' need (Aaker,1989 ;Aharoni,1993;PrahaladandHamel,1990 ,1994 ;Williams,1992).

Bowman & Ambrosini took the view of economists suggesting value has two main components: use value and exchange value (Bowman & Ambrosini 2000). Use value refers to the specific qualities of the product perceived by customers in relation to their needs. This perceived use value is subjective. It is defined by customers, based on their perceptions of the usefulness of the product on offer.

Both use value and exchange value focus on the customer, who can be a consumer or a client. The 'value' that is added via processes in manufacturers/service provider is for customer benefits, e.g. the functionality, convenience, well-being, etc. (Allee 2008; Bocken et al. 2013). The research focuses on only the customer needs rather than the need for all other stakeholders.

Porter & Kramer (2011) argued that for long time that "A firm is largely self-contained entity, and social or community issues fall outside its proper scope.", and "Firms focused on enticing consumers to buy more and more of their products", which results in "commoditization, price competition, little true innovation, slow organic grow and no clear competitive advantage" while "communities in which companies operate perceive little benefits even as profits rise." The concept 'shared value' is advocated by Porter and Kramer, which is defined as "policies and operating practices that enhance the competitiveness of a company while simultaneously advancing the economic and social conditions in the communities in which it operates". Shared value, in contrast to the conventional view of value, recognizes that both societal needs and conventional economic needs define markets in which companies are competing. The best companies should work on expanding "the total pool of economic and social value".

In pursuing this traditional management thinking of value, firms have numerous good practices (the pattern of which has been reviewed in Section 2.2.1) which researchers have observed, studied, summarized, and developed into different domains of business research—strategic management, R& D management, human resources management, supply chain & supply network management, etc. The underlying activities of value creation are the intervention of people, which is necessary to create new use values from the acquired resources (Bowman & Ambrosini 2000) . From the perspective of value chain research, firm gains competitive advantage from how it configures the set of activities involved in creating, producing, selling, delivering, and supporting its products or services.

From the perspective of manufacturing management research, as stated in Decision Support Tools at the Institute for Manufacturing, University of Cambridge, value creation is interpreted to be generated via the system of manufacturing/service organization: "The idea of the value chain is based on the process view of organizations, the idea of seeing a manufacturing (or service) organisation as a system, made up of subsystems each with inputs, transformation processes and outputs. Inputs, transformation processes, and outputs involve the acquisition and consumption of resources - money, labour, materials, equipment, buildings, land, administration and management. How value chain activities are carried out determines costs and affects profits. " (Rowe 1993).

This system view is aligned with manufacturing management and supply chain management research. For decades researchers have studied positioning and the best ways to design these activities, and also how to integrate them. The following sub-sections reviews these basics.

Supply Chain Management Concept and Evolution

The term "Supply Chain Management" is first appeared in the1980s (Oliver and Webber 1982) as the integration of the internal business functions of purchasing, manufacturing, logistics, sales, and distribution. Its development was along with the external logistics integration of customer and suppliers.

Hayes and Wheelwright looked at manufacturing as part of the commercial chain (Figure 2.3) that links the suppliers and customers. In this chain they viewed that the ultimate control of all the chain members can increase the value of a firm's revenue (Hayes and Wheelwright 1984).

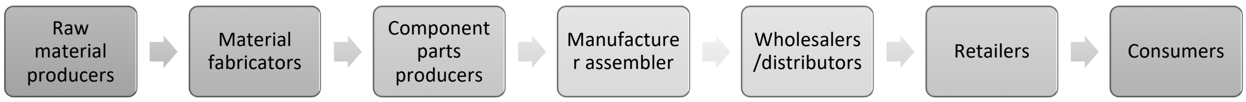


Figure 2.3 A commercial chain

(Source: Hayes & Wheelwright 1984)

During this period, the concept of supply chain management is confined within the chain level. Later on it is extended beyond the chain concept into inter-firm relationship and internationally dispersion perspective, which can be shown in the later literature.

When you take the discussion beyond the boundary of one firm's boundary or one plant, the logistics between firms or plants of firms becomes important and discussed a lot. The difference between logistics management and supply chain management have been researched and pointed out: logistics focuses on minimising total cost, while SCM is concerned more about long-term profitability (Lamey 1996). The clear distinction between SCM and logistics is clarified after the Council of Logistics Management modified the definition of Logistics as 'part of the supply chain process that plans, implements, and controls the efficient effective flow and storage of goods, services, and related information from the point-of-origin to the point-of-consumption in order to meet customers' requirements'.(Lambert and Cooper 2000) Moreover, Cooper also stated that supply chain literature has gone beyond logistics as the supply chain covers such issues that logistics does not cover such as information systems, new product development, and producing planning and control (Cooper, Lambert, and Pagh 1997).

Supply chain management definition has been continually proposed from various different dimensions including activities, chains, and networks. Christopher stated the SCM as "The network of organisations that are involved through upstream and downstream linkage in the different processes and activities that product utility in the form of products and service in the hands of the ultimate consumer"(Christopher 1999a). In the Global Supply Chain Forum Lambert stated that "The integration of key business process from end users through original supplier that provides products, services, and information that add value for customers and other stakeholders"(Cooper, Lambert, and Pagh 1997). In the council of SCM Professionals (CSCMP) the supply chain management is defined as follows that "Supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies."(CSCMP, 2009).

SCM fundamentally involves the management of demand chains from end users and supply chains of a product's origin, coordinating the flow of materials and information along the operations in the chains or networks. Along with the definition of SCM evolution from intra-firm perspective to inter-firm perspective, lots of SCM frameworks emerge. The frameworks of SCM provide a foundation for supply chain configuration/design and operation, and also provide the SCM theory. The low carbon emission SCM should be evolved from the existing theories in order to provide a holistic picture of carbon emission reduction potentials.

Hakansson stated that the supply chain management includes three key elements: actors, resources, and activities, with focuses on three levels: company, dyadic relationship, and network through purchasing and supply perspective (Haakansson and Snehota 1995). Hakansson's framework focuses on the relationship of the supply chain while providing no concrete structure of supply chain mapping. Cooper & Lambert considered the supply chain as a combination of three categories of activities: 1) supply chain network structure; 2) supply chain management components; 3) supply chain business process(Lambert and Cooper 2000). The supply chain network structure consists of the member firms and the links between these firms. Business processes are the activities that produce a specific output of value to the customer. The management components are the managerial variables by which the business processes are integrated and managed across the supply chain. The constituted framework is shown in Figure 2.4. They argued that the supply chain functions and business processes should be integrated internally within the focal firm and externally across the chain. And they also argued that supply chain network structure is different in different industries and could change over time.

Guidelines for the supply network structure decision making are given out, but lacking in details, (Mills, Schmitz, and Frizelle 2004) and also the infrastructure part of the design factors.

Hayes and Wheelwright gave out the structure and infrastructure categorization to the analysis of a firm's strategy (Hayes and Wheelwright 1984). Based on their work, Harland (Harland, Lamming, and Cousins 1999) developed the supply chain strategy identifying the structure and infrastructure elements of supply chain configuration. SC capability, actor configuration, facility configuration, make-or-buy decisions are the structure elements to considered while infrastructural elements are human resource policy, quality system, production planning and control, and new product development. Although Harland's work gives out a good classification of SC configuration elements, it also lacks operational details.

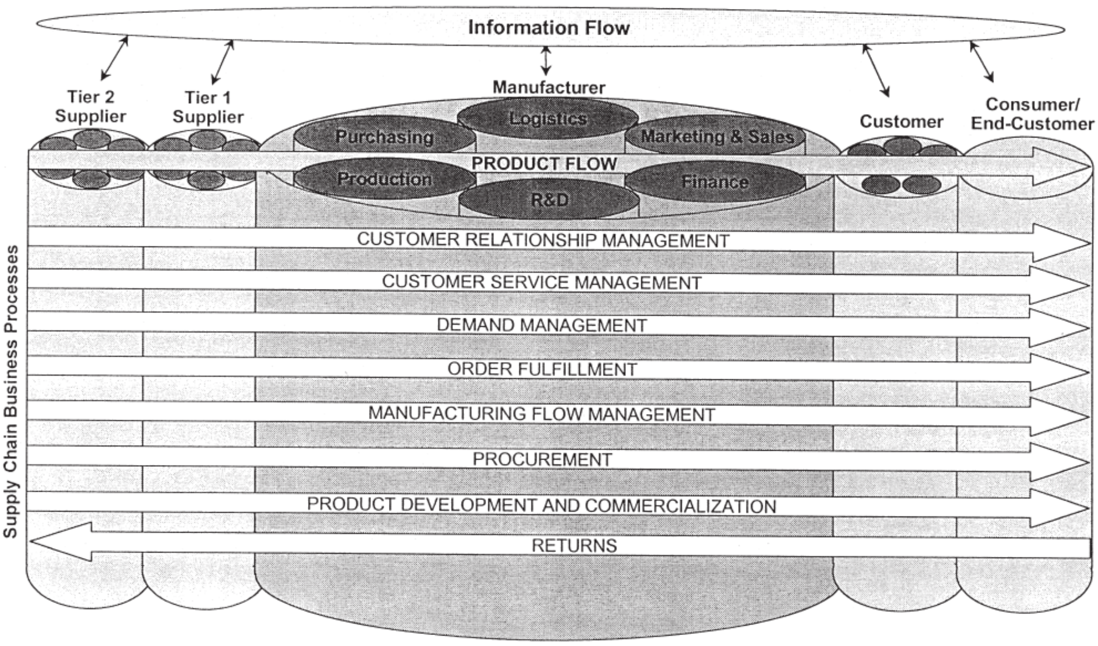


Figure 2.4 Supply chain management Model

(Source: Lambert & Cooper 2000)

Globalisation trend of SCM

From 1980s the issue of globalization began to emerge in the SCM literature discussing plant location decision making for multinational corporates (Hodder and Jucker 1982). For the potential benefits, such as efficiency, lower-cost, risk management, opportunistic development, exploiting product life cycle differences, procurement, closer to customers, pursuing potential abroad (Ghoshal 1987), firms keep exploring the international expanding opportunities. The globalization of SC brings in new issues as well, including longer distance, longer delivery lead time, lower control on subsidiaries, more inventory, and higher political and economic risks, etc.(Flaherty 1996; Das and Handfield 1997; Trent and Monczka 1998).

Supply-Chain Council (SCC, 2009) offers a practical tool to map SC - SCOR (Supply Chain Operational Reference) model. It integrates five business processes: plan, source, make, deliver, and return, within a company and links them with their suppliers and customers. To map a SC, the *geographical context* is the first step considered as the model recognizes the importance of *geographical location and transportation mode*. However, the model itself did not include supporting functions such as administration, sales and marketing, and R&D.

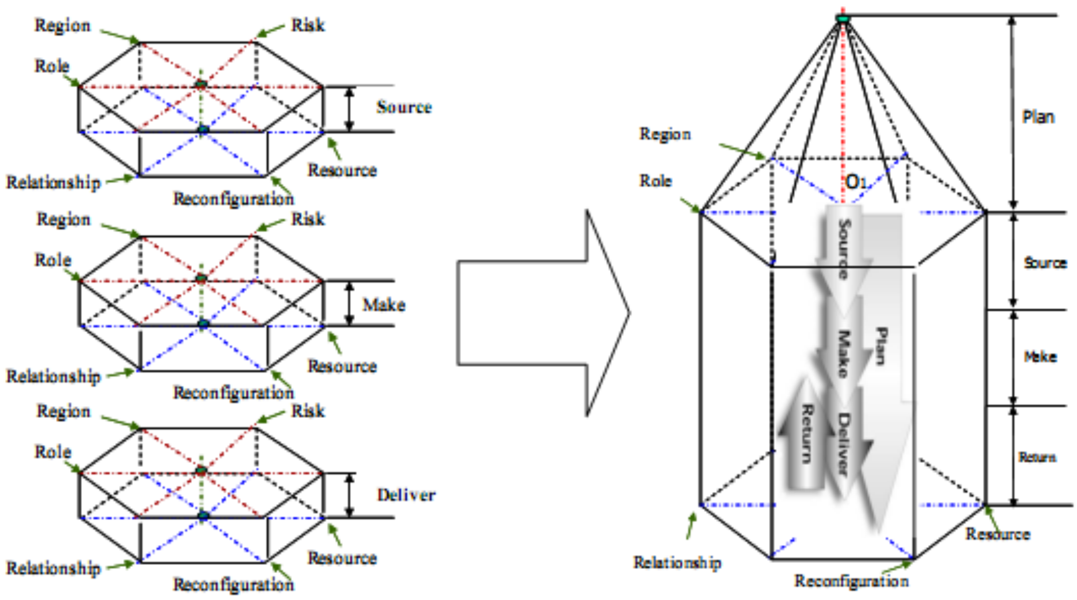


Figure 2.5 International supply network architecture

(Source: Shi & Li 2006)

Based upon the SCOR model, Shi and Li (2006) suggested six essential elements for international supply networks; *Role, Relationship, Region, Resource, Risk, and Reconfiguration (6Rs)*(Shi and Li 2006). They argued that these 6Rs existed in each individual organization. By putting organizations together into a chain according to their operations in the SCOR model (source, make, or deliver), a holistic view of SC could be visualized through the barn model (Figure 2.5). They asserted that the first three Rs (Role, Relationship, Region) referred to structural and static elements whereas the latter three Rs (Resource, Risk, Reconfiguration) presented more dynamic elements. This model extended the key decision areas of supply network towards more *international* perspectives but details within each key element were still unclear.

Supply Networks Concept

Harland defines supply chain management as "the management of a network of interconnected businesses involved in the ultimate provision of product and service packages required by end customers"(Harland 1996) which embedded the concept of network. Harland further defined supply networks as "[a network] nested within wider inter-organization networks and consists of interconnected entities whose primary purpose is the procurement, use and transformation of resources to provide packages of goods and services"(Harland et al. 2001). Or it is defined as "a complex adaptive system: it is emerging, self-organizing, dynamic, and evolving" where "a complex adaptive supply network is a collection of firms that seek to maximize their individual profit and livelihood by exchanging information, products, and services with one another"(T. Y. Choi, Dooley, and Rungtusanatham 2001). Supply network can be defined as a set of supply chains, embodying the flow of goods and services from original sources to end customers. Therefore supply networks not only comprise upstream suppliers but also downstream customers and/or distributors. Supply networks include the activities, actors and resources involved in the production and delivery of a product.

Two streams of research have been developed in the recent concept of 'supply networks': the research conducted by the Industrial Marketing and Purchasing (IMP) group and the researches focused on the operational and logistics-based view on supply chain management. The IMP group researchers developed the model to enable a better understanding of the markets needs and the relationship between the buyers and suppliers, embedding the context as 'supply networks'. This famous model includes the interconnected actors, resources and activities (Haakansson and Snehota 1995). The 'supply chain management' trend originated in 1980s to refer to the management of materials across functional boundaries within an organization, but has now been externalized beyond the boundary of the firm to include upstream production chains and downstream distribution chains (Christopher 1999b). The incorporation of the term 'network' into supply chain management reflects the attempt to expand the SCM and make it more strategic by digging the resource potential of the network in a more effective manner(Harland 1996).

In Ming Dong's paper (Ming, 2001) a supply chain can be defined as an integrated business process wherein a number of various business entities (i.e., suppliers, manufacturers, distributors, and retailers) work together. For years, researchers and practitioners have primarily investigated the various processes of the supply chain individually. Recently, however, there has been an increasing attention placed on the performance, design, and analysis of the supply chain as a whole.

Usually, there are two categories of configuration decisions on supply chain networks:

(1) Structural decisions (long term and strategic issues), which include

· Location of factory, warehouse and retailer

· Capacity for each facility

· Transportation modes

(2) Coordination decisions (short term and operational issues), which include

· Inventory deployment: where and how many

· Centralized or decentralized control for replenishment decisions

· Make-to-stock or make-to-order production policy

· Trans-shipment policies

· Allocation rules for insufficient stocks.

Supply chain configuration is concerned with determining supply, production and stock levels in raw materials, subassemblies at different levels of the given bills of material (BoM), end products and information exchange through (possibly) a set of factories, distribution centres of a given production and service network to meet fluctuating demand requirements.

Supply Networks Design

It is important to have an explicit knowledge and understanding of how the supply chain network structure is configured. Lambert & Cooper (Lambert and Cooper 2000) suggested that three primary aspects of a company's network structure are: 1) the members of the supply chain; 2) the structural dimensions of the network, and 3) the different types of process links across the supply chain. The first consideration is to identify supply chain members to be primary or supporting in the network in order to better allocate managerial attention and resources. The distinction of primary members and supporting members depends on whether the members are carrying value adding activities to the output. The second element to consider is the structural dimensions of the network. What needs to be determined are the horizontal structure, vertical structure, and the horizontal position within the supply chain. Horizontally the network contains multiple tiers, and vertically each tier includes different numbers of suppliers/customers. And the horizontal position describes the geographical points of a focal company which are close to the source of supply or near to the ultimate customers. As important as the first two considerations, identifying the four types of business process links is also of great significance.

The four types are: managed, monitored, not-managed, and non-member business process links. The difference of types depends on its importance for the focal company to integrate and manage (Figure 2.6).

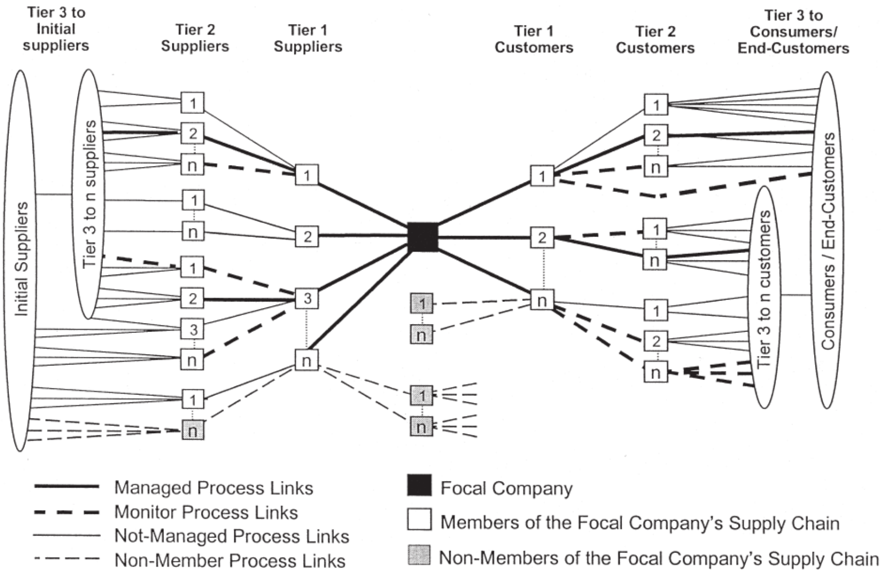


Figure 2.6 Types of intercompany business process links

(Source: Lambert & Cooper 2000)

A successful SCM requires a change from individual functions to integrating activities into key business processes. According to GSCF the key supply chain processes are: customer relationship management, customer service management, demand management, order fulfilment, manufacturing flow management, procurement, product development and commercialization and returns.

Srai and Gregory (2008) stated that despite an abundance of SCM frameworks, the supply network configuration concept is still unclear and further development is needed (Srai and Gregory 2008). They proposed four SC configuration attributes (key elements) through their supply network configuration maps: (i) supply network structure (geographical spread) (Figure 2.7), (ii) flow of material and information (process flow dynamics e.g. make-to-order, make-to-stock; and production process choice e.g. continuous process flow, assembly line) (Figure 2.8), (iii) role, inter-relationships and governance between key network partners (Figure 2.9), (iv) value-structure of the product or service (product demand nature and product variety) (Figure 2.10). Despite the comprehensiveness of their mapping tools and its benefits in practice, the resource and infrastructure that support and facilitate SC operations e.g. information technology and human resources, are dismissed. Furthermore, this framework included product structure as one of four SC configuration attributes whereas many researchers (Christopher et al., 2006, 2009; Fisher, 1997; Harrison and van Hoek, 2005) regarded this attribute as one of key determinants for SC strategy and design.

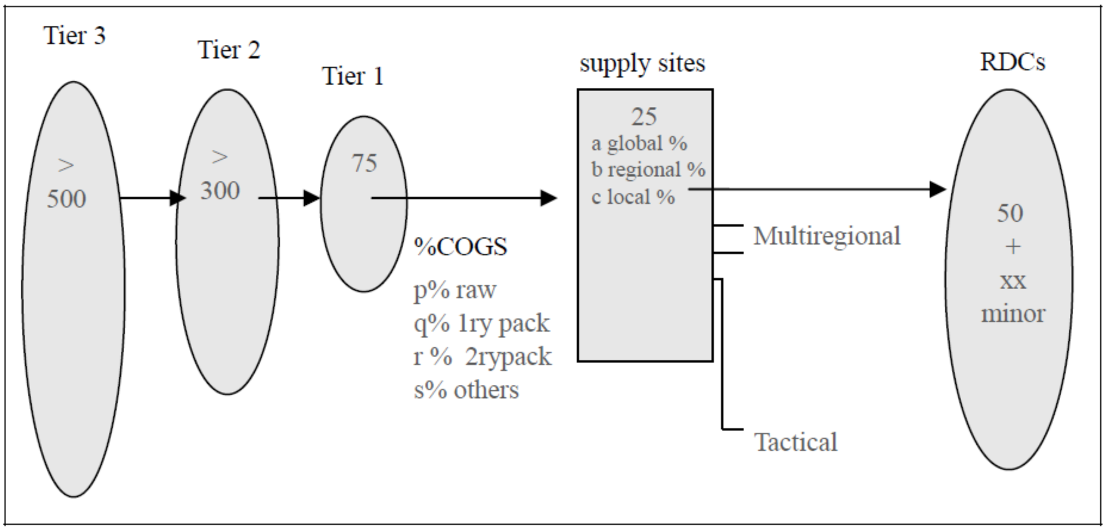


Figure 2.7 Supply Network Structure

(Source: Srai and Gregory 2008)

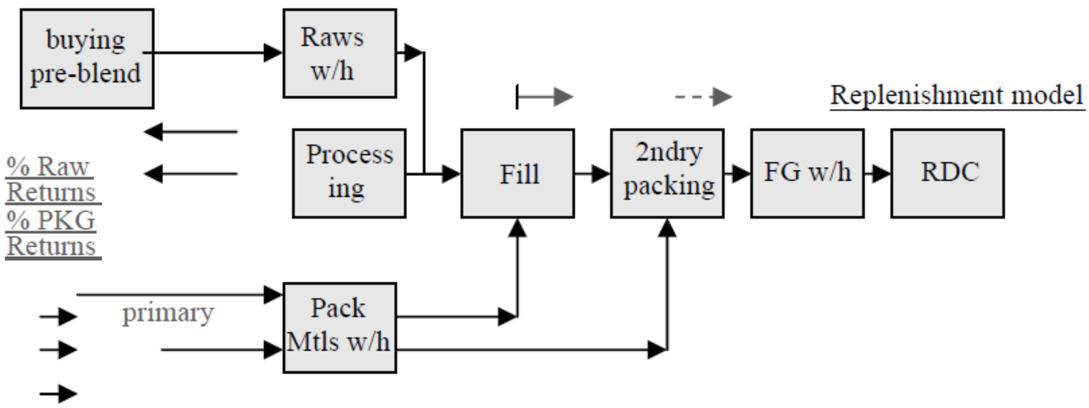


Figure 2.8 Flow of Material and Information Between and Within Key Unit Operations

(Source: Srai and Gregory 2008)

Network governance
contracts / relationship type / network role
Intra-firm
factory network / S&OP process
network ownership / Supply-N and R&D co-ordination
Inter-firm
key suppliers / key customers / geographic dispersion / satisfaction measures (customers & suppliers)

Figure 2.9 The role, inter-relationships, and governance between key network partners

(Source: Srai and Gregory 2008)

Product modularity Shape of Product Structure	None/ single unit/ sub-unit/ factory unit/w/h unit A, T, V, X
Product mix – SKUs – by SBU	Eur NA LA Afr Asia total P 30 7 0 35 6 78 D 60 54 20 54 2 190 S 3 34 5 40 2 84 H 30 3 0 40 9 84 Z 1 50 11 44 6 112 totals xxxx
Innovation churn	New variant/extension 2 – 3 yrs New product form 4 – 5 yrs
Product life cycle	3-6 months trade, 1 wk customer; max: 2 years
Offering	Product only, mainly product,mainly service
Forecast accuracy and planning horizon	Aggregate level: +– 10% ; 3 months out SKU level (wt avg): +– 20 -25% ; 3 months out
Fulfilment process & lead time – customers / suppliers	Supply to stock; 3 months rolling order Supply to stock/forecast: 3 month rolling/call-off
Product Value Density vs. Transport Cost	10te/TEU Euros/tonne / Tonnes/TEU
% SC Cost /sales	yy%

Figure 2.10 'Value-structure' of the product or service

(Source: Srai and Gregory 2008)

Before reviewing the low carbon research, the next section starts from the origin of low-carbon requirements—environmental consciousness, and even to a broader basis—sustainability.

2.3 Sustainability, Green and Low Carbon

2.3.1 Triple Bottom Line

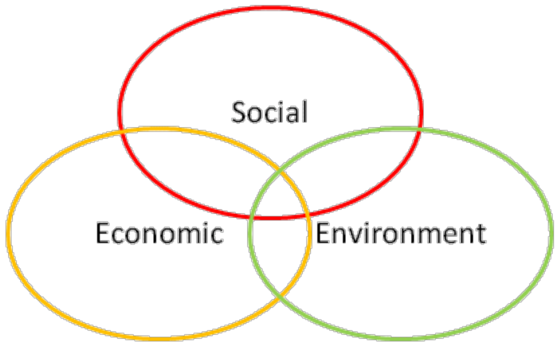


Figure 2.11 Triple Bottom Lines

(Source: Adams 2006)

The original definition of sustainability means that a society meets the needs of the present without compromising the needs of the future generation. Seliger summarized the idea of how to increase the standard of living with a growing world population; the answer is to increase the productivity of scarce natural resources (Seliger et al., 2008). In order to achieve this, innovation in management, technology, process, and product is critical.

In engineering terms, sustainability means 'the application of scientific and technical knowledge to satisfy human needs in different societal frames without compromising the ability of future generations to meet their own needs'(Seliger et al. 2008).

Overall, sustainability can be defined as an attempt to achieve a balance among triple bottom lines – social, environment, and economic- as shown in Figure 2.11 (Adams 2006; Hendry and Vesilind 2005). Economic includes aspects of economic performance, market presence, and indirect economic impacts. Social includes aspects of labour practices and decent work, human rights, community, corruption, public policy, anti-competitive behaviour, compliance, customer health and safety, product and service labelling, marketing communications, and customer privacy. Environment includes aspects of materials, energy, water, biodiversity, gas emissions, effluents and waste, products and services, compliance, and transportation (Bettley and Burnley 2008).

The following sections cover various aspects of sustainable manufacturing, including motivation, green supply chain management, green product design, green sourcing, green manufacturing system design, green packing, 3R (Re-use, Re-manufacture, and Re-cycle) , green logistic, and innovation.

2.3.2 Sustainable Supply Chain Management

The sustainable supply chain management has been on the research agenda since Cairncross (1992) first talked about the relationship between the earth's environment cost and human manufacturing activities. Sustainability refers to an integration of social, environmental, and economic issues. With regard to a macro-viewpoint on supply chains and in order to achieve the balance between the environmental, social and economic dimensions, Carter and Rogers defined Sustainable Supply Chain Management (SSCM) as the strategic achievement and integration of an organization's social, environmental, and economic goals through the systematic coordination of key inter-organizational business processes to improve the long-term economic performance of the individual company and its value network.(Carter and Rogers 2008). The following Figure 2.12 illustrates the scope of the SSCM. The three dimensions of sustainability are visualized as the supporting pillars which are necessary to keep the whole structure balanced, and they are also the key objectives. Risk and compliance management forms the building's foundation. Risks from the market and natural environment have to be identified and mitigated in order to achieve long-term profit. Laws, guidelines and standards are not only served as the instruction of implementation of sustainability along the supply chain, but they are also a strong driving force for sustainability with reasons such as policy power and challenges from competitors which steps ahead in the sustainable supply chain.

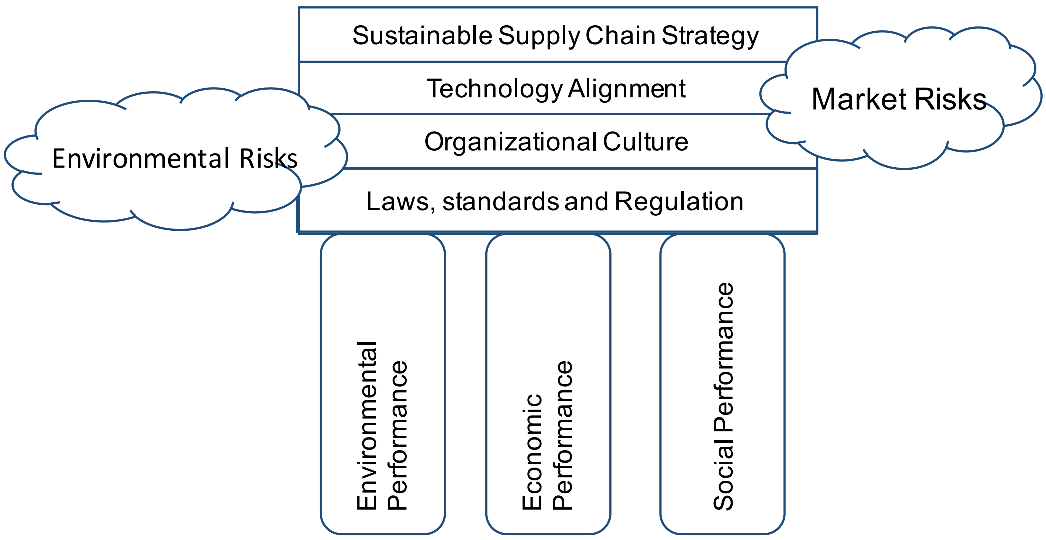


Figure 2.12 Structure of Sustainable Supply Chain Management

(Source: Carter & Rogers 2008; Elkington 2004)

Seuring presented a three-part framework for sustainable supply chain management including: Triggers for SSCM; supplier management for risks and performance; and SSCM for sustainable products (S. Seuring and Müller 2008).

The triggers of the SSCM origins from three object bodies: government, customer and stakeholder. Pressures and incentives from the object bodies to the focal company include legal demands/regulation, customer demands, response to stakeholders, competitive advantage, environmental and social pressure groups and reputation of companies.

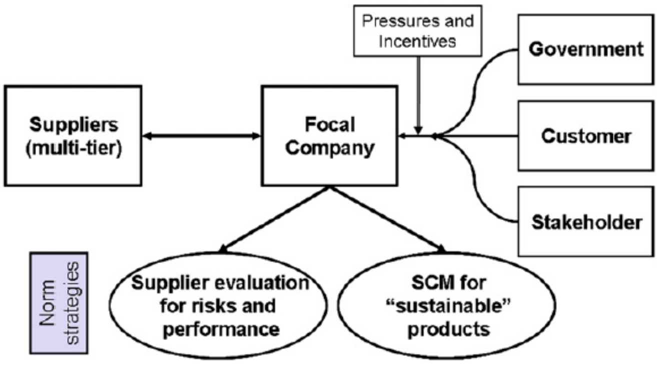


Figure 2.13 Triggers for Sustainable Supply Chain

(Source: S. Seuring and Müller 2008)

The second part of the framework is the supplier management. As a response to the above-mentioned pressures and incentives, a number of companies have introduced supplier evaluation schemes which integrate environmental and social criteria. Related measures include supplier self-evaluation where suppliers have to declare how they deal with environmental and social issues. One way to implement this is to set up standards which give out minimum requirements. This would capture the aim of avoiding risk and the aim of improve the supply chain performance as well.

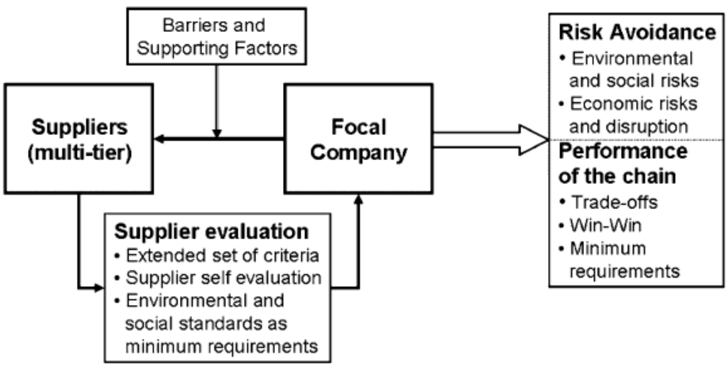


Figure 2.14 Supplier management for risks and performance

(Source: S. Seuring and Müller 2008)

Supply chain management for sustainable products aims ultimately to satisfy customers and gain a competitive advantage in the market. Life-cycle assessment is applied in specifying product related requirements, and focal companies usually are in charge of requesting this assessment from suppliers. So the cooperation with suppliers are of great importance.

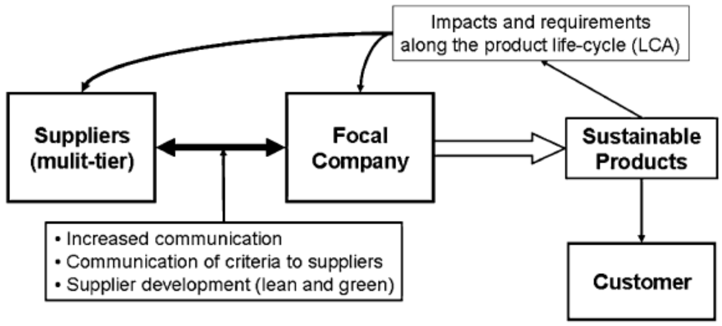


Figure 2.15 Supply chain management for sustainable products

(Source: S. Seuring and Müller 2008)

Evans & Gregory et al. (2009) proposed a system thinking to enable the sustainable industrial system. By introducing sustainable operation cases in Toyota, Xerox and Vitsoe, an overall and boarder view to the system is emphasized, stimulating five implications for developing sustainable industrial system:

- A better understanding to the relationship between the industrial and ecosystems
- A better understanding of customer value
- New mental models to reflect the need for 'closed loop' cycles for components and materials, networked-distributed production, system resilience and learning from biological examples
- Increased sharing between disciplines
- New systems of education, training and research
- Much closer collaboration between consumers, industry and policy makers

It can be found that implications are linked to the interaction mechanism of actors in the supply network. These actors do not limit to supply chain partners but also boarder scope of stakeholders, e.g. customers and policy maker.

2.3.3 Green Supply Chain Management

The green aspect of supply chain management has taken most of the attention while the social issues are rarely touched. The definition and scope of green SCM in the literature has ranged from green purchasing to integrated green supply chains flowing, and even reverse logistic (Q. Zhu and Sarkis 2004).

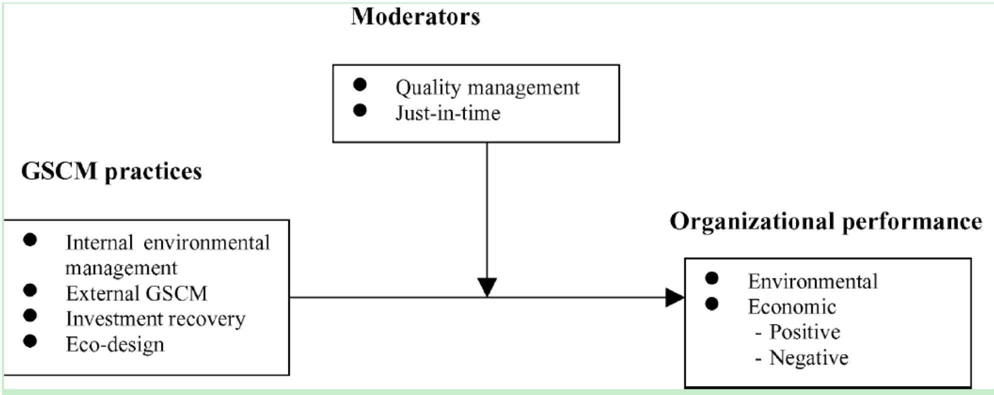


Figure 2.16 Research framework for investigation of relationship between GSCM practices and performance

(Source: Zhu & Sarkis 2004)

The green supply chain here is defined as "integrating environmental thinking into supply chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life". The green supply chain management literature would fall into three categories: the significance of greening the chain, green design of product, and green operations (Srivastava 2007). As shown in the following Figure 2.17, the green supply chain design issues have been classified into different categories based on problem context.

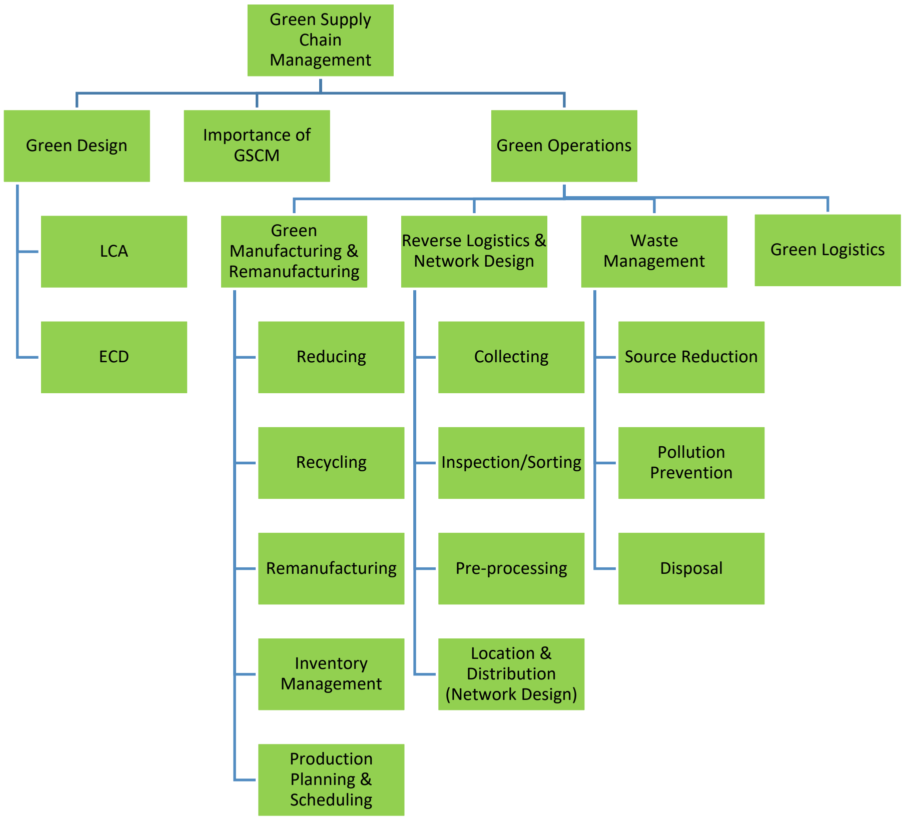


Figure 2.17 Classification based on problem context in supply chain design

(Source: Srivastava 2007)

Researchers have given out different frameworks to categorize the green supply chain practices (Table 2.4).

Table 2.4. Focuses of Green Supply Chain Management in Literature

Year	Authors	Focuses of GSCM
1998	Craig R. Carter and Carter	Environmental purchasing
2005	Hervani, Helms, and Sarkis	Green Supply Chain Management = Green Purchasing + Green Manufacturing/Material Management + Green Distribution/Marketing + Reverse Logistics
2005 2008	Qinghua Zhu, Sarkis, and Geng	Internal environmental management, external green SCM, investment recovery, eco-design/design for environmental practices
2012	Björklund, Martinsen, and Abrahamsson	Logistic, supply, transport, purchase
2012	Ashby, Leat, and Hudson-Smith	Recycling, Cooperation/coordination/collaboration, Reverse logistics, Green purchasing, Reuse, Remanufacturing, Environmental management, Design for the environment, Life cycle analysis
2012	Miemczyk, Johnsen, and Macquet	Generic internal process material, waste, recycling, pollution, cost, compliance and standards, design, energy, CO_2, GHG, LCA, Monitoring, Product, Risk

Green Product Design

Green product design plays a significant role in reducing the environmental impact of the product. It is widely acknowledged that earlier consideration to environmental impact in product design increase the chance to reduce impacts.(Lewis et al. 2001) It is suggested that 70% of the product cost is determined in design stage(Boothroyd 1994). Practitioners have generated tools to help on Design for Environment (DfE), such as Simapro, Gabi, etc. Birch, Hon, and Short (2012) compared 22 DfE tools in terms of their outputs and classify them into four output mechanism. The conclusion comes to that focusing on product-specific output can help to improve DfE result better. the however, the supply network design doesn't duplicate the impact of product design because it focuses on processes, not trying to ignore that product design does impact the network design strategy.

Green manufacturing and remanufacturing

This is a very important area within green operations. Three fields of research: pinch analysis (Linnhoff 1993), industrial energy (Boustead and Hancock 1979) and energy life-cycle analysis (J. J. Lee, O'Callaghan, and Allen 1995), study the techniques to minimise energy and resource consumption in the inbound operations.

Reverse logistics and network design.

Reverse logistics refers to transport used products from the users to a producer for product returns, remanufacturing and re-use of parts and components(Fleischmann et al. 2001);Tibben-Lembke 2002) for profits. Reverse logistics has activities that differ from traditional logistics (Carter and Ellram 1998). Researchers have also discussed the development & implementation (Stock 1998), decision making process (Srivastava and Srivastava 2005), and the importance of IT (Dekker et al. 2004), etc. The majority in this research field use a quantitative modelling approach such as mixed integer linear programming (MILP) models (Mirchandani, Francis, and others 1990), a stochastic programming-based approach(Listes and Dekker 2005), and non-linear mixed-integer programming model to solve reverse logistics problems (Min, Jeung Ko, and Seong Ko 2006).

Waste management

Waste management is another top issue in green SCM which gives more implication to and similarities in carbon footprint management. But waste management includes many other issues such as pollution treatment. Researchers have studied waste management questions such as system design (collection, transportation, incineration, composting, recycling and disposal) (Caruso, Colorni, and Paruccini 1993), location of treatment facility (Giannikos 1998), transportation network design (K. Richter 1996;K. Richter and Dobos 1999) and reuse collection (Mourao and Amado 2005), etc.

The source-reduction/pollution-prevention (SR/P2) strategy focuses on 'preventing' pollution at the source (in products as well as in the manufacturing processes) rather than 'removing' it after it has been created. This concept can also be applied to carbon emission reduction. 'Reuse' and 'Recycle' are the key theme of the prevention strategy. Via an optimizing recycle process network (Dunn and El-Halwagi 1993) there is combustion equipment redesign (Hanna and Newman 1995), and a prioritizing waste recycling preference (Zhang et al. 1997), where practitioners can reduce their emissions.

However, the waste management literature has hardly touched the waste gas management, for example the problem of carbon dioxide (although the CO_2 is not polluted gas, it can be 'prevented' or reduced as other waste gas).

Cleaner Production

Cleaner production has been defined by UNEP (United Nations Environmental Program) to be "The continuous application of an integrated environmental strategy to processes, products and services to increase efficiency and reduce risks to humans and the environment" (UNEP 2014). Khan (2008) described that cleaner production analyses the aspects related to the operation of a business and identifies opportunities for improvement in economic and environmental performance. Cleaner production has been applied in different industries including mining (Jia et al. 2014), ceramics (Huang et al. 2013), food (Yi et al. 2001), etc. The fundamental principle of cleaner production is to identify the flows of material and energy in the organisation and then generate solutions to minimise waste and emissions.

2.3.4 Low Carbon Emission Supply Chain Management

Though there are lots of overlaps between Green SCM and low carbon SCM, the pressure for a green SCM for firms mainly stems from the concerns for environmental protection for the local community, while the climate change issues generate more international pressures towards firms. Similar to GSCM, introduced in the last section, researchers have explored multiple aspects of supply chains in relation to carbon-reduction opportunities.

Sundarakani tried to model carbon footprints across the supply chain (Sundarakani et al. 2010). He makes the statement that a better understanding to the heat flux in supply chains is critical which transforms the carbon emission control to a heat flux analysis. The model of heat flux through a node is given out in Figure 2.18.

In the next step Sundarakani categorized the supply chain into stages including suppliers, logistics, plant and warehouse, and calculated the emission in each stage based on the model. One case in this shows that 25% of the carbon emissions come from the supplier, 22% from the logistics, 40% from the manufacturing plant and 13% from the warehouse/distribution centre. This provides a reason to study carbon emission reduction in supply network level.

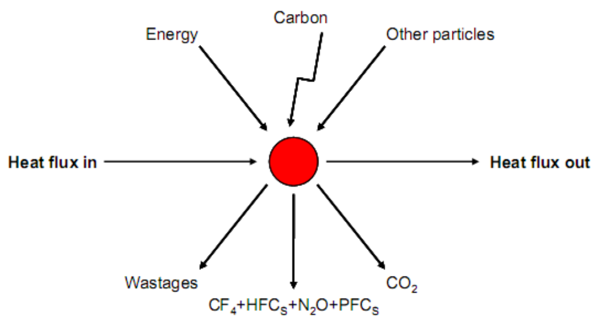


Figure 2.18 Heat flux through a node

Source:(Sundarakani et al. 2010)

However, the calculation can only be established under estimated parameters, and it has not pointed out the carbon footprint reduction methods.

Sundarakani also gave out a system specification in each stage of the supply chain, "At the supplier stage, the processing of raw material and preparing the semi-finished parts emits….At the stage of logistics service provider, the levels and types of carbon emissions depend on the mode of transportation, choice of fuel used, and distance travelled…at the stage of manufacturer can be measured from direct and indirect emissions…at the stage of distribution centre (warehouses) depend on the type of packaging used, trade policy, consumer density, and the level of reuse"(Sundarakani et al. 2010). This specification helps research to determine the elements affecting the carbon footprint in the supply chain.

Cholette and Venkat (2009) calculated the energy and carbon emissions associated with the transportation links and warehousing activities in food and beverage supply chains. Cholette & Venkat utilized a web-based tool "CargoScope" to calculate the carbon intensity, considering the logistic and storage inputs and parameters. The parameters and inputs used in this software include location (of stores, warehouses, nodes), transportation (modes, frequency, volume, utilization rate, batch haul), energy (type, temperature control), and inventory (dwell time, utilization rate).

Except for the above-mentioned two areas of research, the following Table 2.5 illustrates other studies focusing on the design of the low carbon supply chain.

Table 2.5. Summary of Literature on Low Carbon Supply Chain Design

Year	Authors	Research Method	Details
2008	Ramudhin et al.	Analytic	A mixed integer mathematical model formulation for supply chain network design with carbon trading considerations integrated. The model focused on supplier and subcontractor selection, product allocation, capacity utilization, and transportation configuration, and their impact in terms of carbon footprint.
2010	Ballot and Fontane	Analytic	Using collaboration in logistic network to reduce CO_2 emissions with supply chain members to share supply networks. It is found that a potential saving of at least 25% of CO2 emissions from pooled networks versus the current setup can be achieved
2010	Guenther and Kannegiesser	Analytic	Investigates the effect of two mode: emission-cost and emission-constraint mechanisms on the transport mode selection decision. The transportation mode include air, railway, road, waster transport mode.
2011	Acquaye et al.	Quantitative	A hybrid LCA methodology is used to evaluate the life cycle CO_2 equivalent emissions of biodiesel supply chain emission
2011	Edwards, McKinnon, and Cullinane	Qualitative	The paper explores methodological issues associated with carbon auditing conventional and online retail channels. It considers aspects of supply chain including product selection, warehousing, freight transport, retailing, and personal travelling
2012	K.-H. Lee	Qualitative (case study)	This paper develops a map of product carbon footprint which facilitates identification and measurement of carbon emissions across the automobile supply chain management. It focuses on the supplier's carbon performance, calculated the following aspects: - General utility efficiency outputs - Energy and CO_2 flow map for products, parts, and components - Cost savings by delivering more energy efficient operations management.
2012	Abdallah et al.	Analytic	The paper develops a mixed integer program for the carbon-sensitive supply chain that minimizes emissions throughout the supply chain by taking into consideration green procurement also known as environmental sourcing. The main emission aspects considered are: (i) the raw materials of the suppliers; (ii) the delivery of the raw materials; (iii) the facilities (plants and DCs; (iv) the distribution of the products
2012	Cucchiella and Koh	Review	This paper conceptualises a structural model of natural resource based green supply chain management (GSCM), relevant performance measures and institutional drivers. The environmental practices discussed are green purchasing, design for the environment (DfE), and green distribution
2012	Elhedhli and Merrick	Analytic	This paper consider supply network design with emission costs considered alongside fixed and variable location and production costs. The relationship between CO_2 emissions and vehicle weight is modelled as the main variables.
2012	Jaegler and Burlat	Simulation	The research focuses on CO_2 emissions along supply chains covering from freight energy use to inventories storage, using a discrete event simulation. Main variables are manufacturing capability, locations, mode of transportation, types of products.
2012	Pattara, Raggi, and Cichelli	Simulation	This study applied this tool to a wine previously analyzed using the life cycle assessment (LCA) methodology
2012	Shaw et al.	Analytic	This study presents an integrated approach for selecting the appropriate supplier in the supply chain, addressing the carbon emission issue, using fuzzy-AHP and fuzzy multi-objective linear programming. The carbon factor is considered together with cost, quality, lead time, etc.
2012	Trappey et al.	Simulation	This research applies system dynamics modelling to simulate and identify green product redesigns with cost-effective product carbon footprints during manufacturing. It covers the material stage: processes, transportation, materials; Manufacturing stage: assembling; Logistics stage; Use stage; Waste stage.
2012	Chaabane, Ramudhin, and Paquet 2012	Analytic	This paper introduces a mixed-integer linear programming based framework for supply chain design that considers life cycle assessment (LCA) principles in addition to the traditional material balance constraints at each node in the supply Chain.
2013	Hsu et al.	Quantitative	This study constructs 13 criteria of carbon management with three dimensions as the evaluation criteria of supplier selection. These 13 criteria are: Planning: Carbon governance, policy, reduction targets, risk assessment, Training related carbon Management, Life cycle cost management; Implementation: Measures of carbon management, Involvement in initiatives for carbon management, Management systems of carbon information, Supplier collaboration; Management: Carbon accounting and inventory, Carbon verification, Carbon disclosure and report.
2013	Le and Lee	Analytic	The study uses mathematical programming, modelling the supply chain functions--location, inventory, production, distribution functions and transportation mode selections. The solution results include best transportation routes, inventory levels, shipment quantity, and transportation modes.
2013	Skelton	Quantitative	Discuss the maximum potential influence European industry has over its non-European supply chain emissions. Aggregated industry sectors' carbon emission impact is examined by using a Input–Output model.
2014	Tseng and Hung	Analytic	The paper proposes a strategic decision-making model considering both the operational costs and social costs caused by carbon emissions in the supply chain network context.

It can be found that the 'Analytic' method, which refers to mathematical modelling, turns out to be the mainstream methodology on research to 'designing' low carbon supply chain.

There is also research exploring the de-carbonization in different stages of supply chain. Hua et al. (2011) investigated how firms manage carbon footprints in inventory management under the carbon emission trading mechanism. Holweg et al. (2011) assessed the global sourcing risk considering the carbon offset costs. In supplier engagement, Jira and Toffel (2013) discussed factors associated with the suppliers' willingness to disclose carbon information to buyers. Other issues have also been discussed, including aggregate loading in energy management in the production phase (Ngai et al. 2013), waste management (Koh, Gunasekaran, and Tseng 2012), etc. Smith and Ball (2012) focused on the factory level, and developed an "MEW" (material, energy, waste) flow model to provide guidance on systematically analysing manufacturing facilities, and to assist with the identification and selection of improvement opportunities. Choi (2013) discussed the impact of the carbon footprint tax on retailer's sourcing decisions.

Researchers also use LCA methods to measure the carbon footprint in the supply chain of different products and different industries, such as found in: egg production (Pelletier, Ibarburu, and Xin 2013), bananas (Svanes and Aronsson 2013), ethanol (Ortiz-Gutierrez, Giarola, and Bezzo 2013), wine (Pattara, Raggi, and Cichelli 2012), fashion (T.-M. Choi 2013), etc., and some industrial products, e.g. steel & iron (Tianhai 2013). Different transportation methods such as road freight (Piecyk and McKinnon 2010) and maritime (Rigot-Muller et al. 2013) are also studied.

However, there is a clear gap in the methodology and the process of developing the supply chain in a low-carbon way, especially from the practical perspective rather than from the analytic methods in which many assumptions are made.

According to the above-mentioned literature, the low carbon supply chain practices can categorized to 4 general stages:

- **Product**: product design, packaging design, user phrase performance, waste Management, product recycle/reuse;
- **Procurement**: sourcing, supplier management, transportation from supplier, waste management;
- **Production**: internal generic manufacturing process, waste management;
- **Logistics**: transportation to clients, reverse logistics, transportation packaging design.

This classification is used in the case data analysis.

2.4 Build Up the Low Carbon Supply Network—Engagement and Influence

In terms of the influence stage, there are two key areas studied in relation to the motivation that is driving industrial practitioners to reduce their carbon emissions: institutional theory calls for the informal authorities to influence potential practitioners to take action, while stakeholder theory and RDT suggest that network externalities and collective behavior will also impact on practitioners as well.

2.4.1 Institutional Theory

Institutional theory, which has its origins in economics research, has been borrowed by organizational scholars to explore organizational behaviours in so-called New Institutionalism (DiMaggio and Powell, 1983; Lee, 2011), which argues that informal institutions – norms, shared beliefs, cultural pressures, etc. – are just as important as formal institutions – laws, regulations, etc. – to control firms' behaviour. The key argument is that firms need to gain isomorphic conformity in order to obtain legitimacy (DiMaggio and Powell 1983; Suchman 1995) . Zimmerman and Zeitz (2002a) stated legitimacy as a critical resource for organizations, which is as important as other resources such as capital, technology, etc. Scholars have attempted to measure legitimacy with reference to its sources (Aldrich and Fiol 1994; Suchman 1995); for example, Scott (1995) categorized three types of legitimacy source, namely regulative, normative, and cognitive. Regulative legitimacy is derived from regulations, rules, standards created by government, accreditation associations, and professional bodies. Normative legitimacy is derived from the norms and values of society, or from a level of the social environment. Cognitive legitimacy represents "widely held beliefs and taken-for-granted assumptions" (Scott, 1995). In this research, we use this typology to classify firms' legitimacy resources.

The institutional framework has been used with reference to firms' environmental performance by a number of researchers. Multiple issues, including government regulations (Bansal and Roth 2000), cognitive and cultural change (Jennings and Zandbergen 1995), etc., have been covered. In green supply-network research, Zhu and Sarkis (2007) examined the impact of institutional pressures on the Chinese manufacturers' adoption of green supply chains, advocating that coercive, normative, and mimetic institutional pressures drive companies to become green.

However, researchers have only barely begun to discuss and understand the process of institutionalization (Heugens and Lander 2009), and how institutional pressures can be leveraged to engage companies. There is a research gap in the understanding of how this process in institutions takes effect. In addition, most research has taken the non-business sector as the central context, rather than the business sector.

2.4.2 Stakeholder Theory and Resource Dependence Theory

Stakeholders are defined as "any group or individual who can affect or is affected by the achievement of an organization's objectives" (Freeman 1984). Stakeholder theory suggests that companies produce externalities that affect many parties (stakeholders), which can be either internal or external to the firm. Therefore, the key idea of stakeholder theory is to balance different stakeholders' interests, and manage the influences embedded in the relationship between stakeholders and the firm (Lee, 2011). Researchers have used various categorizations to group stakeholders (M. Delmas 2001; M. A. Delmas

2002) because firms have a complex set of stakeholders, and can only pay attention to a limited number of these. In order to explain stakeholders' influential dynamics, a combination of stakeholder theory and RDT is applied by researchers. RDT argues that firms are not fully self-sufficient with regard to strategically critical resources, and have to be dependent on the resources provided by others in order to sustain survival and growth (Salancik and Pfeffer 1978). RDT has been applied by institutional theorists (Hillman, Withers, and Collins 2009) and stakeholder theorists (Frooman 1999) to demonstrate firms' external pressures. On the stakeholder side, the key idea is that a firm's behaviour is influenced by its stakeholders, and this flow of influence is determined by the degree of resource dependence between the firm and its stakeholders (Clarkson 1995). Kassinis and Vafeas (2006) discussed the relationship between an organization's environmental practices and stakeholder pressures; however, following Frooman's (1999) work on stakeholder influence strategy and institutional theories, little research has extended discussion into the detailed process of influence. In particular, there is a research gap that has received scant attention: the classification of resources that are leveraged during a process of influence. Zimmerman and Zeitz (2002a) suggested resources types including human, financial, and intellectual, among others.

Iinstitutional researchers have suggested that social actors, such as community organizations, social movement organizations, etc., are the channels and conduits of institutional pressures on firms (Lounsbury 2001). On the other side, stakeholder and RDT theorists have argued that the marginal stakeholders, who do not control firm's critical resources, can eventually influence firms because they have institutional legitimacy and an urgent message (M.-D. P. Lee 2011). However, the question of how marginal stakeholders obtain the legitimacy and the process of using legitimacy in order to influence focal firms has barely been addressed in the literature. In addition, an overall mapping of all the channels from which firms receive pressures has not been extensively explored by researchers. Frooman (1999) proposed "usage" and "withhold" strategies that are used by stakeholders to influence focal firms but did not address how stakeholders with low-interdependence on the focal firm attain support from the firm's salient stakeholders. Thus, it is necessary to further explore the mechanisms and processes that influence stakeholders' actions towards low-carbon emission.

2.4.3. Drivers for Low Carbon SCM/ GSCM from Firm's Perspective

Green supply chain management literature has given out lots of aspects that the drivers of GSCM implementation may come from, which can be similar pressures for firm to apply low-carbon practices. Table 1.6 summarizes some of the drivers for GSCM identified through the existing body of literature. Drivers for GSCM implementation are grouped into two categories including internal and external drivers. The internal drivers are strongly associated with organization factors, and the external drivers can be further divided into five major categories including regulation, customers, competition, society and suppliers.

Table 1.6 Literature Review of Drivers of GSCM

(Source: Yuan Zhang, 2013[4])

Drivers	Reference
Internal	
Top management involvement	Anderson and Batman (2000)
Employee involvement	Hanna et al.(2000)
Reduce costs	Carter and Dresner (2001)
Quality improvement	Pil and Rothenberg (2003)
Investor pressure	Trowbridge (2001)
External	
Regulatory	
Government regulation	Lampe et al. (1991)
Pre-regulation	Carter and Dresner (2001)
ISO Certification	Handfield et al. (2002)
Customers	
Customer demand	Carter and Dresner (2001)
Customer's concern	Berns et al. (2009)
Business customer collaboration (B2B)	Christmann and Taylor (2001)
Market pressures	Zhu and Sarkis (2006)
Competition	
Gaining competitive advantage	Zhu and Sarkis (2006)
Learn from industrial leader	Zhu and Liu (2010)
Suppliers	
Collaboration	Klassen and Vachon (2003)
Integration	Vachon and Klassen (2006)
Information sharing	Zhang et al. (2008)
Society	
Public pressure	Beamon (1999)
Influence of NGOs	Trowbridge (2001)
Influence of social media	Henriques and Sadorsky (1996)

Hitchcock (2012) summarized the legal pressures for low carbon supply chain that include legislation pressure, supply chain pressure, regulatory pressure and policy pressures.

2.5 Measure Carbon Footprint in Supply Network—Different Methodologies and Protocols

2.5.1 Introduction

Carbon Footprint and Measurement Standards

As generally recognized that only the measurable get managed, it is well regarded that a standardized method to measure and report the carbon emission profile must become a priority(Pandey, Agrawal, and Pandey 2011; Rebitzer et al. 2004).

[4] "Best Practices in Low Carbon Emission Supply Chain Networks: Lessons and Implications from the CDP Survey Data from Four Industry Sectors", Y. Zhang, J. Hu, Y. Shi, Proceeding of Asian Conference Management Science and Applications (ACMSA), Kunming, China, Dec 21-23, 2013

From the perspective of company carbon emission profile, the most widely-used international accounting tool, GHG (Greenhouse Gap) protocol, categorised the carbon emission into three groups or 'scopes'. The scopes are defined by the source of carbon emission in company activities. Scope 1 and 2 cover direct emission source (e.g. fuel used in company vehicles and purchased electricity). Scope 3 emissions cover all indirect emissions due to the activities of the organization. Table 2.7 illustrates the three scopes of carbon emission according to GHG protocol.

Table 2.7 GHG Protocol Carbon Emission Scopes

Scope	Sources
Scope 1	Fuel combustion Company vehicles Fugitive emissions
Scope 2	Purchased electricity, heat and steam
Scope 3	Purchased goods and services Business travel Employee commuting Waste disposal Use of sold products Transportation and distribution (up- and downstream) Investments Leased assets and franchises

(Source: GHG Protocol Standard)

Despite wide use, the term carbon footprint seems to have no clear definition (Wiedmann and Minx, 2008). Based on a review of its use in literature. Wiedmann and Minx (2008) propose the following definition:

"The carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product."

This definition brings in a lot of arguments since researchers have argued that all greenhouse gas emissions should be included which include all greenhouse gas emissions (Baldo, Marino, Montani, and Ryding, 2009; Iribarren, Hospido, Moreira, and Feijoo, 2010; Plassmann et al., 2010; Weidema et al., 2008; Wiedmann,2009). In the Kyoto Protocol six greenhouse gas emissions are identified as the main emission control targets. In our research, we regard the carbon footprint to include the six key GHG according to the Kyoto Protocol, expanding Wiedmann's definition. The carbon footprint concept has been applied to many levels, including products, households, companies, cities and regions, and countries (Peters, 2010). We define in this study that the carbon footprint on the product level as CFP (Carbon Footprint of Products) in our research as defined by ISO (ISO14067 Draft, 2012), and we defined PCF as the abbreviation of the action of calculating/obtaining the CFP--Product Carbon Footprinting.

Surprisingly different from the green issues, the discussion of PCF (Product Carbon Footprinting) is limited in number in the operations and supply chain journals. Both Jensen (2012) and Sundarakani (2010) concluded that the publications of modelling/measuring carbon emissions are much fewer in SCM and operation management compared to Green SCM.

The wording of Carbon Footprinting comes from the 'Ecological Footprint' research in the 1990s (WBCSD, 2010 "Vision 2050, the new agenda for business"; Wackernagel, 2004, ecological footprints and energy). But the methodologies adopted for performing PCFs originate from the life cycle assessment/analysis (LCA) literature.

Wiedmann and Minx (2008) specify Life Cycle Assessment (LCA) as the appropriate method for calculating a carbon footprint. Though recommending that the definition and method of carbon footprint should be kept separate, Peters (2010) identifies LCA as the appropriate approach for measuring the carbon footprint of consumer products. The International Standards Organization (ISO) working group identified a number of core questions regarding standardization of the quantification of carbon footprints, and even in the relatively easy class of LCA needed for carbon footprints there is no easy solution to the identified questions (Finkbeiner, 2009).

The demand for carbon footprint information and the need for further principles and techniques have led to a number of international, national, and sectorial initiatives (Finkbeiner,2009). Plassmann et al. (2010) identified more than thirteen different methodologies for product carbon footprinting under development in 2009. According to the degree of specification, Carbon footprint measurement methodologies can be classified into three different main groups (Baldo et al., 2009):

- General guidelines, such as ISO standards, that represent the normative standard references for CO2 calculation.
- Specific guidelines, such as PAS 2050, that contain ad hoc indication on GHG calculation and monitoring.
- Calculation tools that are aimed at calculating CO2

The British Standards Institute's (BSI) Publicly Available Specification (PAS) 2050 represented the first standards for measuring the carbon footprint of products when released in 2008 (Wiedmann, 2009), as well as some other ongoing standardization efforts such as the WRI/WBSCD's Greenhouse Gas Protocol Scope 3 standards and the ISO 14067 standards (Wiedmann, 2009), ILCD Handbook (Jensen 2012), etc. ISO 14067 is still under development (expected to be revealed in 2014) and based on ISO 14040 and ISO 14044, serving PAS2050 as the seed document. So we will not consider ISO14067 in the following comparison section.

The LCA methodology dates back to the 1970s (Stefan Seuring 2004; Wiedmann 2009). Some researchers argue that carbon footprinting is a subset of LCA because only greenhouse gases are counted in the carbon footprint (Bala et al. 2010; Sinden 2009; WBCSD 2004; Pennington et al. 2010; Schmidt 2009) or even a simplified application of LCA (Pant et al. 2008).

The Comparison Between PCF Methods

Standards are regarded an important tool for measuring and reducing GHG emissions from supply chains (Jensen, 2012). As we mentioned above there are several standards that exist for the PCF process. Jensen gives out the following criteria to compare them: the unit of analysis, the type of PCF, the modelling framework, data timeframe, data sources and the handling of the multifunctional problem. The standards summarized are ISO14040/ISO14044, PAS2050, ILCD and GHG Protocol Scope 3 standards. The following table shows the results of comparison.

Table 2.8 Comparisons and Conclusions in Different Standards

Analysis Category	Options	Explaination and key points
Unit of Analysis (in the Standard)	the funcional unit of product	1.Enable the comparison of different products 2.it is a natural step to identify actors in supply chain
Standard Type	Bottom-up analysis	1. Data usually collected from individual processes (Peters,2010) 2.Under some special conditions IOA type dataset could also satify the requirement (but the standard leaves a gap here to guide users combining the process-based method and IOA
Modelling Framework	Attributional or Consequential	1. For Accounting Purpose--Attributional is preferred 2.For decision making purpose-- Consequencial aproach is preferred using short-term and long-term marginal data 3.Combined approaches are required when determining effects on the economy.(European Commission,2010,ILCD)
Data Sources	Primary data for processes owned, operated, or controlled by focal company	1. Primary data is preferred except the ISO14040 accepts legitimate data 2. Data from upstream/downstream supply chain actors: PAS2050--accept secondary data from suppliers; ILCD--requires primary data from suppliers as well
Timeframe	historial, fact-based, measurable data	Due to the attributional
multifunctional process	economic allocation, physical relationship allocation	very similar between standards

As stated in the table, in most sections the standards have similar settings and suggestions. PAS2050 is the first public available guidelines specialized on GHG emissions, rather than general environmental footprint assessment standards (such as ISO14040, ILCD, etc.). And a few pioneering companies have taken the first step on PCF using/building up PAS2050. Consequentially PAS2050 is more broadly used among companies globally compared to WRI&WBCSD's Product Standard. So in our research we focus on the application process of PAS2050 in case companies, and our analysis is focused on this standard as well. The following section illustrates the inner relations between CFC (Carbon Footprint of Corporate) and CFP (Carbon Footprint of Product) and detailed the PAS2050 methodologies.

2.5.2 General Introduction to the Carbon Footprinting Methods

The Carbon Footprint of Corporate and of Product

CFC (Carbon Footprint of Corporate) and CFP (Carbon Footprint of Products) are two key activities when firms are tackling the carbon issues. Considering the firm as an input-output system, the semi-product going through the system—the firm—get manufactured/processed, while the processes involve energy, material and waste generated, generating GHG emissions. And at the same time outside the key processes, the supporting activities to these processed within the system also generate carbon emission as well. If we look at the system within the firm's boundary, the key processes within the plant and the supporting processes are both included. But following the product lines, only the key processes will be counted and the relevant emission will be allocated to the product. So the CCF (Corporate Carbon Footprinting), such as IPCC/GHG protocol, is targeting the first type of measurement of the carbon emission of the system, and PCF (Product Carbon Footprinting), the life cycle assessment type method, such as PAS2050, ISO14067, is targeting the second type.

Both of the methods can be de-assembled to a basic formula, which is the amount of used Energy/Resources/Waste multiple the conversion factor (CO2 emission/unit). The difference between the CCF and PCF is as follow: The CCF covers all the processes within one corporate, while the PCF covers the key processes along the whole manufacturing chain of the specific product and allocates the ERW related carbon emission to a single product. So the scientific way to do the allocation is also a key part of PCF.

The PCF, if it eliminates some non-important processes, shrinking boundaries and reducing the up-stream or down-stream relevant stages, could then be conducted as a so-called streamlined LCA method(Weitz et al. 1999). The Input-Output methodology in Economics are also used to calculate the Carbon Emission, especially suitable for the country, industry and area level. Some researchers have done studies in the Economic Input-Output LCA (EIO-LCA) Analysis of Carbon Emission(Ferrao and Nhambiu 2009). Both streamlined LCA and EIO LCA have the shortfalls in the uncertainty and accuracy of the PCF result, but with lower cost and time invested. So they are also considered as proper or sometimes efficient PCF methods in different contexts. The next section will detail more on the different LCA methodologies.

Public Available Specification 2050 (PAS 2050) and Life Cycle Assessment

PAS (Publicly available specification), 2050, which is being developed by the Carbon Trust, Department of Environment Food and Rural Affairs (Defra), and British Standard Institute (BSI) in 2008, is a specification for the assessment of the life cycle greenhouse gas emissions of goods and services.

PAS 2050 was developed in reply to a broad community and industry need for a consistent method for measuring the life cycle GHG (Green House Gases) emissions. It was built based on existing life cycle assessment methods established through standards BS EN ISO 14040 and BS EN ISO 14044(Carbon Trust, 2008). Many companies have already joined PAS 2050, including PepsiCo, Boots, Innocent, Marshalls, Tesco, Cadbury, Halifax, Coca Cola, Kimberly Clark, The Co-operative Group, Scottish & Newcastle, Coors Brewers, Müller, British Sugar, ABAgri, Sainsbury’s, Danone, Continental Clothing Company, Colors Fruit, Morphy Richards, Mey Selections and Aggregate Industries. (Carbon Trust, 2008).

PAS 2050 is intended for both product comparisons and communication of this information but does not specify requirements for communication. PAS 2050 specifies that LCA shall be used to assess the GHG emissions of products. The specification distinguishes between business-to-consumer assessments, which employ a cradle-to-grave approach, and business-to-business assessments that employ a cradle-to-gate approach. Additionally, it does not include product category-specific rules, but is intended that these can be developed in accordance with ISO standards and will be adopted by the standard when available.

Carbon Trust Carbon Reduction Label

The PAS 2050 standard recognizes a wide range of potential uses for the information on the carbon footprint of products but does not provide requirements on the use of the assessments that arise from implementation of the specification (Sinden, 2009). It does not explicitly support comparative assertions but recognizes that individual stakeholders may compare results that are placed in the public domain (Sinden, 2009). The Carbon Trust offers a labelling service by its subsidiary consultancy firm 'Carbon Footprint Expert' that allows firms to communicate the carbon footprint of their product, which would allow for comparative assertions. The label was based on the original carbon footprint methodology developed by the Carbon Trust (Carbon Trust, 2007).

In a 2009 review of product carbon footprint schemes the Carbon Trust Carbon Label was by far the largest of the twelve operational programs for product carbon footprints, with 2,000 certified products (Bolwig and Gibbon, 2009). The Carbon Trust claims more than 5,000 products carry the label and that it is one of the largest eco-labels in the U.K.(Carbon Trust, 2011).

Life Cycle Assessment

Life Cycle Assessment method is the basis of PAS2050, a quantitative process for evaluating the total environmental impact of a product over its entire life cycle, referred to as a cradle-to-grave approach. LCA is product focused, with emphasis on quantifying the environmental impacts (Heijungs, 1996).

LCA, as defined by the ISO, consists of four phases: Goal Definition and Scope; Inventory Analysis; Impact Assessment; Interpretation.

In some instances only phases two and four need to be performed, in which case this is referred to as a Life Cycle Inventory (LCI) (ISO, 2006a).

The goal definition and scope phase include identifying the product or function being studied, the reasons for carrying out the study, defining the system boundary, and identifying the data requirements. Inventory analysis involves identifying the process involved in the system, defining the inputs and outputs of each process, and collecting data to quantify those inputs and outputs. Impact assessment defines impact categories and used the results of the inventory analysis to calculate indicator results in those categories. Finally, in the interpretation phase, the results of the inventory analysis and impact assessment are interpreted in terms of the goal and scope definition; the results are checked for completeness, sensitivity, and consistency; and conclusions, limitations, and recommendations are reported (ISO, 2006a).

LCAs generally fall into two categories based on their purpose. An attributional LCA is focused on looking back on a product and determining what emissions can be attributed to it. A consequential LCA is focused on the environmental effects of what will happen due to a decrease or increase demands for goods and services (Ekvall and Weidema, 2004). The two types of LCAs are suitable for different purposes and require different types of data. An attributional LCA is appropriate for making specific environmental claims regarding a product, and typically makes use of average data for the product. The consequential category is more suited to performing scenario analysis. It often requires marginal data for the product as it requires making assumptions about economic factors related to changes in product consumption or production (Tillman, 2000).

In addition to the types of LCA there are two main LCA methodologies: a process-based approach and an Economic Input-Output (EIO) approach. In a process-based methodology all phases of a product are examined and their inputs and outputs are mapped. This is typically considered the conventional method of LCA and is sometimes referred to as the ISO or SETAC method (Lenzen, 2001). The EIO-LCA approach uses broad economic categories to provide environmental impacts, but generally only includes the production phase. The two methods can also be combined to form a hybrid approach (Suh et al., 2004).

The Limitations of Two LCA methodologies and their application scenario

Life Cycle Assessment provides a general framework for measuring the environmental burden of a product or function. Its general structure allows application to a wide variety of items, but also allows considerable freedom in implementation. This freedom makes for difficulty in comparison between any two separate LCAs. Previous work has highlighted this lack of standardization in some important areas of Life Cycle Assessment, including defining system boundaries (Tillman, Ekvall, Baumann, and Rydberg, 1 994)(Suh et al., 2004) and allocation methods (Ekvall and Finnveden, 2001)(Ekvall and Weidema, 2004). This lack of standardization means that while LCA provides a methodology for measuring a carbon footprint, the results of two studies may not be comparable.

Process-based LCAs have also been criticized for reasons related to their data requirements (Hendrickson et al., 1997). The high cost and time of performing process-based LCAs poses difficulties for products with complex supply chains spanning many organizations. A survey of LCA practitioners identified data collection as the most time consuming and costly aspect of performing an LCA (Cooper and Fava, 2006). Collecting data across organizational boundaries presents issues concerned with proprietary and confidential information, data accuracy, and a lack of representative data (Chevalier and Teno, 1996) (Huijbregts et al., 2001).

EIO-LCA provides an approach that requires less detailed process data. This work builds upon the original EIO work of Wassily Leontief (1986), who developed the method for economic study. This method makes it possible to describe the output of one industry sector in terms of the inputs required from other sectors to produce it. By assuming a linear proportionality, any dollar value of output can then be expressed in the dollar values of inputs from other sectors required to produce it. The EIO-LCA model expands on this by adding the environmental burdens linked to industry sectors (Joshi, 2000). Together this can be used to determine the total environmental burden of an industrial sector per dollar of sector output.

An EIO approach has several advantages over a process-based LCA. By including all upstream activity within the economy the data is more complete, and there is no need to draw system boundaries. The data is generally compiled from publicly available sources, allowing for greater transparency than process-based LCAs that use proprietary data. Finally, the EIO approach allows a much cheaper and faster method of providing results. In cases where only an approximate result is needed an EIO LCA can provide a very rapid and inexpensive answer (Hendrickson, Horvarth, Joshi, and Lave, 1998).

The assumptions and methods of EIO analysis do have drawbacks for determining the environmental burdens of a specific product. Though EIO tables may contain hundreds of sectors, this still requires significant aggregation of different products and processes. Some sectors may be too heterogeneous to produce correct results (Hendrickson et al., 1998). The information in the Input-Output tables only captures the effects of production and therefore the use of and disposal phases are not included (Joshi, 2000). Many countries lack the sectorial environmental data needed for analysis, meaning that imports must be assumed to be homogeneous with domestic products (Suh and Huppes, 2005). Finally, the nature of Input-Output analysis assumes proportionality between monetary and production flows (Lenzen, 2001). That is, if a product doubles in cost then the environmental burden doubles as well. Though necessary for the computational results this may not reflect the reality of the production process.

In an attempt to build on the strengths of process-based and EIO-LCAs a third method has emerged, which is a hybrid of the two (Suh and Huppes, 2005). The hybrid method uses a detailed processed based methodology for the important foreground processes and an EIO model to fill in the background processes (de Haes, Heijungs, Suh, and Huppes, 2004). The use of a hybrid method allows the EIO method to be used to inexpensively provide complete data for the less important parts of the system, while using the more detailed and specific process data for the most important parts. In order to perform a hybrid LCA it-is necessary to determine the boundaries between the EIO and process-based systems. Poorly selecting these system boundaries can introduce significant error (Suh and Huppes, 2005). Hybrid LCAs may also involve some double counting, as portions of the process-based LCA may have been included in the 10 data (note can I check the use of 10 here) . However, this may still produce more accurate results than a pure process-based LCA that draws system boundaries and ignores processes which occur outside of the system (de Haes et al., 2004).

The General Process of PCF using PAS2050

The published body of PAS2050—BSI (British Standards Institution) also provides a 'Guide to the PAS2050:2011', helping to initiate the product carbon footprinting process. In the practices of using PAS2050, the guide suggests that companies should consider the following sequentially: business priorities; judicial selection of products; intended audience for the study, which will affect the degree of accuracy and resolution needed for PCF (for identifying opportunities for reduction PCF can be undertaken at a high level initially and for external claims a rigorous approach to data collection should be demonstrated); Project Timescale; Internal stakeholders, gaining aids from internal function departments; and Supplier Engagement (try to involve suppliers in the early stage of PCF, which would help data collection and building stronger relationships) . These issues are all consistent with what has been found in the case data, and they are considered to be key accelerators or obstacles in practising PAS2050. The Figure 2.19 shows the steps of PCF using PAS2050.

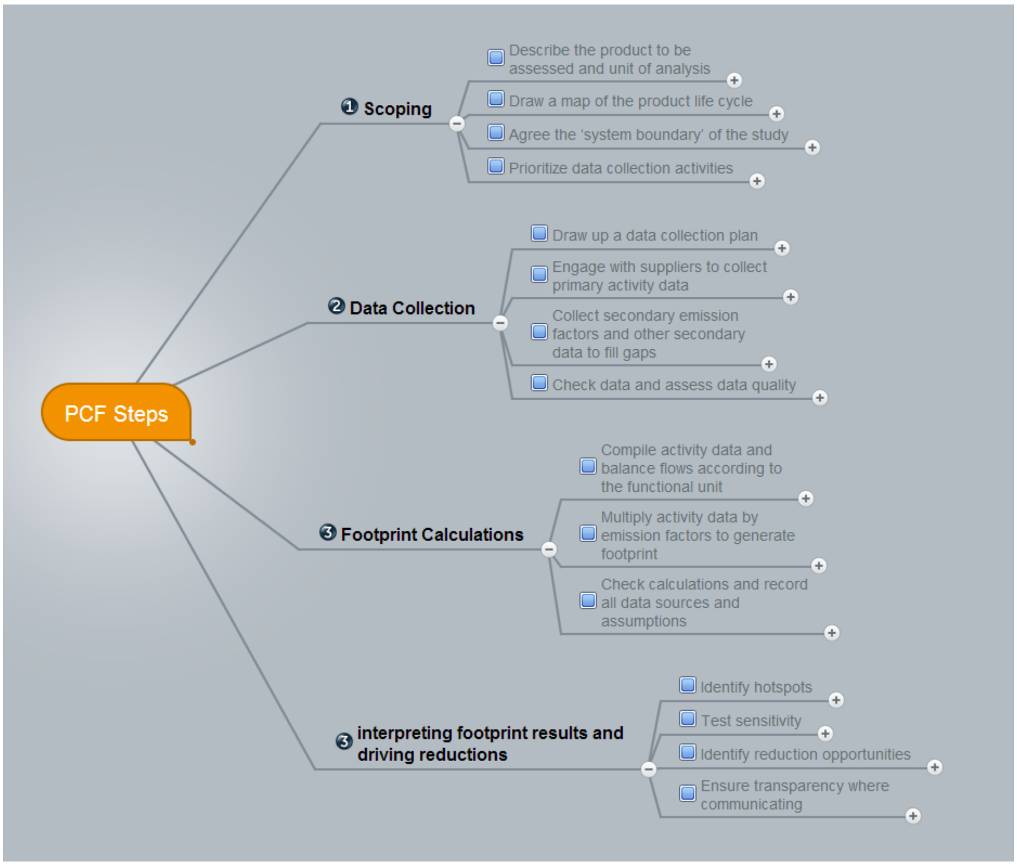


Figure 2.19 PCF steps in PAS2050

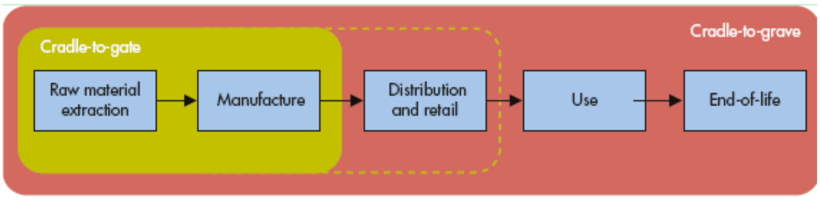


Figure 2.20 Process Map of 'Cradle to gate' and 'Cradle to grave' types of PCF assessments

Table 2.9 Sample of Footprint Data Calculation Table--Process Stage

	Quantity	Unit	Transport distance (for input or waste)	Transport mode and type	Data source
Input					
Fertilizer, total[a]	800	kg	100 km	Articulated HGV >33 t	Fertistat, transport assumed
Fertilizer, as N	150	kg	–	–	Fertistat
Fertilizer, as P_2O_5	50	kg	–	–	Fertistat
Fertilizer, as K_2O	200	kg	–	–	Fertistat
Pesticide, total[a]	40	kg	100 km	Articulated HGV >33 t	Published/reviewed LCA, transport assumed
Pesticide, active ingredient	15	kg	–	–	Published/ reviewed LCA
Energy					
Diesel	50	litres	–	–	Published/ reviewed LCA
Electricity	65	kWh	–	–	Published/ reviewed LCA
Output					
Oranges	22,000	kg	(included below)		FAOSTAT
Emissions					
N_2O from soil (fertilizer application and crop residues)	5	kg	–	–	Published/reviewed LCA/IPCC
Waste					
Un-harvested oranges to land-spreading	200	kg	10 km	Rigid HGV >7.5–17 t	Published/ reviewed LCA, transport assumed
Damaged oranges to land-spreading	100	kg	10 km	Rigid HGV >7.5–17 t	Published/reviewed LCA, transport assumed

From Table 2.9 we could conclude that, for each unit of process, three types of items—material/resources input, energy, waste (if direct GHG emissions included as waste) are the categories to calculate.

After getting together the data of each units of processes, the total PCF will be the summary of all these units. But alongside the summary, the following issues are all needed to be taken care of : Co-product allocation; Sub-process ERW (Energy, Resource Input, Waste) allocation; Biogenic carbon accounting and carbon storage; Energy and combined heat and power (CHP) related (Energy source, such as grid electricity, Renewable energy, renewable electricity tariffs, on-site energy production, etc.); Agriculture (mainly land use change which is complex); Refrigeration; Transport Emission; Recycling (landfill or incineration).

After the footprint result, a hotspots analysis of CFP and an uncertainty analysis should be applied and a CFP reductions plan on self-own production, product design, upstream and downstream supply chain could follow it.

Process Measurement Framework

Ken Platts (1995) has proposed a framework for analysing and providing comparisons between manufacturing strategy processes formulation. This framework is not only applicable for strategy process but also for the performance measurement process (Andy Neely, 1995, 2000, 2002, 2006—

process-based performance measurement system design), so in analysis to company carbon footprinting process this methodology is applied. In this section, firstly the 4P framework (Point of Entry, Participation, Project Management, Procedure) of Ken's model is introduced; then the multiple cases of different companies are introduced on their carbon footprinting journey, finally their PCF activities are framed in by the Ken's model.

Platts (1994, 1995) develops the four aspects of the process--point of entry, participation, procedure and project management, arguing that a process was not just mere procedure--a set of steps, such as the carbon footprinting project. "A useful process should specify how an organization might be attracted to implement the process; who should participate in the process and how the project of implementing the process should be managed".

This detailed framework is not only useful to identify the effectiveness and efficiency of process, but also a 'guideline' for good process.

Point of Entry

The 'point of entry' refers to the starting point of the process being introduced into the management system or platform and then it being conducted. Platts emphasized that it is necessary for the strategy process to provide a 'method of entry' into the company or business unit and then provide a platform to develop the understanding and agreement of the management group. This method of entry should help in: achieving the understanding and agreement of the managing group; establishing the commitment from the managing and operating group; and to clearly define expectations of what the process involves (Platts,1994). So the way of starting the process should first involve acquiring the acknowledgement and commitment from a senior group with proper expectations.

Participation

Participation is mapping the individuals and groups that are involved in the process. It could include three scopes, the width across different department, depth within the key responsible department (manufacturing in this context), and involvement from outside business, such as consultants, etc..

In the width part, different functions within the company are involved in the process. Platts (1995) believe that other functions have been involved in the strategy process for two main reasons: first for specific activities, such as finance assessing the costs and financial benefits of the options; second, for knowledge that can be brought to the debate and implementation, such as personnel's knowledge of the organization. For the depth of participating, Garvin (1992-manufacturing strategic planning) argued that the depth should be emphasized in order to derive credible, implementable strategy using the best appropriate knowledge in the organization. Participants from outside the business unit generally arrive without assumptions, and with the experience of the process, which is the carbon footprinting in this context. Table 2.10 shows the potential participants categorized by the participation type (Platts, 1995).

Table 2.10 Potential constituents participating the process

Partcipation Type	Composition
Width	Manufacturing, Marketing, Product Development, Finance, involvement of all functions
Depth	People with balance of skills and experience, or political heavyweights
Outside	Corporate specialists, consultants in facilitation/project modes (arriving without assumptions, understand to process, expirienced), facilitator

Procedure

Procedure of the process includes a threefold plan according to Platts (1995): the first one is an audit to the current process, then the second is the formulation of a set of action plans that are designed to close the gaps. The third is to implement the action plans. During the action plan formulation, using a business process framework might be helpful, but in the LCA context, most of the action plans are fixed according to the guidelines. Platts has stated that a well-defined procedure should progress through the gathering of information, the analysing of information and through identifying opportunities for improvements, which guides the action plan. And easy-to-use tools, techniques and a written record of results at each stage should be included as well.

Project and process management

In Platts's research, two issues in the project management need to be tackled. The first one is the adequate resources for the process, including three aspects: managing, supporting and operating groups. The managing group should have secured resources for backing the process implementation, gaining cooperation across the different functions where the senior management group are providing the point of integration. The supporting group performs as the 'expertise' in the process, embracing the actions of arrangement, guidance, and details-checking. This supporting group most likely would be one person—a facilitator—referenced by some researchers. This is the case in most situations in the carbon footprinting context and the facilitator acts in the most importance role in the process. The operating group comprises the people who are doing the real work: collecting and analysing the data; assessing the requirements of the business, etc. The composition of the operating group may change during the process. The second issue of project management is that a time scale should be set. Platts suggested setting a tight but achievable timescale.

Table 2.11 4P model of describing process Platts

(Source: Platts, 1995)

	Explaination	Typical Practices
Point of Entry	• Method to achieve the understanding and agreement of the managing group; • Method of establishing commitment from the managing and operating groups; • Clearly defined expectations of aims of what the process involves • Aims: obtain the agreement of the managers to committed involvement in the project	• "Competitive Profiling" • "A tactical to strategic management development programme" raised issues of management style, team membership and a possible workshop(T SWEENEY, 1992) • "Responsibility of board to ensure that a process to make up strategy exists" (Voss) • "New Product introduction" (Leonard-Barton, 1992)
Procedure	• Well defined with clear stages of information gathering, analysing and opportunities identified for improvement • Simple and understandable tools and techniques in use • Written record at each stage • Aims: well defined structure could help operation managers to "see the overall structure of the methodology and appreciate how the individual pieces fitted together"	• A short written report of the process at each stage
Participation	• Individual and group participation team • Workshop style interpretation meetings to collectively agree objectives, identify problems and develop improvements, and to catalyse involvement • A decision making forum leading to action • Aims: generate group working platform across functions team with wide range of opinions and close work between personnel	• Workshop • Decision Making Forum
Project & Process Management	• Adequate resources including managing, supporting and operating group • An agreed timescale	

It also needs to be mentioned, that Platts claimed that the process will bring in not only audit to the current operation, but also the delivery of organizational learning (Platts, 1995).

2.6 Chapter Summary

This chapter reviews the evolution of manufacturing research, detailing the origins of low carbon supply chain management. The underpinning theories and methodologies are reviewed and analysed, including multiple organizational theory, LCA analysis, green supply chain management, etc. It is found that though the organizational and the relevant environment have been explored much in different studies, but the organizational response to external pressures in the special circumstance of decarbonisation requirement presents a gap in the current research. What's more the resource dependent theory, stakeholder theory and institutional theory have not provided an answer to core resources which firms obtain from external environment. The up-to-date ecology measurement literature also provides potential answers for suitable footprint estimation methods, however, a practical footprinting methodology and suitable guidelines are not available and especially for different commercial measurement purposes. Sustainability, sustainable supply chain, and green supply chain have been an important research topic in the operations management area for nearly three decades. As the carbon emission issue becomes more vital in the sustainability research, some exploration to the industrial practices and the implication to green supply chain are in prompt need. The above literature review to up-to-date theories sets up the basics to generate research gaps and a research question which will be stated in the next section.

CHAPTER 3 CONCEPTUAL FRAMEWORK AND RESEARCH DESIGN

3.1 Introduction

This chapter aims to illustrate what the research gaps are that have been rooted from the industrial gaps and research gaps for the purpose of future work. The industrial challenges that being faced have been discussed in the previous chapter and also the related research that is needed to provide a suggested solution to this. Research questions are suggested to meet these research gaps. According to the research questions posed, related research methodologies are reviewed and research design is illustrated after the selection of methods. Finally the process framework of research is detailed.

3.2 Research Gaps

Research Gap Identification

The literature reviews in Chapter 2 demonstrates that little attention has been given to the low carbon supply network by existing research, although the supply network/supply chain research has been in its development for two decades. The review also shows that the carbon issue is one of the most important areas to be considered in the supply network due to the urgency of climate change.

The review also demonstrates a large research gap in explaining firms' behaviours due to environment pressure at the network level from the perspective of external influences. Especially, a new perspective of the network and its constituents—linkages between firms and other actors in the network, is not yet in position. This new perspective emerges when the network is under pressure to change.

The practical review also highlights that the carbon footprint measurement in the network, as the first step to manage an emission profile, is difficult, time-consuming, and costly for the majority of firms. The demand for a process model of efficient carbon footprint measurement is strong but not adequately fulfilled by existing theories and practices.

Though there exists plenty of research on supply network configuration and design methods, there is currently no research that provides a comprehensive guideline regarding low carbon supply network improvement, as well as practical guidelines or a best practices list which can be referred to in order to provide step by step guidelines for practitioners in industry.

In summary, the significant theoretical gaps and industrial issues are addressed on the low carbon supply network transition of manufacturing firms.

3.3 The Research Questions, Sub-Questions and Research Framework

3.3.1 Research Question and Conceptual Framework

Regarding to the research gaps that are identified in previous sections, existing literature and practices fail to answer the following question:

How can supply networks in emerging economies be developed to reduce carbon emission?

To address this, a conceptual framework is developed, which has defined the main issues for investigation and their presumed relationships. Shown in the Figure 3.1, the conceptual framework consists of three building blocks, which are regarded as three key areas for the transition of the low carbon emission supply network---namely influence, measurement and improvement. The three components follow a logical trend and form a loop.

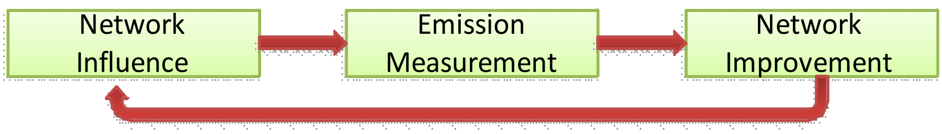


Figure 3.1 Conceptual Framework for Low Carbon Emission Supply Network

More specifically, each building block is defined below.

- **Network Influence.** The firms in a network are influenced and encouraged to be involved to take action in green thinking policy and carbon emission reduction. This building block aims to explore the mechanism of motivating/stimulating firms from the perspective of the network. In an attempt to understand the composition and functioning of this mechanism, constructs of network influence will be examined—network linkages, firm type and firm context. The influence process in the network will be explored based on these constructs.

- **Emission Measurement**. This building block is concerned with the emission measurement activities in a network, which is the fundamental step of low carbon supply network management. The corporate and product level carbon emission disclosure not only gives out mapping information for a firm's carbon emission performance, but also is a way of involving other actors in the network.

- **Network Improvement**. Improvements in carbon emission reduction is the ultimate goal of all the above actions. Before the fundamental radical redesign to supply network is implemented, incremental improvement is adopted by most of firms according to explorative cases. This building block is investigating the holistic system of a firm's low carbon transition activities in the network. Framework and systematic methodologies that firms apply to reduce carbon emission are explored to develop a practical understanding of the mediums that lead to the low carbon emission supply network.

- **Network Improvement leads to new stage of network influence.** The practices of improvement that are implemented at the network level links firms in the network and starts a new cycle of involving more firms in the network, via the carbon emission reduction practices. This close loop of network improvement and network influence forms a circular step of low carbon emission supply network transition.

3.3.2 Sub-Research Questions

Following the framework, three research questions are formulated as follow:

- How can firms in the emerging economy be influenced to take action in carbon emission reduction under the supply network context?

- How can carbon emission be efficiently measured in the supply network?

- How can firms reduce carbon emission in the supply network?

In order to address these questions, the next step is to choose an appropriate research methodology and to design the research process, as described in the following sections.

3.4 Research Methodology

3.4.1 Theory Foundation – Philosophy and Tool Box

Different research methods result in a significant difference in research results, thus the appropriate research approach is crucial to the whole picture of research design. Positivism and social constructionism are regarded as the currently two main contrasting paradigms in qualitative research (Easterby-Smith, Thorpe, and Lowe 2002), and eight different features are listed out in the Table 3.1 as below. Audi stated that the '*facts are distinct from values and that the scientific knowledge consists almost exclusively of observable facts*' (Audi 1999) which indicate that positivist draw its findings from existing facts in the external world, while an interpretive explanation related to social phenomenon is the job of the social constructive researcher. And positivist qualitative research is often seen as a precursor to more quantitative theory-testing (positivist) studies e.g. exploratory studies of new phenomena (Cooper and Schindler 2006).

Although the distinction between the two research paradigms appears to be clear, it tends to break down when the issues of research design and choice of methods are considered (Easterby-Smith, et al., 1991). Researchers may combine the research methods favoured by different paradigms and involve periods of inductive and deductive learning.

Table 3.1. Contrasting implications of positivism and social constructionism

Source:(Easterby-Smith, 2002)

Features	Positivism	Social Constructionism
Observer	Must be independent	Is part of what is being observed
Human interests	Should be irrelevant	Are the main drivers of science
Explanations	Must demonstrate causality	Aim to increase general understanding of the situation
Research progress through	Hypotheses and deductions	Gathering rich data from which ideas are induced
Concepts	Need to be operationalised so that they can be measured	Should incorporate stakeholder perspectives
Unit of analysis	Should be reduced to simplest terms	May include the complexity of 'whole' situations
Generalization through	Statistical probability	Theoretical abstraction
Sampling requires	Large numbers selected randomly	Small numbers of cases chosen for specific reasons

Easterby-Smith, et al. (1991) has contended that the research paradigm should fit with research aims and the setting within which the research takes place. Considering that the essential elements and features of the low carbon supply networks are embedded in a networks' particular business environment, and the lack of existing theories upon which hypothesises can be developed, this study will stand on the social construction paradigm to build the theory of low carbon supply network from empirical studies.

The research question determines, to a large extent, the methods or strategies, available to the researcher. Yin (1994) identified the major research methods or strategies within social sciences and provided a summary of conditions for selecting an appropriate one (Table 3.1). The conditions are described as below.

(i) The type of research question posed. This study is to understand how supply networks can be improved to reduce carbon emission, including the involvement, measurement and improvement processes. This is a question about 'how' and 'why'. Survey or archival analysis may not be able to support enough depth in the richness of the necessary data.

(ii) The extent of control an investigator has over actual behavioural events. The researcher has little control over the organisation, operation, performance, or transition of low carbon supply networks. Experiments are impractical for this study.

(iii) The degree of focus on contemporary as opposed to historical events. This study aims to identify and understand the evolution practice of supply networks. Based on the leading practice, the researcher can develop the framework to integrate their essential elements, and to suggest tools for implementation. Histories or archives cannot reflect the ongoing changes.

After choosing the selection criteria mentioned above, case study strategy stands out as the choice, as shown in the Table 3.2.

Table 3.2 Choosing Research Strategies

Source: (Yin 2002, p6)

Strategy	Form of Research Question	Requires Control of Behavioural Events?	Focuses on Contemporary Events?
Experiment	How, why? ✓	Yes ✗	Yes ✓
Survey	Who, what, where, how many, how much? ✗	No ✓	Yes ✓
Archival analysis	Who, what, where, how many, how much ✗	No ✓	Yes/No ✓
History	How, why? ✓	No ✓	No ✗
Case study	How, why? ✓	No ✓	Yes ✓

The use of the case study is advocated by a group of researchers including (Yin 2002),(Eisenhardt 1989), (King, Keohane, and Verba 1994), and described as similar to the quasi-experimental methods of experimental social science research (Easterby-Smith, Thorpe, and Lowe 2002). Yin argued that case study should be scientific and case studies that emulate the scientific method are “likely to be of higher quality than those that do not” (Yin, 2002).

According to Yin (2002), conducting multiple cases is the most appropriate to address the ‘*how*’ of this research, and as noted by (Herriott and Firestone 1983), multiple case studies allow the research to be more compelling and more robust than through single case study.

In regard to the information above, this research will be conducted mainly through multiple case studies together with secondary information analysis from other sources like archives.

3.4.2 Theory Building Process

Eisenhardt (1989) suggested a process for theory building from case studies and the rationale behind each step. Yin (2009) also proposed a similar process but elaborated more in the areas of case selection and analysis. Accordingly, this research organizes the theory building process into three stages: preliminary study stage, empirical study stage, and theory development stage.

Table 3.3. Theory Building Process and Relevant Chapters

Research stages	Eisenhardt (1989)	Yin (2009)	Key activities in this research	Chapters
Preliminary study stage	·Getting started ·Selecting cases ·Crafting instruments and protocols	·Develop theory ·Select cases ·Design data collection protocol	·Identify research question ·Develop a conceptual framework from the existing literature, experiences, and preliminary observations (exploratory cases)	Chapter 1-3
Empirical study stage	·Entering the field ·Analyzing data	·Conduct case studies ·Write individual case report	·Semi-structured interviews ·Documentation ·Observation ·Within-case analysis ·Analyzing secondary data in Database	Appendix
Theory development stage	·Shaping hypothesis ·Enfolding literature ·Reaching closure	·Draw cross-case conclusions ·Modify theory ·Develop policy implications ·Write cross-case report	·Within-case analysis ·Cross-case analysis ·Development of the conceptual framework and research findings ·Evaluation of the research implications ·Research limitations and future opportunities ·Conclusion and report	Chapter 4-7

The preliminary study stage aims to acquire a good understanding of the key issues related to low carbon supply networks and to develop a conceptual framework as a starting point. Preliminary observations with exploratory cases, which demonstrated the practical issues in the low carbon supply network design, were conducted. Relevant literature was also explored. This preliminary study demonstrated the urgent need to improve the supply network into a low carbon status, however, there is a lack of research in this area. This has led to the identification of the research question and the development of the conceptual framework.

The empirical study stage aims to retrieve semi-structured data through detailed case studies. Main data collection approaches include semi-structured interviews, documentation, and observations. The triangulation of data collection sources ensures the quality and validity of the research. Interviewees in the case companies were mainly senior managers involved in CSR, Supply Chain, and manufacturing operations. Over 60 senior managers/experts were interviewed across 25 ICT/Food & Beverage/Steel manufacturing firms in UK, US, Mainland China and Taiwan. A set of rich secondary data was collected via CDP Supply Chain Program Database, in which participating firms are requested to provide the list and detail of their carbon emission reduction practices.

The theory development stage aims to iteratively enrich and refine the conceptual framework through within-case analysis after data collection. In parallel with the literature review, cross-case analysis was conducted and the conceptual framework was gradually enriched and refined. The main data analysis approach used is cross-case synthesis (Yin, 2009) whereby individual case studies were first treated as a separate study and the findings are based upon the analysis across a series of individual cases.

Eisenhardt (1989, p.546) argued that theory building from case studies can be iterative as researchers "move from cross-case comparison back to redefinition of the research question, and out to the field to gather evidence on additional cases". Yin (2009) similarly stressed this stage as a redesign stage. The theory building process goes between divergence into new ways of understanding the phenomenon and convergence into a single theoretical framework. As a result, the strength of theory building from case study research is highly likely to generate a novel theory via iterative processes. In this research due to the novelty of the low carbon issue, the research follows iterative cycle of theory building research process from case studies in the above-mentioned three stages.

3.5 Research Process Framework

3.5.1 The Three-stage Research Process and Unit of Analysis

Yin (1994) suggested five key components of a complete research design: a research question, its propositions (if any), its units of analysis, the logic linking the data to the propositions, and the criteria for interpreting the findings. The first two components have been addressed at Section 3.3-3.4. This section 3.5 will focus on the rest.

Table 3.4. Types of Case Studies

(Source: Yin, 1994:39)

	Holistic (single unit of analysis)	**Embedded** (multiple units of analysis)
Single-case designs	**Type 1**	**Type 3**
Multiple-case designs	**Type 2**	**Type 4**

Yin (1994) proposed four types of case studies by the use of single or multiple cases, and the use of single or multiple units of analysis as shown in Table 3.4.

Single/Multiple Case

A single-case study will be the most appropriate when the following criteria are reached:

(i) the research questions may represent a critical case in testing a well formulated theory;

(ii) the research may represent an extreme or unique case;

(iii) the research may represent a revelatory case (i.e., the observation of a phenomenon previously).

If the above conditions are not applicable, multiple case studies will benefit the research design by allowing for the comparison or triangulation of results and arguably providing a more 'robust' set of results (Herriott & Firestone, 1983). The logic underlying the use of multiple case studies is based partly on the rationale of replication, rather than sampling logic. It is not a matter of choosing a sample from a population which will provide the most representative view of the population as a whole, as would be the case when using a survey.

Single/Multiple Unit of Analysis

The single unit of analysis will help the research to focus on the perceived target. It has the advantage of simplicity and clarity. But when the nature of the research target shifts during the research, the initially selected unit of analysis may be inappropriate, and thereafter the research questions or the unit of analysis may need to be changed. On the contrary, the multiple units of analysis approach have the advantage of allowing investigation to take place at different levels. However, it has a disadvantage of shifting the focus of attention away from the original research issues (Yin, 1994).

As the research questions of this study has implied, the unit of analysis of this study is the low carbon supply networks of a firm, which consists of the focal firm and other actors within the network—

suppliers, distributors, customers, etc. Relevant issues to investigate have been grouped into three main categories, as follows.

- *Network Influence*: to investigate how the actors and focal firms in the supply network are influenced to take action, including the process, method, and context
- *Emission Measurement*: to investigate how do firms in the supply network measure their carbon emission at the network level, including the process, resources, and skills
- *Network Improvement*: to investigate how the supply network can be improved to reduce carbon emission, including the process, systematic methods and practices

As the above three aspects can be investigated in one case company, so in this research a shared cases pool is built up to introduce all cases as a whole, and the detail practices in each issue is abstracted from each case pool to form a cross-case analysis, as shown in Figure 3.2, and the case data are elaborated in the same format in the Appendix. All the three issues are conducted in the cross-cases analysis. In the "Network Improvement" part, investigation to supply network's improvement practices includes two parts: 1) the systematic way of generating innovative improvement decision; 2) industry-specific best practices. The second issue is more applicable with documentation of large data set in order to give creditable result to the research question.

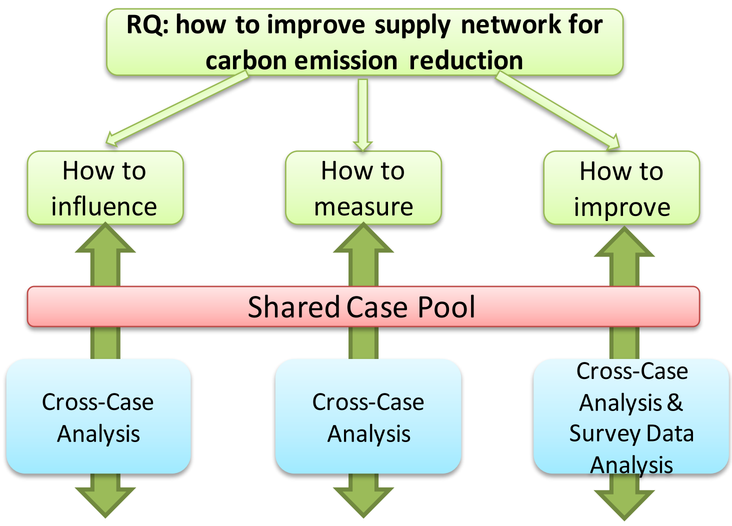


Figure 3.2. Research Process Framework

Besides, multiple cases from different industry sectors will be investigated to generate a cross-section view. Figure 3.3. presents the multiple-case design.

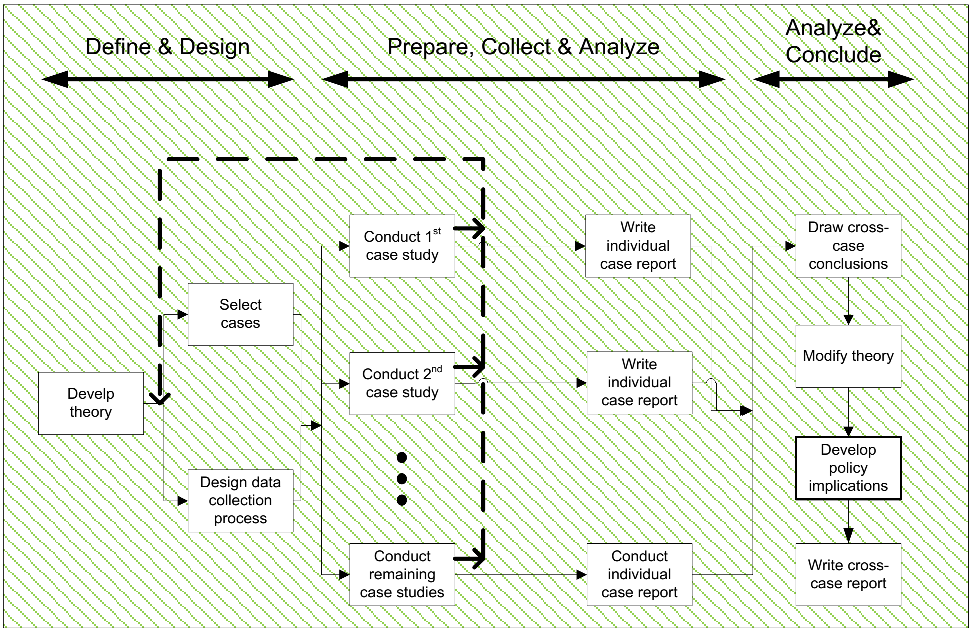


Figure 3.3 Case study method (Yin 2002)

3.5.2. Case Sampling

The sampling strategy of theory-building research is based on theoretical sampling, rather than statistical robustness (Glaser & Strauss, 1967). Theoretical sampling has been defined as the data gathering driven by concepts derived from the evolving theory and based on the concept of making comparisons (Strauss & Corbin, 1998). The purpose is to go to places, to people or events that will maximise opportunities to discover variations among concepts and to differentiate the categories in terms of their properties and dimensions. It means to select cases on the basis of concepts that have proven to be of theoretical relevance to the evolving theory (Strauss & Corbin, 1998). The sample size is not in itself valuable, or critical to qualitative research, but rather multiple comparisons are of a more critical nature in developing categories driven by theory development. The rationale of multiple case studies is based on replication rather than statistical sampling.

Table 3.5. Main Cases Pool

	Case Name	Influence	Measurement	Improvement
Mainland China	**WWF**	The program engages middle-size manufacturers which are OEMs or suppliers of large Electronic/Garment Brands to adopt GHG management system and carbon emission reduction practices. A large group of manufacturers are involved and significant monetary reward for company was achieved.	GHG protocol	GHG management practice Factory General Utilities Practices Manufacturing Process Practices
	Lenovo	Customer Pressure and Industry Trend	Product: Desktops. Lenovo's PCF (Product Carbon Footprinting) started from 2008 and it conducted the first desktop product carbon footprint in mainland China. Lenovo implemented two other footprint measurement projects in 2009 and 2010 with more rigorous standards. Lenovo is also actively involved in the Chinese electronic carbon standard formation and cooperates with international standard organizations as well as footprint relevant research institutes such as MIT Life Cycle Assessment Lab.	In 2013 Lenovo was the world's largest personal computer vendor by unit sales, followed by HP and Dell. Lenovo works closely with international organizations to set up carbon standards in ICT industry. And Lenovo is the first Chinese ICT company to measure product carbon footprint
	Tsingdao Beer	Proactive Carbon Strategy	Product: Beer in 330ml-bottle exported to UK. Both corporate level and product level carbon emission are measured in Tsingtao. Tsingtao is the first beverage brand to measure the carbon footprint in mainland China. Tsingtao invited a special consultancy to tutor the carbon footprinting process.	Tsingtao Brewery was the earliest Chinese brand entering international markets, and has topped the list of export volume among Chinese breweries. Tsingtao Brewery set up a position named carbon officer as the internal professional who specialises solely on carbon management issues
	ZTE	Customer Pressure	Product: Mobile. ZTE conducted the PCF due to the request of a European customer. ZTE has not measured the corporate-level carbon emission. The measurement team is positioned in the product quality department.	The request from European customer triggers ZTE to consider low carbon issues. Due to the manufacturing stage only takes up a small amount of ZTE's operation, it focuses on the product energy efficiency and data centre energy efficiency as its de-carbonization strategy.
Taiwan	**Taiwan IDB**	Taiwan government organized the Product Carbon Footprinting program to support Taiwan local large and Medium manufacturers to conduct PCF. With funding support from IDB and technical support from consultancy, more than 100 manufacturers including Acer, AUO, etc. participated the program.	N/A	N/A
	Acer	Industry Trend, Customer Pressure, NGO Pressure	Product: PCs. Acer as the leading brand in personal electronic products has therefore received higher pressure from consumer and the media on environmental issues. Because most of the production is outsourced to OEM and suppliers, Acer has set up a detailed plan to engage and tutor supply chain partners into this carbon measurement project.	Due to outsourcing manufacturing, Acer focuses its low carbon effort on product design. EMEA area takes up 38% of Acer's total sales, this fact makes Acer sensitive to low-carbon request.
	AUO	Industry Trend	Product: LED panel. AUO LCD TV is at the time (2009) had the most complicated products to conduct footprint measurement due to the large number of sub-components and suppliers. AUO generates its own carbon footprint calculation e-system in 2011 for suppliers to fill in footprint-relevant information	AUO performed the world's first product carbon footprint measurement for TFT-LCD panel which was the most complicated product that has been measured. AUO has been in member of Dow Jones Sustainability World Index for 4 consecutive years since 2010.
	Benq	Industry Trend	Product: LCD TV, Monitor, Projector. Because BenQ does not produce most of the products and outsources to OEM, BenQ developed a detailed plan to coach suppliers. One to one tuition for suppliers were conducted in order to ensure data quality	BenQ focuses on product design, logistics, and especially the supplier management. At 2012 BenQ gained the Carbon Neutral certificate for its LED product according to PAS2060 standard.
	TSMC	Proactive Carbon Strategy	N/A	TSMC is the world first of its kind and also largest dedicated independent semiconductor foundry company. TSMC is the first Taiwan company to be named as Dow Jones Sustainability Index (DJSI) Industry Group Leader, showing its excellence in sustainability performance.
	China Steel Corporation	Proactive Carbon Strategy	N/A	CSC actively involve with the De-carbonization projects of World Steel Association (WSA), and was awarded 'WSA Climate Action Star Member' in 2013. CSC forms a strong network with its local partners to put industrial symbiosis into a practice, gaining high reuse efficiency of waste energy and materials.

				waste energy and materials.
	Tungho Steel	Government Legitimate Pressure	Product: 'H' shape steel. Tungho steel and its over 10 of its suppliers were grouped together to participate in the Taiwan IDB PCF program.	Tung Ho is first steel manufacturer that participated the product carbon footprint measurement tutorial project from Taiwan Industrial Development Bureau, together with its 10 suppliers.
U.K	**CDP Investor**	Successfully attracted over 80% of Global 500 public listed Corporates to disclose carbon emission profile on a yearly basis	GHG protocol	N/A
	CDP Supply Chain	Successfully attracted over 3000 SMEs who are suppliers of large MNCs to disclose carbon emission profile, achieving a 66% increase from 1800 in 2011, and 300 from 2009.	GHG protocol	N/A
	Carbon Trust	Encourage companies to measure carbon footprint of their products or services according to special guideline. A certificate from Carbon Trust will be awarded and can be used on company product and website.	Generating PAS2050 Standard	N/A
	Trucost	The second largest Magazine in terms of subscription publish a ranking of largest MNcs worldwide with excellent performance on tackling climate change on a yearly basis. The magazine selects Trucost as technical partner to determine the ranking methodology. The companies with high ranking can build up a better image to public as a responsible corporate citizens.	N/A	N/A
	British Sugar	Continuous focus on material efficiency	Product: Granulated Sugar. British Sugar is one of the first six companies that have been involved in the trail practices of PAS2050. The footprint measurement process in British Sugar focuses on the internal production processes.	British Sugar is famous for its extensive and innovative material utilization (e.g. raise tomato by using residual CO2 from CHP plant) in sugar beet processing of Wissington factory. The recycle and reuse to co-products that generated in this process makes up the staggeringly high process efficiency: for every tonne of product, less than 2kg of waste is made.
U.S	**Greenpeace**	The NGO Greenpeace publishes reports to cricize the poor performance of Electronic companies for their non-clean energy supply in data centre. Since they have a strong impact to the public, companies on the 'Dirty Cloud' list, such as Apple, Samsung, receive great public pressure. Greenpeace also conduct protest campain on corporate's office or plant to disturb corporate's operation in order to express their request	N/A	N/A
	Dell US	Industry Trend and Customer Pressure	Product: Laptops. Dell calculated the Laptop carbon footprint using all secondary activity data in LCA software rather than from primary data. It is shown that the manufacturing and user phrase take up the two largest portions of total carbon footprint profile.	The company is well known for its innovations in supply chain management and electronic commerce, particularly its direct-sales model and its "build-to-order" or "configure to order" approach to manufacturing—delivering individual PCs configured to customer specifications.

In Table 3.5 the main cases and the related building blocks are shown that the case data can apply to. First of all the majority of cases selected are examples in emerging economies. In this study, case companies are identified based upon their perceived leading performance in the low carbon supply network operations and to provide a cross section of industries. At the same time, each individual case should demonstrate distinguished and internally consistent features in either one or all of the three areas--"influence, measurement, improvement".

The selective industries are divided into two types: assembly-oriented, such as ICT, and process-oriented, such as beverage, and steel manufacturing. Selecting industries that have a large carbon emission impact on the supply network is the second-priority, such as ICT and the chemical industry. The third criteria is that the case companies should focus on manufacturing rather than on service, and this criteria means that the majority of the cases companies will be from the Great China Area, due to the current global manufacturing landscape. The excellence of the firms' low carbon performance is also considered.

Accessibility is another, and perhaps the most critical, issue when selecting cases.

Even though this research focuses on the main cases in Table 3.5., which are in themselves relatively complete, and in-depth, all the other non-presented cases which have different degrees of completeness and depth, as well their engagements with NGOs and consultancies, contribute to the theoretical saturation of the theory.

Some of the non-manufacturing organisations are included due to several considerations: firstly, the decarbonisation practices are at a primitive stage for companies; therefore, there is not a sufficient amount of companies that have conducted decarbonisation programmes, and these non-government-organisations that are selected have all implemented low carbon initiatives which involve companies in progressing decarbonisation. Therefore, these examples from NGOs can be good supplements on decarbonisation practices. For example, the WWF Low Carbon Manufacturing Programme in the Pearl-River-Delta area in China developed a guideline and protocol of green manufacturing practices in plants at different levels. Secondly, in these low carbon initiatives NGOs serve as one of the key stakeholders of focal firms who are exerting a powerful influence. These organisations have important institutional factors in the focal firms' external business environment. Therefore it is necessary to investigate these organisations in order to answer the sub-research-question which is "How to influence firms to take decarbonisation actions".

3.5.3. Data Source and Collection

Case study data can be collected from primary sources and secondary sources (McCutcheon and Meredith 1993), and Eisenhardt (1989) gave out possible collection methods including archives, interviews (structured, semi-structured, unstructured), observation (convert or over, participant or non-participant, structured, semi-structured, or unstructured), and questionnaires. Yin (2002) analysed the strengths and weakness of six types of data collection methods shown in the Table 3.6. Data could be collected from any combination of these methods. At the same time, the source of data can be considered as primary or secondary. Primary data refers to those data sources specifically acquired for the research, whereas secondary data refers to data collected for some other purpose and kept archived in some form (Stewart & Kammins, 1984). In this research, the "Network Improvement" part, a large set of secondary data is applied.

Table 3.6 Strengths and weaknesses of each case study approach

Source:(Yin 2002)

Source of Evidence	Strengths	Weaknesses
Documentation	✓ Stable-can be reviewed repeatedly ✓ Unobtrusive-not created as a result of the case study ✓ Exact-contains exact names, references, and details of an event ✓ Broad coverage-long span of time, many events, and many settings	✓ Retrievability-can be low ✓ Biased selectivity, if collection is incomplete ✓ Reporting bias-reflects (unknown) bias of author ✓ Access-may be deliberately blocked
Archival records	✓ [same as above for documentation] ✓ Precise and quantitative	✓ [same as above for documentation] ✓ Accessibility due to privacy reasons
Interviews	✓ Targeted-focuses directly on case study topic ✓ Insightful-provides perceived casual inferences	✓ Bias due to poorly constructed questions ✓ Response bias ✓ Inaccuracies due to poor recall ✓ Reflexivity-interviewee gives what interviewer wants to hear
Direct observations	✓ Reality-covers events in real time ✓ Contextual-covers context of event	✓ Time consuming ✓ Selectivity-unless broad coverage ✓ Reflexivity-event may proceed differently because it is being observed ✓ Cost-hours needed by human observers
Participant Observation	✓ Same as above for direct observations ✓ Insightful into interpersonal behaviour and motives	✓ Same as above for direct observations ✓ Bias due to investigator's manipulation of events
Physical artifacts	✓ Insightful into cultural features ✓ Insightful into technical operations	✓ Selectivity ✓ Availability

Interviews and documentary studies are the main data collection approaches adopted in this study. Interviews provide the primary data for this study. This method can capture qualitative data from original sources in an immediate and personal manner, with the aim to extract six types of information: facts, beliefs about facts, feelings and motives, standards of action, present or past behaviour, and conscious reasons. This data collection approach allows the researcher to obtain facts, opinions about phenomena, and insights into the phenomena from first-hand sources (Yin, 1994); and provides an opportunity for the researcher to probe deeply to uncover new clues, open up new dimensions of a problem and to secure vivid, accurate and inclusive accounts that are based on personal experience (Burgess, 1984). As a data collection method for case studies, interviews are preferable to surveys and secondary data which typically sacrifice the richness and subtlety of understanding because they are unable to clarify questions or elaborate on answers (Parkhe, 1993). Interviews are particularly useful when (Easterby-Smith, et al., 1991):

• the step-by-step logic of the situation is not clear;

• the subject matter is highly confidential or commercially sensitive; and

• the interviewee may be reluctant to be truthful about the issue other than confidentially in a one-to-one situation.

In this study, the existing knowledge could not offer a structured way to understand the new emerging low carbon supply network issues. At the same time, some data such as the business strategy with carbon reduction consideration are usually considered as sensitive and confidential. Therefore, interviews seem to be the most appropriate method for this study. The semi-structured interview approach has been adopted because it allows the flexibility to ask questions about the issues that emerge during the research, while keeping the researcher focused within the research boundary (Bernard, 1995).

Interviewees are CSR directors, environmental affairs managers, supply chain/manufacturing managers and low carbon product design engineers at group, region or headquarter level. The question list will be prepared and sent to interviewees at least two days before an interview. Meeting notes will be prepared by the researcher and verified by interviewees after the interview. A presentation will be prepared for the first engagement with interviewees to demonstrate the background, objective and adopted approach of this research. The presentation slides will be tailored for the particular situation of a case company. The interviews usually follow a brief agenda to identify the key issues which will be discussed later through e-mail or telephone. As discussed previously, accessibility is a critical issue to case selection. The same thing happens to interviewee selection.

Eisenhardt (1989) contended that the use of multiple data collection methods provides stronger substantiation of constructs. *Triangulation* of data sources is necessary to avoid respondent and interviewer biases, clarify detail, and cross-check responses. The rationale is the same as in hypothesis testing research (Eisenhardt, 1989). Yin (1994) contended that the use of multiple sources of evidence in case studies allows the researcher to address a broader range of historical, attitudinal, and behavioural issues. At the same time, *triangulation* can address the potential problems of *construct validity* because multiple sources of evidence provide multiple measures of the same phenomena (ibid, 1994). In this study, the secondary data source (e.g., documentary studies) and the primary data source (e.g., interviews) are mutually reinforcing. Documentary studies (e.g., literature, reports, or news archives) enrich and offer a systematic structure for the discursive interview data.

The conceptual framework of the low carbon supply network guides the implementation of data gathering and data analysis and has been refined throughout this process.

• *Network Influence*: the major drivers and main barrier of firms considering to take action in carbon reduction, and the tools and mechanism of other actors in the network to engage firms. It is to answer the question: how can firms in a network be influenced.

• *Emission Measurement*: the key process, methodology, skills & patterns in carbon footprint measurement projects. It is to answer the question: how the emissions in the network are measured.

• *Network Improvement*: the patterns, methods, capability and best practices in firms' activities of changing to a low carbon emission mode. It is to answer the question: how to construct a low carbon supply network.

• *Relation*: relationships between influence, measurement, and improvement, and the loop back from improvement to influence.

Interviews in the exploratory stage are relatively open-ended. The discussion was usually around a number of broad themes such as:

• *network environments*, including pressures, motivations, strategy, technologies of carbon-related actions;

• *low carbon capabilities*, including the main methods, personnel, training to enable carbon-related actions, and the evolution roadmap of carbon-related actions;

• *low carbon network configurations*, including the organisation structures, coordination mechanisms, governance systems, support systems, and evolutionary trends.

Interviews became increasingly structured and specific when progressing to the latter stages.

An example of the question list in the development stage is presented in Appendix.

3.5.4. Data Analysis

The distinction between data collection and data analysis is difficult as the two processes proceed simultaneously (Glaser & Strauss, 1967; Easterby-Smith, et al., 1991). Rather than imposing an external structure on the data, qualitative studies (especially the grounded theory approach) use data to derive the structure (Easterby-Smith, et al., 1991). Yin (1994) mentioned that the logic linking the data to the propositions and the criteria for interpreting the findings might be the least well-developed area in the case studies. However, the overlap between data collection and data analysis allows the researcher to take advantage of flexible data collection, making relevant adjustments along the way (Eisenhardt, 1989). This adjustment can be the addition of cases to probe particular themes which emerge, the addition of questions to an interview, or the addition of data sources. The flexibility allows researchers to take advantage of the uniqueness of a specific case and the emergence of a new theme to improve the resultant theory (Eisenhardt, 1989).

Data coding occurs within the context of a progressively and iteratively analytical abstraction process which results in the synthesis of data into the conceptual framework. Strauss & Corbin (1998) proposed three major types of coding.

• *Open coding* is the analytical process through which concepts are identified and their properties and dimensions are discovered in the data (ibid, 1998). Researchers group certain concepts under more abstract or higher order concepts based on their ability to explain what is going on. Iteratively, the data or concepts can be grouped into main categories which are useful in explanation and prediction. In this investigation, one example of open coding is the result of generating constructs from data of improvement practices. The data is the text of firms' description of carbon reduction projects. After open coding, the three constructs 'Supply Network Stages, Emission Reduction Factors, Process Change Types' are identified (see Figure 6.16).

• *Axial coding* is the process of relating categories to their subcategories to form more precise and complete explanations about phenomena (ibid, 1998). The term 'axial' implies that the coding occurs around the axis of a category, linking categories at the level of properties and dimensions. The purpose is to reassemble the data that were fractured during *open coding*. *Open* and *axial coding* are not necessarily sequential processes. Rather, they usually occur simultaneously. In this investigation, one example of axial coding is the 2nd order categories of constructs from the data of improvement practices (see Figure 6.16).

• *Selective coding* is the process of integrating and refining the theory (ibid, 1998). Categories are organised around a central explanatory concept through integration. The first step of integration is to identify a core category, which represents the main theme of the research and accounts for most of the variation in a pattern of behaviour. Once the core category is identified, the next step is to integrate major categories around the core category to outline the theoretical scheme. Techniques to facilitate the integration include writing the storyline, using diagrams, reviewing and sorting memos, and so on. In this investigation, one example of axial coding is the 1st order categories of constructs from the data of improvement practices (see Figure 6.16).

The final activity of *selective coding* is refining the theory by means of reviewing the scheme for internal consistency and gaps in logic, filling in poorly developed categories, eliminating redundant ones, and validating the scheme. The three coding methods have been iteratively used throughout the three stages of theory building. Categories, sub-categories, dimensions, and properties of the low carbon supply network framework were significantly changed along the research timeline. New rounds of literature review were carried out to facilitate the changes of the framework.

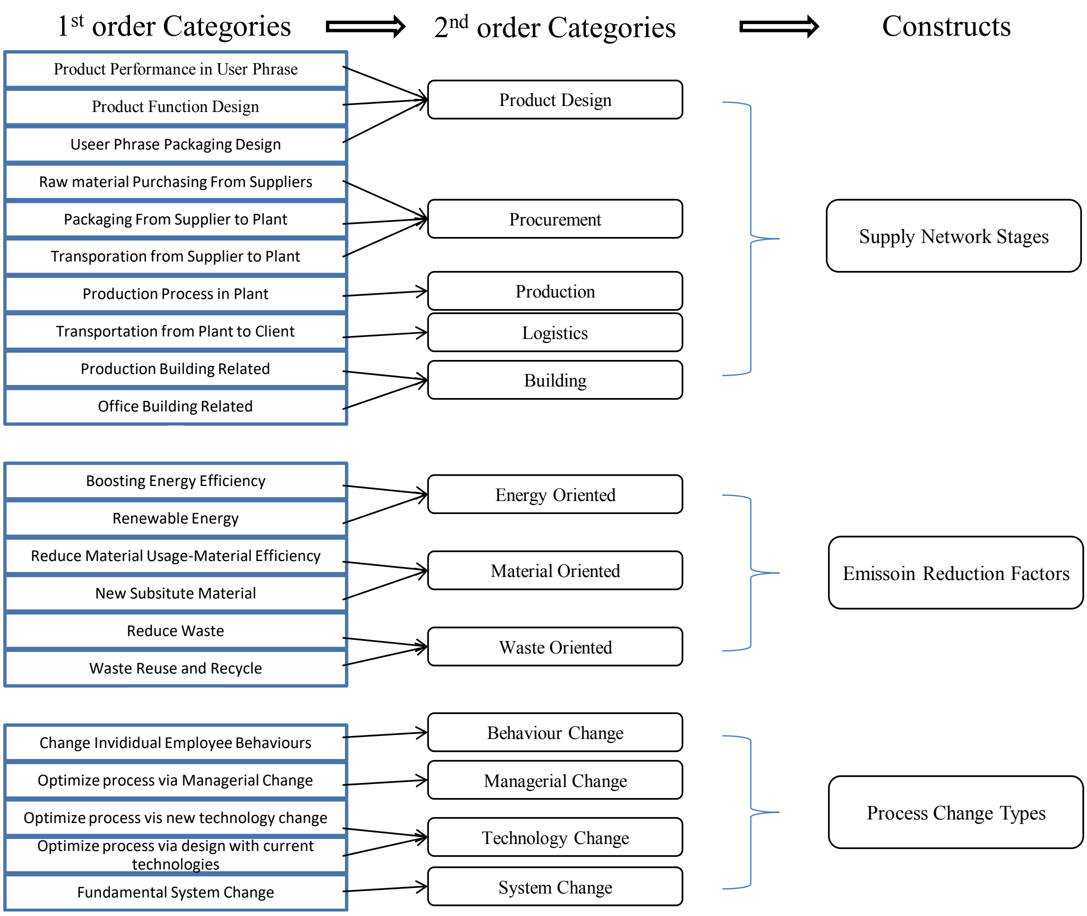


Figure 6.16. Three Constructs from Data of Improvement Practices

In addition to *coding*, *pattern-matching* serves as another important data analysis method. The logic is to compare an empirically based pattern with a predicted one, or with several alternative predictions. If the patterns coincide, the results can help a case study strengthen its *internal validity*. Yin (1994) proposed three types of *pattern-matching*: non-equivalent dependent variables as a pattern, rival explanations as patterns, and simpler patterns. Yin (1994) contended that the actual *pattern-matching* procedure involves no precise comparisons.

No matter which type is chosen, the fundamental comparison between the predicted and the actual pattern may involve no quantitative or statistical criteria. This lack of precision can allow for some interpretive discretion on the part of the investigator, who may be overly restricted in claiming a pattern to have been violated, or overly lenient in deciding that a pattern has been matched (ibid, 1994:110).

In this research, key patterns were generated in all three building blocks: the influence pattern in terms of resource linkages; the measurement pattern in terms of carbon-action objectives; and the improvement pattern in terms of “aspects of reduction focus”. To make the method more precise, the researcher generalised the “influence mode” and “influence choices” for the network influence part;

and introduced a "Three-scenario" measurement model for the carbon emission measurement process; and finally built a framework of the potential aspects that carbon reduction practices can focus on.

3.4.5 Validity, Reliability, and Generalizability

Research design quality depends primarily upon the researcher's rigour in dealing with reliability and validity issues (McCutcheon & Meredith, 1993). Easterby-Smith, et al. (1991) suggested three criteria in examining the value of research: validity, reliability, and generalizability (external validity). Although these concepts are developed from quantitative research practices and usually perceived as representing the application of the positivist viewpoint, using them for interpretative research can provide a 'useful discipline' for ensuring the consistency and coherence of the material acquired (ibid, 1991). Yin (1994) proposes reliability and three types of validity (i.e., construct, internal and external) to ensure the quality of any empirical social research. See Table 3.7.

Table 3.7. Case study tactics for four design tests

(Source: Yin:1994)

Tests	Case Study Tactic	Phase of research
External Validity	Use replication logic in multiple-case studies	research design
Internal Validity	Do pattern-matching Do explanation-building Do time-series analysis	Data analysis Data analysis Data analysis
Construct Validity	Use multple source of evidence Establish chain of evidence Have key informants review draft case study report	Data Collection Data Collection composition
Reliability	Use case study protocol Develop case study database	Data Collection Data Collection

External validity refers to the extent to which findings are applicable to other populations, i.e., generalisability. Yin (1994) argued that case studies should not be equated to data points and that, in fact, generalisation is possible. Theory building research relies on 'analytical generalisation', rather than 'statistical generalisation' (McCutcheon & Meredith, 1993). The use of replication logic in multiple case studies would provide more external validity (Yin, 1994). Christensen & Sundahl (2001) asserted that the external validity of a theory should be established through classification rather than by applying it to each conceivable industry, company or situation- that is an impossible task. This research addressed this issue with the multiple case studies and the combination of primary and secondary data. Each case has its own features from the perspectives of product, technology, customer, competition, or history. However, the cases demonstrate patterns and similarities in the aspects of design, capability building, cooperation and configuration in their separate supply network. The integrating framework of

"Influence-Measurement-Improvement" should not be limited to any case companies or any industry sectors and can be applied to other settings.

Internal validity refers to the ability to determine cause-and-effect relationships. The use of longitudinal cases can improve internal validity because of the capability of linking cause and effect (Leonard-Barton, 1990). In this research, the low carbon supply networks were studied with a view of evolution. Following the drastic restructuring programs of case companies, the researcher can observe and articulate the changes happening to their supply networks. In this study, many interviewees have worked for the same companies since the starting point of transition to low carbon status, some even experienced the earlier transition of green manufacturing and thus have the opportunity to experience or direct the projects. Their valuable experience helps the researcher to gain a complete view of the networks changes, and to understand their reasons and results as well.

Construct validity relates to the establishing of the theoretical territory that goes with the defined construct and ensuring consistency between it and other recognised constructs. The key is to establish correct operational measures for the concepts being studied (Yin, 1994). This was assured with the process of theory building and the deliberate case study design. The result of this study should be able to extend the existing theories on carbon-related research and network theory. In addition, the researcher has continuously consulted academic and industrial expertise to ensure the novelty, the theoretical and practical contribution of this study.

Reliability concerns that the operations of a study (such as the data collection procedures) can be repeated with the same results (Yin, 1994). It is an assessment of the extent to which different researchers are expected to make similar observations on different occasions. The objective is to minimise the errors and biases in a study (Yin, 1994). The well-developed preliminary framework and detailed process for data collection and data analysis should be able to ensure the repeatability of this study. In addition, multiple data gathering methods and data sources have been used in this study. Such *triangulation* helps to improve the validity and reliability (McCutcheon & Meredith, 1993).

3.6 Chapter Summary

This chapter describes the methodology to understand how a supply network can be improved in order to reduce carbon emission. A theory building approach based upon the social construction paradigm has been adopted to develop the theory from empirical studies. A multiple-unit-of-analysis and multiple-case design is chosen. Data has mainly been gathered through interviews and documentary (including secondary-data database) studies and analysed through coding and pattern-matching approaches. The preliminary framework built upon the literature has guided the process of data collection and data analysis and has been improved throughout the process iteratively. In addition, the evaluation criteria, and the strengths and weaknesses of this methodology have been discussed.

CHATPER 4 NETWORK INFLUENCE—INVOLVE FIRMS TO ACTION

The previous chapter develops the conceptual research framework, which are network influence, emission measurement and network improvement. This chapter aims to present the in-depth case studies and findings to answer the research sub-question: How can emerging-economy firms in a supply network be influenced to take action with regard to carbon emission reduction?

This chapter begins with an introduction to 7 cases which are all carbon emission influence initiatives. Based on cross-case analysis a focal firm external resources model and a typology of influence choice are built up, which serve as the underpinning components of the four-step influence framework which is being proposed afterwards.

4.1 Introduction

It was shown in the background introduced in Chapter 1 that emerging nations have to tackle the dilemma between fast economic growth and climate change constraints. However, governments in developing countries are more reluctant to set up stringent domestic regulations over carbon emission reduction, as they have serious concerns about slowing down industrial development and harming the economy. Since manufacturing industry takes up approximately 17% of total CO2 emission[5], there is a need to consider how to involve firms to take action where there is currently no strict legislation in place to control a corporate's carbon emission profile.

NGOs, governments and some proactive manufacturing firms are already seeking the answer to the above-mentioned challenge—"How can more and more firms be influenced?". Some initiatives have been conducted but prove to be very limited, such as the World Steel Association example discussed in the general background information in Chapter 1 . In this chapter, we aim to explore seven cases in order to answer this question. These cases are listed in Table 4.1.

[5] Source: IPCC (2007)

Table 4.1 Cases Pool

NO.	Cases	Region	Explanation
1	CDP Investor Program	UK, China	Successfully attracted over 80% of Global 500 public listed Corporates to disclose carbon emission profile on a yearly basis
2	CDP Supply Chain	UK, China	Successfully attracted over 3000 SMEs who are suppliers of large MNCs to disclose carban emission profile, achieving a 66% increase from 1800 in 2011, and 300 from 2009.
3	Carbon Trust PCF Standard	UK	Encourage companies to measure carbon footprint of their products or services according to special guideline. A certificate from Carbon Trust will be awarded and can be used on company product and website.
4	Trucost&Newsweek Magazine Green Ranking	UK	The second largest Magazine in terms of subscription publish a ranking of largest MNcs worldwide with excellent performance on tackling climate change on a yearly basis. The magazine selects Trucost as technical partner to determine the ranking methodology. The companies with high ranking can build up a better image to public as a responsible corporate citizens.
5	WWF Low Carbon Manufacturing Program (LCMP)	China	The program engages middle-size manufacturers which are OEMs or suppliers of large Electronic/Garment Brands to adopt GHG management system and carbon emission reduction practices. A large group of manufacturers are involved and signifant monetary reward for company was achieved.
6	Greenpeace 'Dirty Cloud' Campaign and Direct Action	US, Europe	The NGO Greenpeace publishes reports to cricize the poor performance of Electronic companies for their non-clean energy supply in data centre. Since they have a strong impact to the public, companies on the 'Dirty Cloud' list, such as Apple, Samsung, receive great public pressure. Greenpeace also conduct protest campain on corporate's office or plant to disturb corporate's operation in order to express their request .
7	Taiwan Bureau of Industry Development (IDB) Product Carbon Footprinting (PCF) Program	Chinese Taiwan	Taiwan government organized the Product Carbon Footprinting program to support Taiwan local large and Medium manufacturers to conduct PCF. With funding support from IDB and technical support from consultancy, more than 100 manufacturers including Acer, AUO, etc. participated the program.

After the introduction of cases in section 4.2, 4.3, a framework of influence process is generated through cross-case analysis in section 4.4. Identifying key resource ties, constructing influence tools, accessing firms and implementing influence impact are the core four steps in the proposed framework. In the following section 4.5 the firms' resource model is built up and its effectiveness on influencing firms is also discussed according to the cases pool. Correct identification of the key resources ties underneath relationship linkages is the key step in the influence framework. The effectiveness is affected by the criticalness of the resource tie, its context around the target firms and the firm's characteristic nature.

4.2. Carbon Disclosure Project—Investor Programme and Supply Chain Programme

4.2.1 Investor Programme—Investor Power over Public-listed Firms

Introduction to CDP History and Its Origin

Carbon Disclosure Project (CDP) is an international collaboration of institutional investors concerned about the business implications of climate change. It was launched in 2000 by Paul Dickinson, with the original aim of engaging the investment and corporate communities to work together to tackle issues of climate change. Paul set up the CDP as a secretariat for institutional investors to gain insight into the climate risk profiles of the FT500 firms originally. The basic idea is to follow the financial report released by corporations for the transparency of their financial situation to the current or potential shareholders. Although it now surveys a much larger and more international group of firms, company responses to the CDP questionnaire are also made publicly available on the CDP website.

International agreements such as the Kyoto Protocol have proved to be problematic, and individual governments have been reluctant to develop stringent national limits on emissions for fear of big companies relocating their factories and jobs to nations with laxer regulatory regimes. So CDP attempts to side step these national interests by focusing on individual companies rather than on nations. CDP brings together institutional investors to focus attention on carbon emissions, energy usage and reduction – wherever companies and assets may be located.

The Influence Strategy of Investor Project

The CDP represents a voluntary effort to develop standardized reporting procedures for firms concerning their climate-related activities, in a form intended to complement annual financial accounts and provide information relevant to investors relating to the business risks and opportunities from climate change.

The core strategy for the CDP Investor project is to recruit and persuade institutional investors who would give pressure to companies in which they invest for carbon disclosure. This strategy leverages the investor's power to pursue a broader civil accountability agenda of all companies. It should be noted that there are no costs or carbon commitments for signatory investors to attend this program. So, CDP build up the argument for carbon emission disclosure to leverage the investor first. The message to persuade investors is: "*prudent investing increasingly needs to take account of companies'* *environmental performance and specifically their exposure to the regulatory and cost burdens of carbon abatement regimes."*[6]

The letter sent to the major corporations submits a request for participation and provides a questionnaire for them to fill out. The one-page letter states that they may be a current or future investor in the company, and that they seek to examine the potential risks and opportunities related to climate change, and to improve their understanding of possible impacts on the value of the investments that the firm holds.

The key information CDP have used to leverage these institutional investors and lenders are the embedded potential risk of climate change to the companies they invest into. It is within the concern of investors that whether the invested firms have been aware of or taken action of mitigation and adaptation, in order to reduce the long-term risks arising from these environmental externalities. From the collected responses from the companies, CDP has built up an information platform giving global investors access to firms' year-on-year information on greenhouse gas emissions, water usage, and strategies for managing climate change, water and deforestation risks.

> *"CDP's data set is a unique and valuable tool in quantifying and comparing companies' carbon emissions management and strategies. CDP's work is a key part of GS SUSTAIN's analysis of the direct and indirect impacts of climate change on corporate performance, which will become increasingly important to investment analysis."*
>
> *Andrew Howard, Executive Director of Goldman Sachs*[7]

The number of institutions signing the letter requesting firms to answer the questionnaire has increased from 35 in 2003 to 315 in 2007, an annual 30% increase, and then with a steady 10% growth every year, reaching 655 in 2012. Correspondingly, the assets which these institutions represent have increased from 4.5 trillion USD in 2003 to 41 trillion USD in 2007, and 78 trillion USD in 2012, which is illustrated in Figure 4.1

[6] CDP Investor Fortune 500 Report, 2012, P55

[7] CDP Investor Fortune 500 Report, 2012, P5

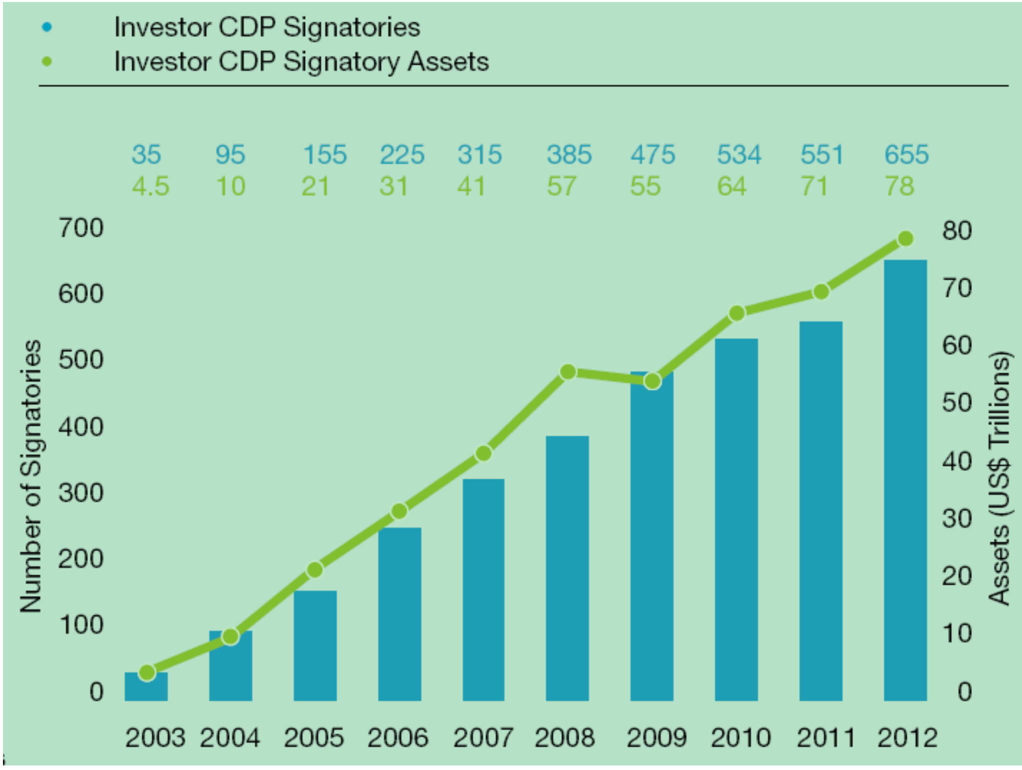


Figure 4.1 CDP Investor Signatories & Assets(USD Trilion) against time

The Process of CDP Investor Project

TimeLine of the project

The CDP climate change investor program runs on a yearly basis. In early November of the previous year the new invitation to institutional investors to be involved in next year's CDP signatories are sent out. After collecting all the responses from the investors, a formal information request letter will be dispatched to selected public-listed companies on 1^{st} of February. These companies are all listed in the major national stock exchange, including S&P, Nasdaq, FT, etc. Companies are required to fill in the related information via CDP's online response system. Technical and inquiry support are available to assist companies in the filling in of the survey. They are required to finish the questionnaire by the end of May. CDP cooperates with SAP for technical support, including the online response system and the database analysis. From May to August, partnering with different consultancy firms, such as A.T.Kearney, PWC, and local ones in separate regions, the analysis reports will be announced from September onward. This yearly routine is illustrated in Figure 4.2.

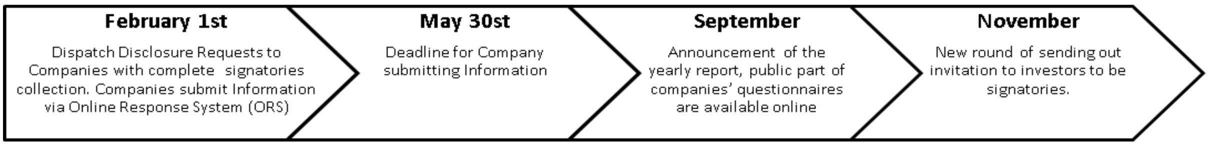


Figure 4.2 Timeline of CDP Investor Project

CDP has as a result gained exceptional influence in the investment industry which is reflected in Figure 4.1. CDP rang the opening bell for the New York Stock Exchange (NYSE), which marks the launch of its annual S&P 500 report looking at how the largest US companies are managing climate change issues, on 12th Sep on 2012. And CDP was called "The most powerful green NGO you've never heard of" by the Harvard Business Review on 2010[8].

The partner and service network of CDP

The success of CDP relies on its strong network of partners providing support on diffusing the information, techniques and consulting service. The global partners of CDP include a general advisor on project management and reporting implementation, which are PWC and Accenture. The technology sustains the data collection and analysis is provided by Microsoft and SAP with their data technology platform.

The most important network partner for persuading corporations to fill in questionnaires are the service partners, providing help to firms on multi-carbon issues, as shown in Table 4.2:

Table 4.2. CDP Investor Project Partners

Name of CDP Partners	Supporting Service
Calculation partners	To assist firms on emission data gathering process
Reduction partners	Offer technology and services consultancy to firms to reduce carbon emissions. These reduction projects generate the intrinsic motivation of companies to be involved.
Consultancy partners	Help companies to perform better on the data disclosure and engaging with CDP
Data partners	Work with CDP to publish influential reports using CDP's data. Bloomberg serves as the gold partner in this category.
Education & training partners	Work with CDP to encourage global corporations to undertake high quality carbon management training.
Index partners	CDP needs these partners to generate its index such as Carbon Disclosure Leader Index (CDLI). FTSE is one of these groups.
Verification partners	Provide verification services to companies under international standards, making their data disclosure more creditable.

This partners system supports those participating corporations offering a well-rounded management solution on the carbon issue, which fulfils their needs and greatly eases any corporation's difficulties

8 'The Most Powerful Green NGO You've Never Heard Of', Andrew Winston, http://blogs.hbr.org/2010/10/the-most-powerful-green-ngo/

in participation, ensuring the success of the CDP investor project— which aims to engage as many corporations as possible.

The Evolution of Content in CDP Questionnaire

The yearly CDP report is a summary and analysis according to the responses of companies. This report drills into companies' carbon management information, including measurement of emissions, organizational preparations, technological investments, and trading and offsets.

The original questionnaire of CDP contains four sections: The first section asks firms to identify commercial risks and opportunities from climate change including regulation, physical risks from extreme weather events, changes in technology and shifts in consumer attitude and demand; The second section asks about the firms' current and anticipated future responses to the risks and opportunities associated with climate change; The third asks for detailed information about the firm's accounting for greenhouse gas emissions, which is the numbering of carbon emission; The fourth asks who is responsible for climate change in the firm (CDP,2007).

The CDP questionnaires are evolving as well, take the latest CDP 2013 questionnaire (Table 4.3) for example, it includes 14 questions in three categories: Management, Risk & Opportunities, and Emission. The management issue has been highlighted as the most important disclosure part as positioned in the first section of questionnaire. The organizational structure ensures the carbon emission reduction issue are in the top list of their agenda. Attention from senior management enable the credibility and successful implementation of the carbon disclosure.

Table 4.3 CDP Investor Project Questionnaire 2013

Management		
	1. Governance	Group and individual Responsibility Individual Performance
	2. Strategy	Risk Management Approach Business Strategy Engagment with Policy Maker
	3. Targets and Intiatives	Targets Emission Reduction Initiatives
	4. Communicatioins	
Risk & Opportunities		
	5. Climate Change Risk	
	6. Climate Change Opportunities	
Emissions		
	7. Emissions Methodology	Base year Methodology
	8. Emission Data	Boundary Scope 1 and 2 Emissions Data* Data Accuracy External Verification or Assurance Carbon Dioxide Emissions from Biologically Sequestered Carbon
	9. Scope 1 Emission Breakdown	
	10. Scope 2 Emission Breakdown	
	11. Energy	
	12. Emissions Performance	Emission History Emissions Intensity
	13. Emission Trading	
	14. Scope 3 Emissions*	

The Influence Process is summarized in Figure 4.3.

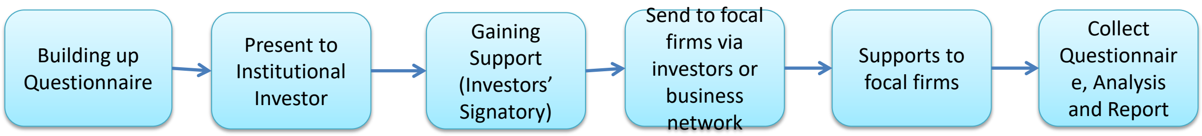


Figure 4.3. CDP Investor Programme Influence Process

The Great Success of CDP Investor Program in Developed Countries

The first year CDP data was collected was 2003. From 2003 to 2005 the questionnaire was only sent to the FT500, the largest global public firms by market capitalization. In 2006 the number of firms the questionnaire was sent to increase to 1900, and in 2007 to 2400. From 2008 CDP developed a different special focus of the survey, including the traditional climate change project, supply chain project, water project, city project, etc. Developing countries contribute a higher percentage of the world's total carbon emission—nearly 60% from Non-OECD countries, and Especially China and

India who produce nearly 33% of the total carbon emission[9]. Consequently CDP expanded its project to corporates in these developing countries. In 2012, there are 27 projects and the disclosure reports, covering different regions--such as China, Latin America, Brazil, Europe, Australia and New Zealand, etc., and different stock markets—such as FTSE 350, S&P 500, Global 500, etc.

In 2012 CDP asked over 6,000 companies around the world to report their carbon emission profile. Focusing on the largest companies, Global 500 Report selects the largest companies by market capitalization included in the FTSE Global Equity Index Series.

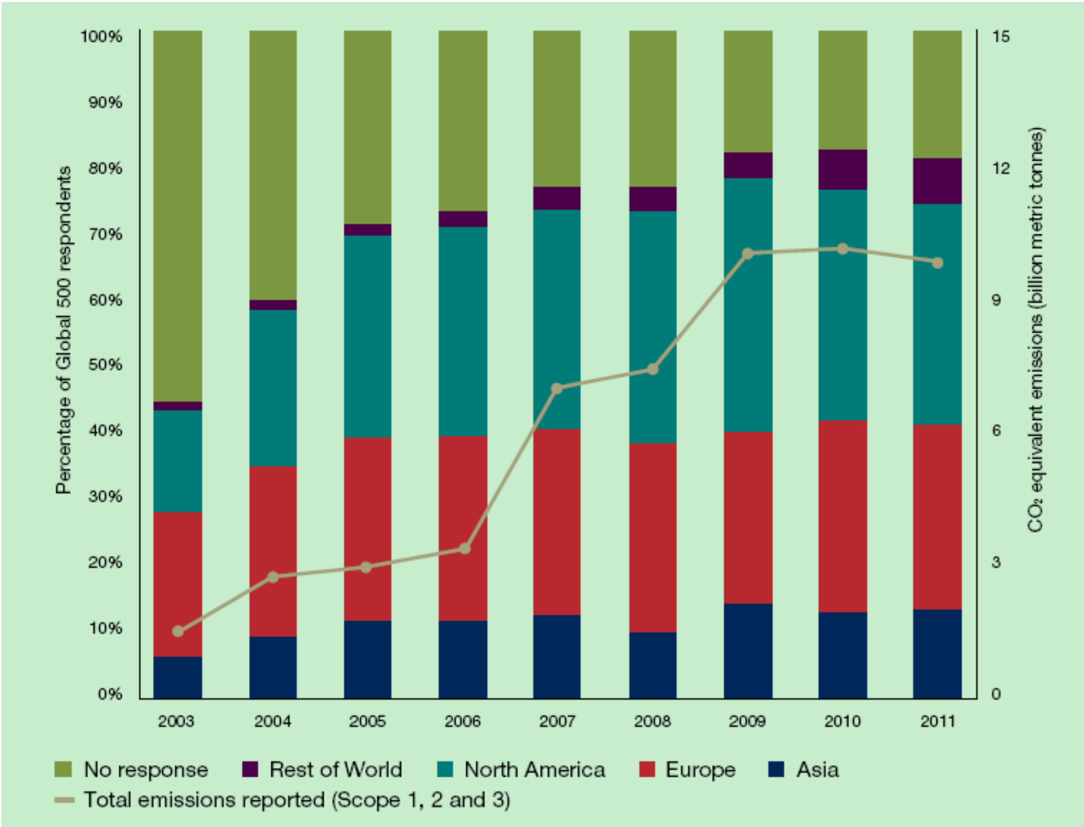


Figure 4.4 Total response rates and disclosed emissions over time by geography

(Source: CDP Global 500 2012 Report)

Figure 4.4 illustrates a clear trend of more large companies being involved in the CDP investor project. The largest amount of Global 500 companies are in the North America, Europe and Asia. The

[9] 2011 data collected by Carbon Dioxide Information Analysis Centre in Department of Energy of U.S.

regional breakdown of the companies and their response to the CDP 2011 program is shown in the Table 4.4:

Table 4.4. Regional Breakdown of Companies' Response

Region	NO. Global 500	NO. Response	Response Rate
Asia	122	67	55%
Euro	145	131	90%
North America	190	168	88%
Rest of the world	43	38	88%

It is clearly shown that Asian firms are relatively more reluctant and passive to disclosing GHG emission data to the public while their European peers are much more active, after 8 years of the CDP project being run. .

Exception in Developing Country Context

CDP's investor programme is not so successful in the developing country context, especially in the Asian market such as China. China is fast growing as the manufacturing factory for a lot of products globally and it is the second largest economy in terms of GDP after the U.S... Still being a developing country China is a good example for examining the diffusion of the worldwide carbon issue. According to CDP's 2012 China Report, the 100 companies come from 25 industries and the 23 companies that answered CDP questionnaire reside in 7 industries. The average rate of response is 23%, with the high rate of 75% from Telecommunication, 66% from IT, 50% from Energy, and 28% from Financial. The questionnaire is sent to the Top 100 companies listed on the Shanghai Stock Exchange in term of market value.

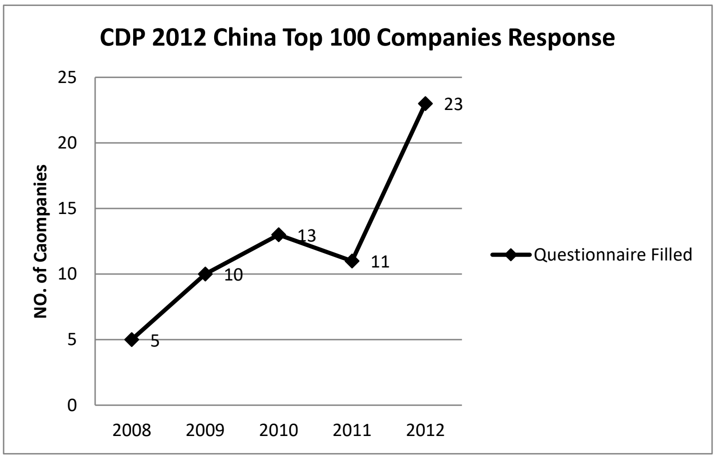


Figure 4.5. CDP China Top 100 Responses 2012

(Questionnaire Filled: The companies filled in the CDP survey and returned it)

Although the response rate has significantly increased in 2012, the overall rate of 23% is well below the average rate of CDP's Global 500, and the one (55%) in Asia of Global 500 as well. In the Global 500 survey, only 2 of the 13 Chinese companies responded (Figure 4.5).

The low response rate suggests that the Chinese companies are not so motivated by the CDP programme and are reluctant to attend. The same data can be monitored in other developing countries, taking the CDP Global 500 program as an example and this shows the percentages as the following: Chile 33%, Hong Kong 29%, Singapore 17%, Malaysia 33%, Mexico 33% etc.. There are multiple reasons that can be suggested for this situation, including the different legitimacy environments, and their culture and financial markets as well.

Explorative interview with Chinese Companies

Several interviews have been conducted with Chinese commercial banks that did not attend the CDP signatory and several public listed firms that did not reply to the CDP Investor Project's questionnaire. The following rationales have been identified as the reasons why they were reluctant to attend.

On the investor side, banks stated that a dilemma existed in the situation. The public-listed firms, which the bank invested a large amount into, are also important customers of the banks---the large part of the deposit which is regarded as baseline for the banks are from these public-listed firms. So the green investment principle may not be applicable in this context to require the large firms to disclose their GHG emission performance, as these investors do not hold enough strong power over firms due to the interdependence of resources.

On the public-listed firms side, reasons for ignoring the request can be summarized into several points: lack of coercive legislation on climate change issue; lack of the requirement from the government bureau which are the main shareholders (state-owned) of these public-listed firms; Worries about the information disclosure to the public.

From the above explanation shareholder power is found not necessarily to be the most powerful influence to the firms. The effectiveness of this influence can be affected by the position of the shareholder, the mutual resources dependence between firms and shareholder, etc. In highly developed capital markets with highly discretely distributed investors and strict requirement for information transparency, the investor power might be more mighty and influential.

4.2.1 Supply Chain Programme—Large MNCs Power over Suppliers

Introduction of CDP Supply Chain Project

After attending the CDP Investor Project for one year from 2006, Walmart started to think about the combination of the carbon issue with its core business unit—supply chain management due to an idea to enhance energy efficiency and to achieve better understanding of its supply chain management, because for Wal-Mart who doesn't actually manufacture products, pushing its suppliers is a realistic approach. The trigger came when Walmart discovered that the refrigerants used in grocery stores accounted for a larger percentage of Walmart's greenhouse gas footprint than its truck fleet and were therefore able to put in place new strategies to address the issue. They then realized the potential benefit of their suppliers disclosing to CDP as well. In September, 2007 Walmart announce a partnership with CDP to measure the energy used to create products throughout its supply chain, including the procurement, manufacturing and distribution process. This action triggered CDP to re-think its engagement methodology and their ultimate goal to engage/influence as many corporation as possible, and the supply chain provided a natural and powerful network to diffuse the initiative.

To accelerate the network effect, CDP has launched a supply chain initiative to enlist large companies to persuade their suppliers to begin reporting to CDP. The supply chain provided an extended network to diffuse the carbon emission reduction practices rather than contacting corporates one by one.

Influencing Strategy of Supply Chain Project

The CDP encourages the large corporation to attend the project by its business network and brand image—which was brought in by the CDP Investor Project.

The suppliers are then influenced through the member corporations' supplier network.

The Process of CDP Supply Chain Project and its Timeline

Each year CDP started the project by sending out the membership invitation to the large corporation. The argument to do this was presented by CDP are as follow:

- To help a corporation build a resilient supply chain that is prepared for changes to the physical, regulatory and market environments that climate change and its related effects will bring.
- To engage suppliers on climate change by utilizing the streamlined system.
- To build a targeted list of suppliers, engage them effectively, and make sense of the data that what kind of risks should be paid attention to.

The argument or reasoning of CDP to these large corporations was the embedded risk and opportunity available in a corporation's supply chain, and better performance of carbon emission along the holistic supply chain, especially for the proactive large corporations.

> *"As a founding member of CDP, Unilever believes that CDP's standardised approach to emissions reporting can provide real benefits. In 2010, we will expect an increase in the number of our suppliers engaged through CDP. Unilever will continue to drive emissions reduction activities across the supply chain, and we expect real progress in suppliers' emission reduction".*
>
> ---Marc Engel, Group Chief Procurement Officer, Unilever (CDP 2012)

Timeline of Supply Chain Programme

Each year the supply chain project starts with the large corporation paying the membership fee to CDP to become supply chain members in the coming report year. CDP will assign an account manager to the specific member.

With the help from account managers, member corporations review its suppliers and selects out those who will be included in the information disclosure request. Through this stage, member corporations usually get the opportunity to examine their suppliers and identify the ones with that have potentially a larger amount of energy and material usages. After the suppliers list is generated, briefing and engagement events will be conducted by the members to their suppliers, stating the requirement for them to take part in the survey and the importance of doing so. After the briefing, requests are sent out the suppliers via two paths: by the member companies or by CDP. These two pathways bring in significantly different response level , the response rate via members are much higher than that directly from CDP. Suppliers received the email and are asked to fill in the disclosure form via the CDP online system, more or less the same as CDP investors. During these processes, CDP and members offer encouragement and technical support to suppliers.

Figure 4.6 CDP Public Procurement 2008 (similar to the CDP Supply Chain Program)

After the response deadline, CDP and its partner will produce analysis to the cohort data on the ORS (Online Response System) and generate report. Member corporations could review the responses and summaries of responses from suppliers. And member corporations will also provide feedback to CDP on the whole project process as well as the questionnaire design. The timeline of this yearly project is as follow (Figure 4.7):

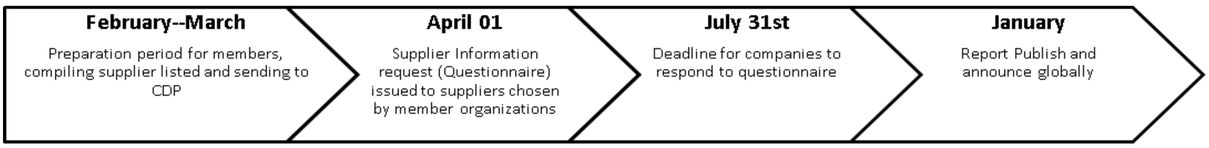


Figure 4.7 Timeline of CDP Supply Chain Project

There are four parts in the questionnaire for suppliers to fill out: strategic awareness, carbon reduction ambition, reporting capabilities, and implementation practice.

Support to the member and the suppliers

There is an account manager assigned to each member. The account manager would provide help to corporation members on supplier listing, communication between members and suppliers, and the process plan that members use to engage suppliers.

Tools like progress updates, supplier scorecards, and customized feedback can help in the transforming of the member-corporation’s procurement process to effectively control climate risk.

The influence process is summarized in Figure 4.8.

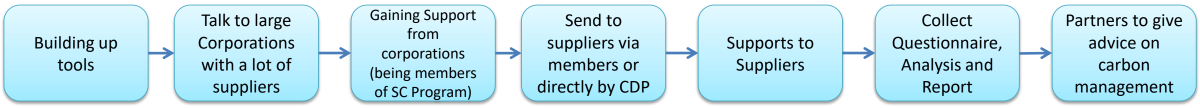


Figure 4.8. CDP Supply Chain Programme Influence Process

The Success of Supply Chain Project Globally

On 2013 CDP information request was sent to more than 6000 suppliers on behalf of 52 of the 54 Supply Chain members. Responses were received from 2415 organizations, including the 52 members. These corporation members represent a combined spending power of almost US$1 trillion.

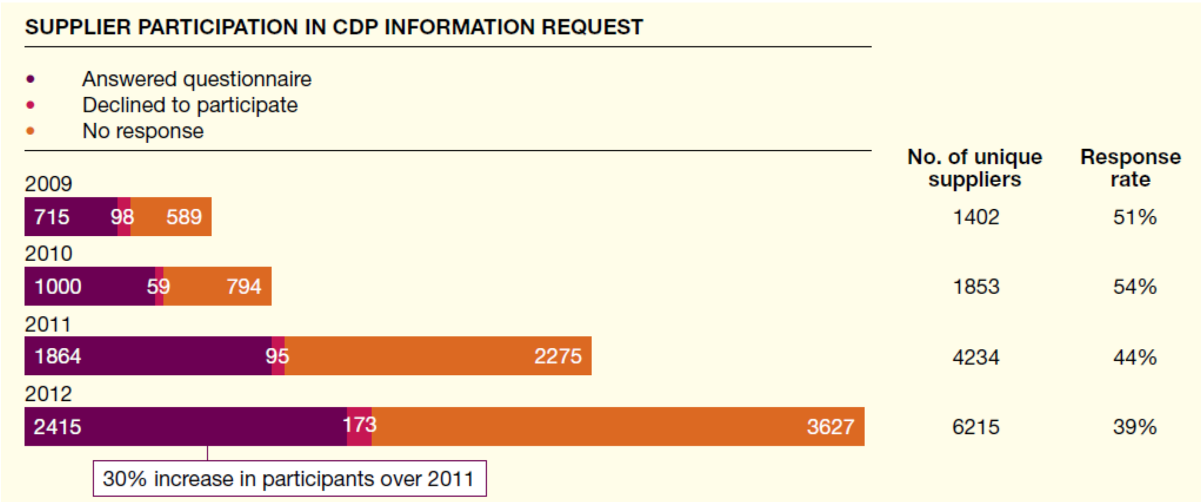


Figure 4.9. CDP Supply Chain Project 2012 Suppliers Participation Summary

Since its inception, the number of suppliers that response to CDP information request has continuously increased, by 40%, 86% and 30% (Figure 4.9). Even though the response rate seems to drop for 2012, this was because of the significant increase of suppliers to which the questionnaire were sent. Our findings show that the Supply Chain Project, compared to the Investor project, has a relatively lower response rate. However, if we focus on the number of companies involved, it illustrates that the supply chain project has achieved great success and will increasingly motivate more to participate.

Success in Developing Countries as well

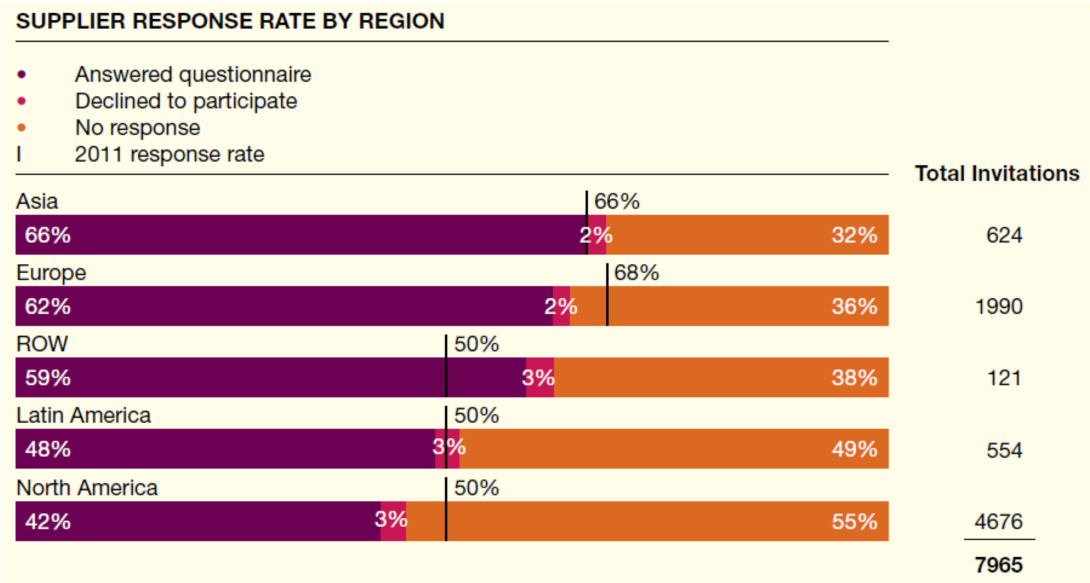


Figure 4.10. CDP Supply Chain Project 2012 Suppliers Participation Summary by Regions

In the Figure 4.10 it shows the response rate by regions. It should be noticed that in this figure the number means the invitation rather than the number of suppliers that have received the questionnaire. Because one supplier may have received multiple invitations, therefore the number of invitations is larger than the number of suppliers that attended

Compared to the low response rate of the Asian corporation in the Investor project, the Asian suppliers are much more active on the supply chain project. Asia tops other regions by its 66% response in the answering of questionnaires.

Especially in China, the Supply Chain program has achieved a much better result than CDP's Investor program in terms of the motivation of companies on disclosure their GHG emission data.

> *"After the introduction of supply chain program in 2009, more and more inquests on support of disclosure forms are received at the CDP China Office, contrasting sharply to the ignorance from large firms towards investor project."*
>
> ---Rusong Li, Director of CDP China

From 2010, CDP's China division kept receiving lots of requests from manufacturing companies, mainly export-oriented ones, to receive some guidelines on how to complete the questionnaires.

Table 4.5. The involved Chinese companies amount in supply chain program

Years	2008	2009	2010	2011	2012	2013
No of Response Chinese Companies	5	24	41	83	89	159
Increase Percentage	NA	480%	171%	202%	107%	179%

The continuously increasing number of Chinese companies demonstrated that supply chain power is more effective than investor power in China, in terms of leveraging the firms to participate.

Where Supply Chain Loses its Magic Power

Large public-listed corporations in China seem to be still untouched or not effectively influenced by either the investor projects or supply chain projects, especially those who do not directly sell products to customers or export products to Europe and US markets. Regulation pressure and concerns on energy resilience in operation are potentially the more powerful motivation for these corporations to take actions.

4.3 Other Influence Cases

4.3.1 WWF LCMP (Low Carbon Manufacturing Programme)

Introduction

The Low Carbon Manufacturing Programme was first launched in 2008 with three pilot companies implementing the project. Developed by the World Wildlife Fund environmental group, it initially targeted the plastics, electronics and textile industry in the Pearl River Delta (PRD) of South-eastern China. The Programme is focusing on these three sectors because they are among the largest number of factories in PRD.

The PRD is a heavily industrialized and polluted region of China that stretches from Hong Kong inland to Guangzhou. There are roughly 55,000 factories with whole shares owned by Hong Kong companies. According to the initial reduction by the pilot plants, which is at a rate of 12%-24% yearly reduction--19% of their total GHG emission--4053 tons, WWF estimates that if most of these Hong Kong-owned factories adopt the LCMP management system, the region could cut 7,400 million tons of CO2 emissions each year, which amounts to the cohort emission of most Scandinavian countries.

The Core Influence Strategy and Influence Process

The core strategy WWF-LCMP has used is to label firms with green/low carbon tags. After being involved in the project right to the end, companies are then certified with a LCMP label, which are certified, silver, gold, and platinum according to the rating from low to high, as it is shown in the Figure 4.11.

Figure 4.11. LCMP Certification

The certification system examines the company on three aspects: 1) GHG management system implementation level; 2) Energy efficiency best practices adoption level; 3) GHG reduction achievement.

The LCMP highlights the key benefit to the firms is that it could differentiate them apart from their competitors on the green issues. The target group---manufactures in PRD areas, are mainly OEM (Original Equipment Manufacturer) factories with the products manufactured for the large brand corporations. Getting orders from clients are the main focus of these companies, so with relatively similar technology skills and capacity, better performance on the climate change issue will be next criterion for selecting the producers.

There was a strategy for WWF to identify these three pilot companies. After receiving the funding from Bowen Capital Asia, Green Dragon fund and Hong Kong Productivity Council, WWF developed the related tools and methodology of the LCMP GHG emission, and set up the target companies according to the following logic:

1) The WWF Hong Kong division is based in Hong Kong, and the program gets support from the Hong Kong Productivity Council, so the companies in Hong Kong are relatively easy to access;
2) The PRD cluster is the largest manufacturer for the retail business in the world, while a large portion of these factories and plants is owned by companies in Hong Kong, with them headquarter in Hong Kong or registered in Hong Kong;
3) There is a business consortium of these Hong-Kong-based companies, connecting members and spreading the ideas of carbon management;
4) These Hong-Kong-based exporters have already experienced the request and pressure from clients on carbon emission disclosure actions;

5) The main export products, as well as the cluster in PRD, are electronics, textile, and plastics, with large amount of GHG emission as well.

So the Hong-Kong-based manufacturer in the above industries are targeted and approached via the business consortium. And the proposal of pilot plants are welcomed and supported by the companies as expected.

In order to encourage companies participating in LCMP, the following potential benefits to the companies are listed out:

- Improve energy efficiency, saving money in the long run
- Standing out in the global competition
- Attract new customers and retain current customers
- Low or even no investment cost
- Prepared for the future global regulatory challenges
- Demonstrate vision to shareholders and investors

According to the summary of Helen Ho, the program manager of LCMP, after 3 years running, the key driving points to leverage companies to take part in LCMP is to retain current clients and reduce production costs—by optimizing energy management.

Project Process and Timeline

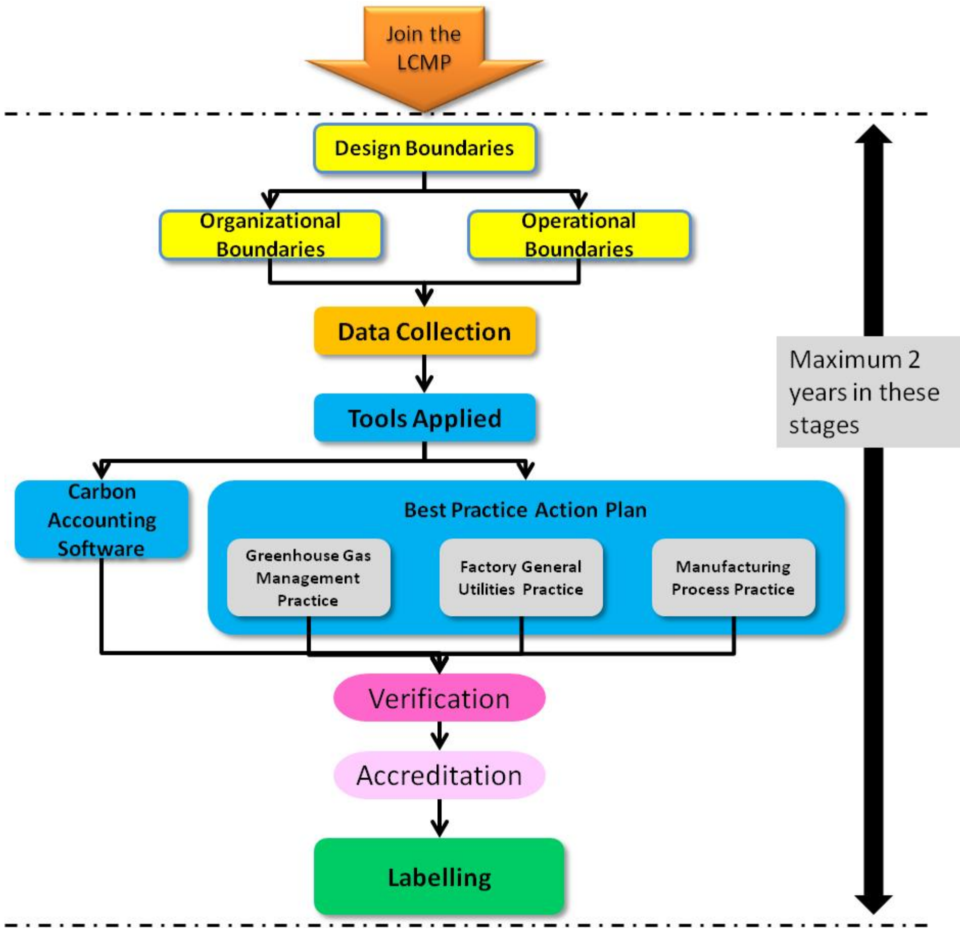


Figure 4.12. The process of LCMP (Adopted from the LCMP Factsheet)

The Figure 4.12 clearly shows the main processes of attending LCMP: Determine the boundaries, data collection using apply tools to manage, verify and accredit data , which is finally then labelled. In setting the boundaries, organizational boundaries are examined to help participants to specify how many factories will be in the scheme. The operational boundary setting follows the GHG Protocol in ascertaining the scope of activities to be included in the calculation. Data collection is for setting up a GHG inventory list, and ongoing monthly data are collected from primary and secondary sources through a variety of channels for entry into the carbon accounting system. In the tool applicable list, the carbon accounting software is an online monitoring and reporting tool for carbon accounting based on the GHG protocol and local—Chinese fuel emissions factors. A Checklist compatible with ISO14001 helps to ensure the best GHG management practices implemented, serving as one of the tools. Factory general utilities practices are also a checklist of improvement measures to maximize efficiency in design and the maintenance of the utilities in the factory (such as heating, ventilation, air-conditioning, lighting, compressed air and stream system, etc.). Manufacturing process practices gives advice on how to streamline industry-specific production processes facilities that directly related to producing, monitoring and controlling machines. An independent verifier and independent accreditation committee are involved and provide a contribution before the final label is granted to the company.

The influence process is summarized in Fi1gure 4.13.

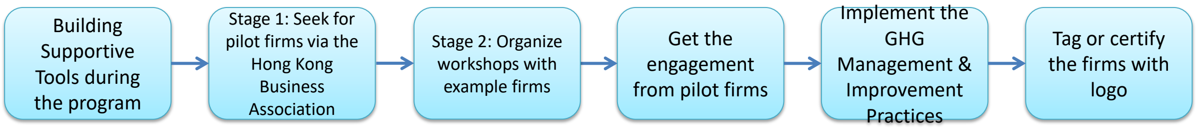


Figure 4.13. WWF LCMP Project Influence Process

The Success of LCMP

Starting from 2008, 3 pilot plants participated in the LCMP program. In 2013 the attending company number has grown to 56. And the involving industries have exceeded from textile, electronics and plastics to printing as well. And the program has built up influence scope from PRD to some companies in Yangtze River Delta and even northern cities of China.

In the three pilot cases, LCMP has proved its effectiveness: all practices have generated significant additional cost saving with a payback period of investment less than 1.5 years, with continuous saving about 2 million RMB on energy bill.

The practices tools developed in LCMP were applied to companies, generating an innovative and practical best practices guidebook. Some of them are shown in the Table 4.6:

Table 4.6. The Best 20 Energy Conservation Practices in LCMP Cases

(Adopted in LCMP Factsheet)

	Annual Energy Cost Saving (RMB)	Investment* (RMB)	Payback (Year)
Overall Total	> 2,600,000	< 3,200,000	1.2
Diesel and Solar System			
– Conduct proper maintenance	60,000-70,000	◆	Immediate
Compressed Air System			
– Raise awareness of all users on the proper use of compressed air	40,000-50,000	◆	Immediate
– Implement a leakage reporting and repair program	N/A	◆	Immediate
– Use of high-efficiency motors instead of normal motors	30,000-40,000	◆◆	1.0
– Install Variable Speed Drive (VSD) control	30,000-40,000	◆◆	1.0
– Optimize the control of multiple compressors	30,000-40,000	◆◆	1.0
– Install heat recovery measures where appropriate	100,000-120,000	◆◆◆◆	1.7
Lighting System			
– Use natural light to reduce the need for lighting	70,000-80,000	◆	Immediate
– Implement good management policy of lighting system	30,000-40,000	◆	Immediate
– Redesign the lighting system	30,000-40,000	◆◆	0.5
– Use high-efficiency lighting equipments	120,000-130,000	◆◆◆◆	2.6
HVAC System			
– Increase temperature setting point of HVAC system by 1-2°C	50,000-60,000	◆	Immediate
– Ensure refrigerant pipes are properly insulated	15,000-20,000	◆	Immediate
– Clean filters	10,000-20,000	◆	Immediate
– Use scale control for condensing water	90,000-110,000	◆◆	0.1
– Use solar shading devices	190,000-200,000	◆◆◆	0.8
– Retrofit chiller plant	90,000-100,000	◆◆◆	2.0
Production Machines			
– Reduce idle and standby time	225,000-235,000	◆	Immediate
– Install VSD control on motors	735,000-745,000	◆◆◆◆	1.0
– Replace standard motors with energy efficient motors	440,000-450,000	◆◆◆◆	3.2

Information comes from one of the LCMP pilot companies. Data is approximate, and for reference only.

* ◆: < RMB 10,000 | ◆◆: RMB 10,000-99,999 | ◆◆◆: RMB 100, 000–199, 999 | ◆◆◆◆: > RMB 200, 000

Innovative energy saving practices include building a transporting bridge between factories to avoid the use of lifts, and applied after-use hot water to heat staff accommodation, etc. These innovations happen in the real-time operations of the factory under a random idea generating process.

The Limit of LCMP Influential Power

Large corporations in the developing countries, especially those that produce industrial products rather than consumer products, stayed comfortably in a pressure-shielded position since neither strong regular forces nor customer forces are present.

4.3.2 Carbon Trust—Carbon Footprint Labelling

Carbon Trust is an organization originally funded by UK government department DEFRA (Department for Environment, Food and Rural Affairs). Now it has turned into an independent organization helping business, governments, and public sector to accelerate moving to a low carbon emission economy through carbon reduction, energy-saving strategies and commercialising low carbon technologies.

Three types of services are provided by the Carbon Trust: 1) Providing advice on sustainable low carbon transition and strategies; 2) providing services on the measurement and certification of the environmental footprint of the organisations, and their products and services; 3) to help develop and deploy (such as investment) low carbon technologies and solutions, including energy efficiency and renewable power. And Carbon Trust also conduct investment on low carbon technology, acting as a "green bank" giving out 0% interest loans to clean-tech start-ups.

The key part of Carbon Trust's effort to encourage companies to take part in carbon reduction action is the carbon footprint measurement certification and labelling. Together with Defra, BSI (British Standard Institute) and six companies, Carbon Trust developed the first-in-world carbon footprint measurement protocol—PAS2050(Public Available Standard 2050) and provides the consultancy service to measure carbon footprint, and verification as well. The detail introduction of PAS2050 is in Chapter 5.

Carbon Trust provides mainly four types of certification/labels. One of them is for the organizational level carbon footprint verification. The second one focuses on the continuous overall CO_2 reduction. The final two focus on the carbon footprint of the product and are called the 'Reducing CO2 label' and 'CO2 Measured label'.

Reducing CO2 label signifies that the corporation has measured and has certified the carbon footprint of its products and services, and also shows its commitment to reduce CO2. This label could be used on and off products, communicating the companies' carbon reduction commitment and achievements to the end customers, usually the household users.

CO2 Measured Label shows that the corporation has accurately measured the footprint and communicates the carbon footprint. However, no commitment to reduce the products' carbon footprint can be made using this label. The specific footprint number of the product could be with or without the certificate.

For both labelling options PAS 2050 and/or the WRI/WBCSD the GHG Protocol Product Standard will be the certification requirement. The use of the Reducing CO2 Label also requires re-certification every two years, when it must be demonstrated that the carbon footprint of a certified product or service has been reduced. Use of the CO2 Measured Label enables firms to communicate the carbon footprint of products or services.

In order to get the certification, the certified carbon footprints must meet the requirements in the Footprint Expert™ Guide and the Code of Good Practice developed by Carbon Trust.

The Core Influence Strategy of Carbon Trust

The key messages for Carbon Trust to persuade focal firms include the following benefits:

1) **Corporate reputation and brand preference**—to drive the awareness of the focal organisation's and products' environmental credentials to customers and stakeholders and improve environmental rankings and demonstrate CSR.
2) **Increase sales---** the carbon footprint label can enable organizations to differentiate its products from competitors. The Carbon Trust believes the low carbon product is a customer's procurement requirement, and so could increase customer loyalty and help drive sales.
3) **Broaden market distribution**---demonstrate a product's commitment to carbon reduction to meet retailer demand and gain better distribution of the product.
4) **Benchmark the products and organisation**--- assess product's carbon management performance against organization's product portfolio and find out how the organisation compares to other competitors in the sector.
5) **Cost saving** --- reduce the organisational energy use and associated costs, identify carbon hotspots in the life cycle of the product to reduce carbon emissions and costs among organization's suppliers.

The Carbon Trust tries to leverage the power of the end customer through the it labelling of the product with the carbon footprint certificate. The end customer--consumer is able to see the carbon footprint of a specific product on its label, especially the pilot products such as food, beverage, and some electronic household equipments. So the consumer with environmental concerns could decide their purchasing preference on the product with reference to this. According to the Carbon Trust, 90% of UK households bought a Carbon Trust labelled product in 2010.

These labels are helping corporations to gain or retain the social normative legitimacy which are virtually given by the consumers, when the consumers execute their buying power in purchasing. The label builds up the brand image of the corporation to the consumer, as the way a firm gains social normative legitimacy and then gains the purchase from consumer.

The Influence Process of Carbon Trust Carbon Labelling

1. Carbon Trust started by conducting research to generate the first-ever carbon footprinting standard label, following the previous eco-labels procedure, e.g. energy star;

2. Co-operate with pilot firms to test the label standard, leveraging these proactive companies brand name to build up the standard impact.
3. Advertise the importance of the label and the importance of getting the label. In 2008 it invested 1 million pounds to advertise its advisory service, encouraging businesses to contact it for carbon reduction advice.
4. Keep producing reports discussing the potential benefits for carbon footprint measurements and reduction. It has published over 5 reports on the low carbon trends of consumer behaviours, and the benefits for corporations to reduce carbon emission.
5. Organize events to encourage firms attending. Regular events on sharing their experience of the carbon footprint label standard are held, as a showcase with well-known corporations such as Coca-Cola, Unilever, etc. participating to share their successful story.
6. Apart from the main consultancy practices, Carbon Trust has developed software to help firms manage their carbon emission performance---Footprint Expert tool. This software is designed to comply with PAS 2050, assisting the firms to measure their carbon footprint.
7. After the firm's involvement, in getting the certified label, the Carbon Trust then encourages the firm to use this label on the products or on websites/CSR reports etc., and further expand the impact of the label.
8. Beyond carbon footprint measurement and labelling, the Carbon Trust then provides firms with further advice on low carbon strategies and policies, and how to develop and deploy low carbon technologies by prioritising, designing, and delivering large scale renewable energy programmes, as well as how to put energy efficient equipment, renewable energy sources and other low carbon solutions into practice, especially, with complementary financing solutions.

The influence process is summarized in Figure 4.14.

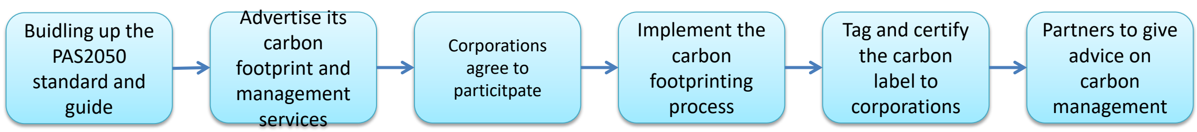


Figure 4.14. Carbon Trust Carbon Footprint Label Influence Process

The Success of Carbon Trust Carbon Labelling

Over 650 organisations have achieved the Carbon Trust Standard since it was launched in June 2008. The certified product carbon footprint have been given to many B2C and B2B products, including food, beverage and agricultural products.

Over 35 of the FTSE100 companies worked with Carbon Trust, and they can leverage the Carbon Trust Label to boost positive corporate images in different ways, such as the CSR report, adverts, websites, brochures, and internal communication magazines. For example the McLaren Group Ltd use the logo on its F1 cars and in its corporate video.

4.3.3 Green Ranking—Trucost & Newsweek Magazine's Green Ranking

Introduction of Trucost

Trucost is an environmental consultancy, providing the service to calculate the natural capital dependency of firms. It was founded at round 2000 in London. Based on the economic input output model, or so call EIO-LCA method, Trucost could advise firms with a rough answer to the carbon emission of their supply chain.

Trucost builds up an environmental profiling model which accounts for 464 industries worldwide and tracks over 100 environmental impacts. The model also examines the interactions and cash flows between sectors in order to map each sector's supply chain. This model is the core of Trucost's analysis. So based on this model, Trucost arbitrarily allocates a value to these natural capitals, then firms could get a mapping of the 'real' cost of their purchasing, operation and waste.

Since 2009 Trucost has been selected as the research partner of Newsweek Magazine to generate the Green Ranking list with the largest public-traded American companies and the Global 500 companies. The green ranking was firstly announced at 2009. The companies are ranked according to their actual environmental footprint, management of footprint, and sustainability communications. The detail three parts of the scores are Environmental Impact score (45%), Environmental Management Score (45%) and Disclosure score (10%).

The Influence Strategy of Newsweek Magazine

Each year this Green Ranking report ranks the 'top greener' in U.S, global and as well as the least green corporations as well. Due to the high visibility of the magazine, the ranking's visibility is huge and generates a large impact in the largest American corporations. Companies are believed to have a stronger incentive to improve their environmental impact.

So Newsweek does not directly get in touch with the companies but uses its own high impact as the top 2 popular magazines in the States. Newsweek is the largest household magazine following Time magazine, with about 2 million subscribers. The Green Ranking not only reveals the top performers but also the least green companies in 20 sectors naming Financial Services, ICT, etc. The key influence strategy of Trucost, or Newsweek Magazine, is to influence the magazine audience--mostly business individuals as well as people in the public sector. So the key trigger point of the Green

Ranking is to promote or deter firms to gain customer and social normative legitimacy as corporate citizens.

Timescale and Process of Green Ranking

Analyse company data

Trucost initially analyses firms' public-available financial information to establish the business activities of an organisation and then apportions its revenues to those activities.

Mapping to company data

Using this information, Trucost applied its environmental profiling model to calculate an organisation's direct and supply chain environmental impacts.

Incorporated reported data

Each analysed company is then invited to verify or refine the environmental profile Trucost has created. Trucost validates and authenticates any amendments or further disclosures made by the company.

Prioritise environmental impact

Trucost generates reports on an organisation's environmental impact and assesses which areas need to be prioritised to reduce this impact.

Quantifying environmental impacts in financial terms

Trucost also converts quantity data into financial values. The price applied to each impact is formulated by an academic panel and derived from environmental economics literature. The price reflects the damage each environmental impact causes and the consequential costs to the nature and society.

Analyse the potential risk & opportunities

This standardised, quantitative and complete data can then be used to assess risks, opportunities and relative environmental performance against peers and across sectors.

However Trucost does not provide further advices or consulting services on how to improve/mitigate the risks.

Trucost also generates the S&P/TOPIX 150 Carbon Efficient Index.

The influence process is summarized in Figure 4.15.

Figure 4.15. Newsweek Magazine Green Ranking Project Influence Process

4.3.4 Greenpeace--Obstruct Firms Getting Resources

Introduction to Greenpeace

One of the possibly most well-known NGO, Greenpeace, demonstrates the third-party to influence the companies in a straight forward but damaging way. Greenpeace usually will try to describe the firms' negative environmental impact in an exaggerated way directly through the press or on-site protest against the firms.

Greenpeace is a non-governmental environmental organization with offices in over forty countries and with an international coordinating body in Amsterdam. Greenpeace states its goal is to "ensure the ability of the Earth to nurture life in all its diversity"[4]and focuses its campaigning on worldwide issues such as global warming, deforestation, overfishing, commercial whaling, genetic engineering, and anti-nuclear issues. This global organization does not accept funding from governments, corporations or political parties, relying on 2.9 million individual supporters and foundation grants, so it claims its independency to perform direct action to governments and corporations.

Greenpeace uses direct action, lobbying and research to achieve its goals. In the research, Greenpeace publish reports to rate/rank the companies on performance.

The Influence Strategy One--Devalue firms' Brand Image

In Greenpeace's first version of 'Greener Electronics' report (Figure 4.16), some of the well-known brands of electronic companies are specially tagged as a 'low scorer in all criteria', including Apple. This report hits a ripple in the public awareness to the greening issue of IT companies and triggered most of them to put extra effort into tackling the issue.

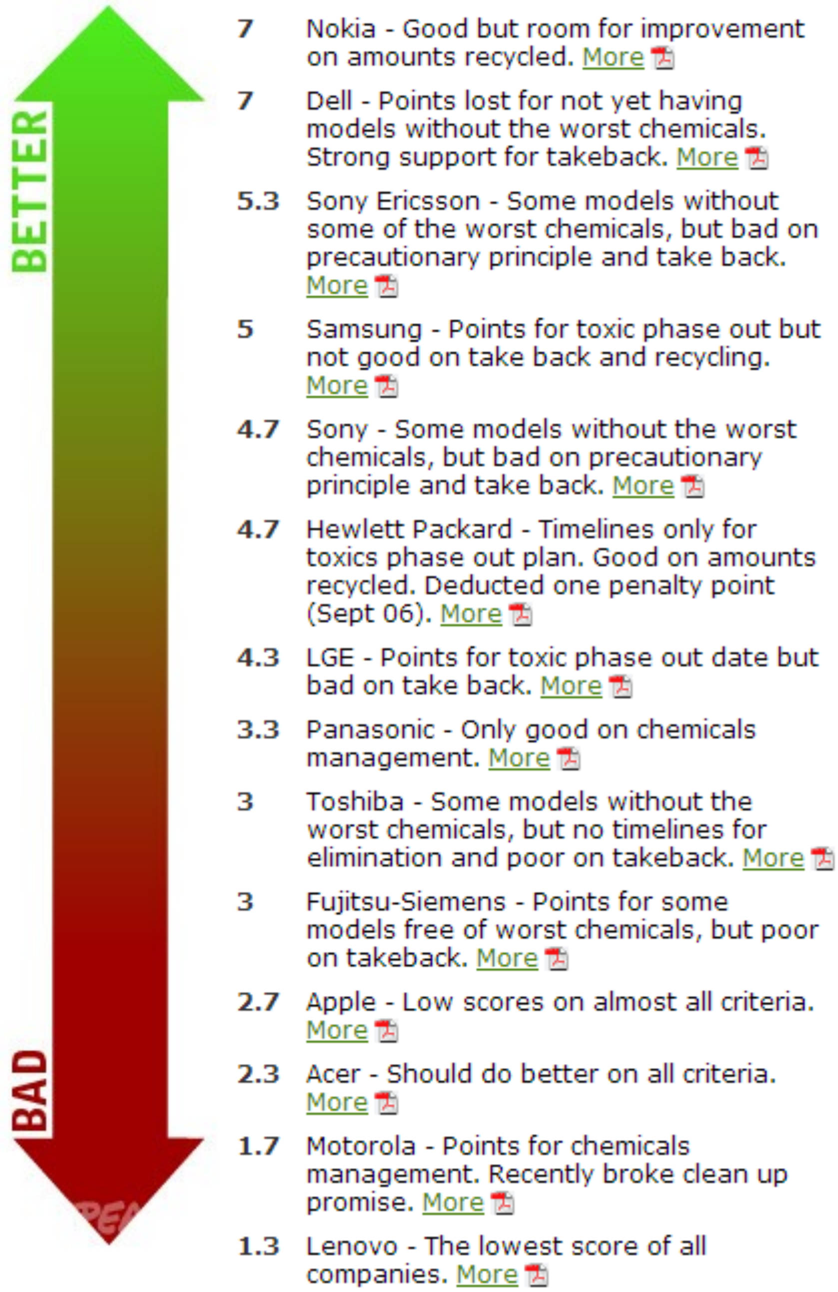


Figure 4.16. Greenpeace 'Green Electronics Ranking Report' first edition on 2006

Especially on the climate change issue, Greenpeace has pushed a campaign to urge IT giants to replace coal-fuelled energy to renewable energy for their data centres. Apple has been particularly targeted. Started from April of 2012, Greenpeace published a report named 'How clean is your cloud' evaluating 14 IT companies and their electricity supply chains of over 80 data centres based on key elements needed to build a clean cloud service. The report shows a growing split within the tech industry between companies that are taking steps to power their clouds with clean energy, like

Google, Yahoo and Facebook, and companies like Apple, Amazon and Microsoft who lag behind by choosing to build their growing fleets of data centres to be powered by coal and nuclear energy.

Greenpeace then collected support from consumers and presented it to Apple. At the beginning Apple did not reply and preferred to ignore them. However, after receiving lots of request from consumers, Apple was forced to take action after one month and reveal a   plan to change to a renewable-energy-supporting data centre. And within one-year Apple revealed further plans to improve on this. In this case, Greenpeace had tried to stop Apple getting the social normative legitimacy from its end consumer.

The influence process is summarized in Figure 4.17.

Figure 4.17. Greenpeace Green Electronics Ranking Project Influence Process

The Influence Strategy Two--Direct Action to Influence Firms

This type of direct action is the second focus of our research, which is taking direct action towards the firms to stop firms getting the resources for operating and selling products.

Some of Greenpeace's strategies involve taking direct action to warn firms. In September 2013, 40 of the Greenpeace activists in Germany chained themselves to a railway line to block coal shipments to a power station owned by Swedish state-owned energy company Vattenfall. These plants burn brown-coal (or Lignite), the most polluting way to generate energy according to Greenpeace's view.

But most of the time, if a third-party organization cannot stop or deter the focal firm getting outside resources if they are not the resources owner, only under the circumstances, that this third party can control the usage of resources, such as the secretary of department doesn't own the power but still can exert power.

The influence process is summarized in Figure 4.18.

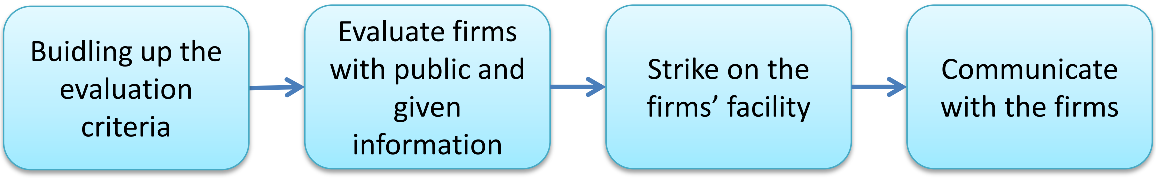


Figure 4.18. Greenpeace Direct Protest Project Influence Process

4.3.5 Taiwan IDB (Industrial Development Bureau) PCF (Product Carbon Footprint) Program

Introduction of Taiwan IDB Project

The Industrial department bureau is under the Ministry of Economic Affairs of Taiwan, built in 1970. As the key sector in Taiwan, manufacturing sector development is the main focus of Taiwan IDB. The task of IDB include: 1. promoting a service-oriented manufacturing industry, an internationalized and high-tech services industry, and a specialty-oriented traditional industry; promoting the development of key industries; fostering investment and removing investment barriers; encouraging foreign enterprises to establish R&D centres in Taiwan; promoting sustainable development, etc..

On 2010 July IDB started a carbon footprint tuition project named "Manufacturing Industry Product Carbon Footprint Counselling and Promotion Program," and also launched a four-year (2011- 2014) strategic plan to help the Taiwan industry establish foundation capacities on product carbon footprint analysis.

The reason for the Taiwan IDB to carry out this project is as follow: The manufacturing industry in Taiwan is an exporting-oriented industry, however, most of the companies are SME which do not have enough skilful human resources and new technical knowledge, so the government supporting resources are important for these SME to build up their own capacity facing carbon footprint revealed requirements from international customers.

This manufacturing industry product carbon footprint counselling and promotion program aims to nurture carbon footprinting practices in Taiwan's manufacturing industries, building up the mechanism for carbon footprint management, and finally encouraging low carbon product manufacturing.

The program contains four parts of work streams to support the manufacturers, including building infrastructure, pilot counsel, technique training, and promotion. IDB put in efforts into these four areas.

The Influence Strategy

The key power for this program is the government-promoted action to establish industry normative legitimacy and coercive legitimacy which the firms are seeking for.

The IDB targets the supply network--focal company and its key suppliers as one unit, rather than the single focal firms, though IDB also provides counsel service to single plants/facilities as well.

The Process of IDB PCF Project

The IDB PCF program process is shown in Figure 4.19.

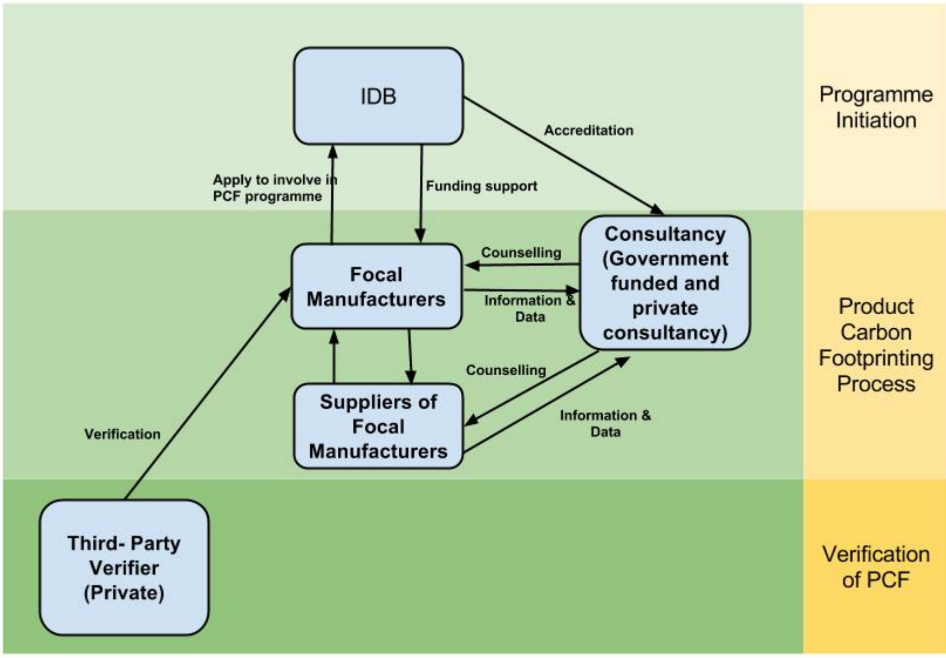


Figure 4.19. IDB PCF Program Process

Since the project is government-leading, companies have a stronger motivation to participate in the program. And the other motivation for firms to take part is due to the funding support provided for participants. After the initial spinning out, the project detail is uploaded online which could be accessed by public, including the focal firms and consultancy.

Except for the counselling plan, IDB has also promoted the training of PCF professionals. The “Train the trainer” courses were organized over 12 times with about a 200 audience at each. The participants consist of consultants, firms’ specialist, etc. These professionals contribute to the actual promotion effect of the PCF program, because the message of the industrial trends and the IDB free counselling service is brought back by these professionals. For the consultancy, they are motivated by the IDB’s funding support which could generate monetary benefits to their own business. So they would visit potential clients directly to persuade their engagement, for the mutual benefits of both.

The project accepts the application from the supply network units--focal firm and its key suppliers as a whole, with the application request from focal firm. IDB will form a technology board to evaluate these units by using the criteria of green capacity, supply network maturity, product groups and the brand name of the focal company. After the units were elected and implementation are rolling, monitoring of process and progress were in place as well.

The influence process is also summarized along the timeline as Figure 4.20.

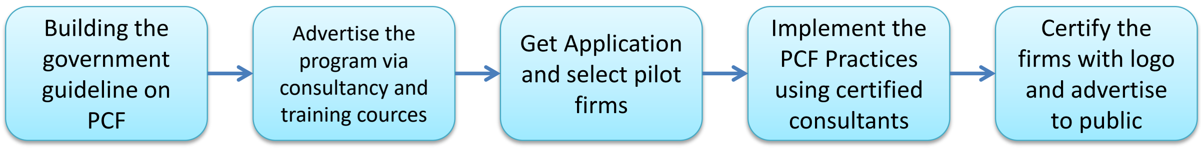


Figure 4.20. Taiwan IDB PCF Project Influence Process

The Success of IDB PCF Project

After the implementation of the MIPCFCP project, PCR(Product Category Rules) of certain Taiwan manufacturing products are set up and especially an initial database of raw materials' carbon footprint has been built up. In terms of the influence, the project has involved 22 supply network units (focal firm and 5-10 key suppliers) and 11 single plants till Dec of 2011. These units and plants cover a broad scope of industries including semiconductor manufacturing, optoelectronic, electronics, wires, paper milling， textile， metal producing etc. The total firms that are involved amount to 249.

In the technique training part IDB have organized 5 training courses and certified 124 consultants on PCF. Among these firms there are well-known manufacturers such as TSMC, Tungho Steel, etc.

The key resources that firms would like to fetch, via attending the programme, are the normative legitimacy--as being the qualified corporate on low carbon issue in the industry, and compliant to potential customer request, and the cognitive legitimacy as well--building the brand image as the leading corporate on low carbon issue. The coercive legitimacy, which is not directly present in this case because the PCF requirement is not in the legislation/regulation of Taiwan, however, is expected to be at hand in the longer future, since these companies attended this government-leaded programme.

4.4 Resource Ties of Focal Firm and Influence Effectiveness

From the above-mentioned cases it can be found that these case organizations try to use different methods to engage firms to take action in reducing carbon emission. Though these cases can only represent a small number of all potential methods, they help to explore how to influence more and more firms to take action in reducing carbon emission, especially in the network context. This section starts from introducing the Resource Dependence Theory (RDT) view, which serves as the basis of discussion. After summarizing the resource ties that are leveraged in these cases, a resources model of the focal firm is illustrated. These resource ties have different levels of power in terms of influencing firms, as demonstrated in the case study. Then the relationship among 'the influence effectiveness of resource ties', 'Firm Context' and 'Firm Type' is then discussed.

4.4.1 Resource Ties of Firm

Research in Stakeholder Theory have pointed out that a firm's behaviour is affected by its stakeholder's network. Frooman (1999) combined the stakeholder theory and resource dependent theory (RDT) to explain the different stakeholder influence strategy. But the research has not reached as far as to list out all the stakeholder linkages that have strong influence power, and under what context. So RDT is further explored in Chapter 2- Literature Review for the theory basis.

According to RDT, firms are dependent on resources provided by others in order to sustain growth (Pfeffer and Salancik, 1978), so an organization on which other organizations are dependent may consequentially gain power over them. From the cases above, it can be found that underneath the relationship is the resources that focal firms depend on. The relationship serves as a resource tie between organizations.

A short summary of the influence rationales in each case is presented in Table 4.7. The analysis focuses on the conditions for influential ideas to emerge and the rationale beneath the ideas. Therefore influence strategy and its rationale are the analysis unit in the table title. Consequently, the underpinning resources links that enable the influence process to emerge, is shown on the right side of the table.

Table 4.7. Summary of Influence Strategy in Cases

Case	Influence Idea Generation	Influence Rationale	Tools and Outcome	Key Points to enable Influence	power over firm	Resources that focal firm needs
CDP Investor	Founders worked in London Financial sector and clean energy investment. They generated the idea from the perspective of risk-avoid, sustainable-focus investor.	Persuades institutional investor to exert request to public-listed firms who are invested by these investors	Tools: Questionnaire, Public Available Outcome: Information of firms' carbon management information & CDLI (Carbon Disclosure Leaders Index)	Start from Institutional Investors	Investor	Capital from investor
CDP Supply Chain	Triggered by the observation of Walt-mart's request to its suppliers to participate in CDP questionnaire	Encourages the large corporation to request its suppliers to disclose and manage carbon emission	Tools: Questionnaire Outcome: Public Available Information of firms (suppliers of large corporations) carbon management information	Start from large Corporations	Large MNCs—client of supplier firm	Normative Legitimacy from the clients
WWF LCMP	The project was supported by the HK Productivity Council, and most of the HK business set up factories in the PRD area	Label firms with certified green/low carbon tags which may differentiate them apart from their competitors on the green issues.	Tools: Labelling system; workshops to advertise the benefits of engagement Outcome: Pilot successful case factories; Award Ceremony to the successful firms	Searching Pilot companies via HK business association	Clients of these manufacturing firms	Normative Legitimacy in the industry among competitor
Carbon Trust Carbon Footprint Label	Work with BSI, which is the specific organization of making standards; mimic other eco-labels	Labels firm's product with carbon footprint, leverage the end customer power to influence firm.	Tools: PAS2050; workshops with successful companies to share experience Outcome: 'Reducing CO2' Label, and 'CO2 Measured' Label on companies communication package, website, and products	Engage famous pilot case company; advertise consultant services	End consumer	Normative Legitimacy from end consumer
Newsweek Magazine Green Ranking	The company was started by financial professionals armed with economic input-out modelling speciality.	Ranking firms on their 'Green' performance, influencing the audience to form a view towards these firms	Tools: Trucost Economic Input-Output Model Outcome: Newsweek's Green Ranking on US Top 500 and Global 500	The grand exposure of the popular magazine's readers	General Public	Cognitive Legitimacy from general public
Greenpeace 'Green Electronics Ranking'	This NGO aims to generate impact with no violence. It gets used to publish reports for rating firms	Generate the public awareness to the greening issue of IT companies through their publication	Tools: green ranking criteria; internet media Outcome: Greenpeace 'Greener Electronics Guide'	Publish Reports to influence end consumer, leveraging consumer power to urge focal firms	General Public	Cognitive Legitimacy from general public
Greenpeace On-site Protest	This NGO aims to generate impact with no violence. It gets used to publishing reports for rating firms	Taking direct protest action to stop firms getting the resources for operating and selling products	Tools: NA Outcome: NA	Public exposure	Not Applicable	Operating Material to support production
Taiwan IDB PCF Project	'Government to provide guides' is the 'Taiwan' model, because the SMEs do not have enough specialist skills and information	Government-promoted action to establish industry standard which can be legislated in future.	Tools: counselling package; workshops to involve firms and especially consultants Outcome: PCR--carbon footprint database of Taiwan's manufacturing products; public available results of pilot case companies	The key point--government program with potential regulation in future	Government body	Coercive Legitimacy from government legislation

According to the summary of 'Network flows' and 'firm's external resources' in literature review, we have generated the model of focal firms' resources as Figure 4.21 below. The Table 4.8 illustrates the detailed meaning of each inward/outward resource ties. The concept and examples of each type of resources are presented as well.

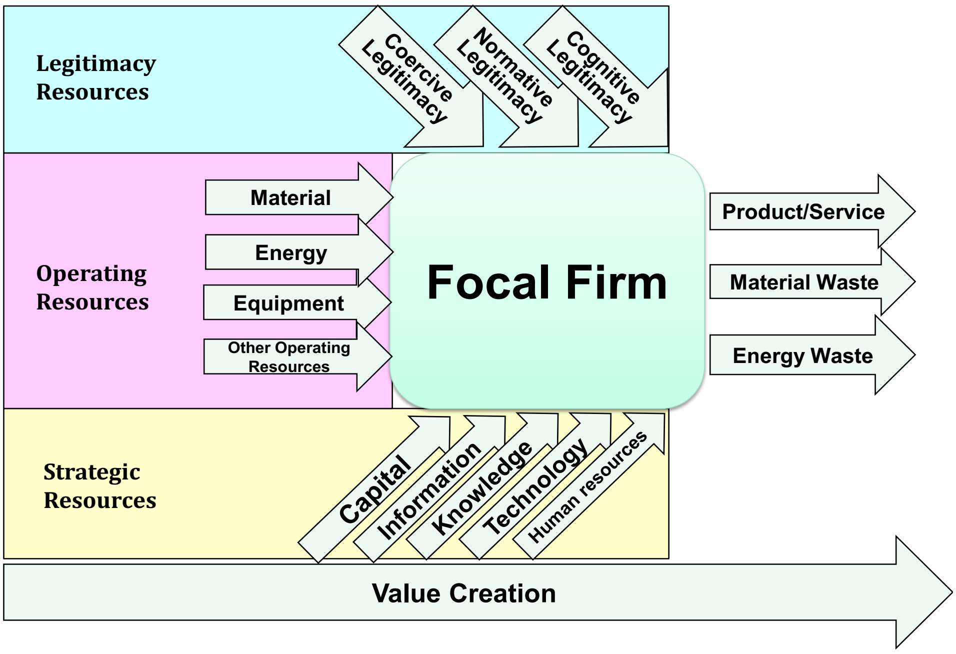


Figure 4.21. The Resources Model of Focal Firm

Table 4.8. The Detail Description of Resources Ties

	Resources	Description
Operational Resources	Material	The input manufacturing-related material and semi-products
	Energy	Includes electricity, CHP, fuel and gas, renewable energy, etc.
	Equipment	Manufacturing related equipment
	Other Operating Resources	Including infrastructure, land, etc.
Strategic Resources	Capital	The finance input to support firms' operation, including public listed, funds, and loans
	Information	Including industry information, market information, supply & demand information
	Knowledge	Organizational skills, management knowledge
	Technology	Including the manufaturing, equipment, process and industry technology,
	Human Resources	Including the people in plant, management and senior level
Legitimacy Resources	Normative Legitimacy	Recognition at the industry level (compared to its competitors) from customer, including the brand name, recognition as a trustful product/service provider
	Cognitive Legitimacy	Recognition from the end consumer, local community
	Coercive Legitimacy	Recognition according to the legislation
Output	Product / Service	The result of manufacturing, the products/services provided by focal firm that generates income
	Material Waste	Including physical waste e.g. waste water, gas, scrap
	Energy Waste	Including extra stream, heat and other fuel & gas

Most of the resource ties model is self-explained. The inward resources of the focal firm is categorised into three sectors:

Operational Resources, represent the resources that directly contribute to the value creation process of the firm—production, manufacturing the products. Also Equipment, energy, material (such as the raw material, semi-products, water, assisted-chemicals for production), and other operating resources (such as the plant facility, infrastructure). Without these resources the focal firm cannot operate functionally to generate products or services.

Strategic Resources, are the supporting but also critical resources around the operation. Capital is needed to purchase equipment or in the expanding of the manufacturing scale. Information, knowledge and technology could arm the focal firm with competitive advantages over rivals. Human resources, which means the staff, are the basis for all the activities of focal firms.

Legitimacy Resources, give focal firms the rights to sustain growth. Coercive legitimacy originates from government regulation and legislation, which has the strongest power over firms. Normative legitimacy represents the norms, standard requirements from industry, customer and end consumer. The normative legitimacy could be allocated into three types: social, customer, and industry. The social normative legitimacy is gained from the end customer, the society is regarded as a whole of individuals; customer normative legitimacy comes from the recognition of the customer. Sometimes when customers are also end consumers these two legitimacies merge; industry normative legitimacy represents the norms and standard in the industry. Proactive firms especially the key players in industry usually adopt new practices to seek for performance improvement, and as well setting new industry norms, in order to gain advantage over rivals. The followers, driven by so-called 'mimetic isomorphic pressures'(DiMaggio and Powell, 1983), will replicate those initiators' practices, in order to gain industry normative legitimacy. The cognitive legitimacy gains again from the society but not only the end consumer. It is culture recognition to the firm, which is usually obtained by a long-term commitment and numerous activities, rather than from a single action. And the firms' benefits of cognitive legitimacy are blurred, intangible and long term. It is hardly reflected on boosting revenue directly.

Though there are multiple inward resources, they are all serving the economic goal---generating more revenue and reduce the cost paid for inputs (such as an energy bill). So an action that could help on this goal can also exert influence power over firms. Regarding the criticalness and scarcity of these resources to the focal firm, influence strategies that are leveraging on different resources have significant efficiency to persuade focal firms. The effectiveness of these resources ties are discussed according to the cases in the following section 4.4.2.

4.4.2 Resource Tie Effectiveness, Focal Firm Context and Focal Firm Types

The influence cases reflect the resource ties between the resources owner and focal firms. And all these cases contribute to the examination of the relationship between ties, firm context and the firm type.

The CDP Investor Program aims to leverage on the capital linkages between Institutional Investors and the public-listed firms. Capital resource, as a critical supporting input for the firm, can affect a firm's operation greatly. The firm's shareholders, as a whole, have direct decision power over the firm. The shareholders meeting is the firm's authoritative unit. So the influence power of the institutional investors are based on the constituent structure of shareholders as a whole. The global large companies are usually listed in the stock exchanges in the developed countries like New York, London, etc. And the stock exchange has less constraints, in a relatively free market mode. So the institutional investors could own a relatively large part of the firm's share. So the voice of investor has a powerful influence on the firm's behaviours. As well, the information transparency of listed companies towards investors is a normative rule in the developed countries' exchanges. The power of this basic requirement is much weaker in the developing countries, where there are less mature markets. So the great success of the CDP Investor Program is spotted under these conditions, which could be marked in a Triple "Capital, Developed Market, Public-Listed Firms".

As discussed the CDP Investor Program has limited power in the emerging market such as Asia. For the public-listed companies in some emerging markets, the majority of the shares are controlled by the government, and the market is less mature on providing information to investors. The influencing power of CDP Investor Program is much weaker. While the CDP Supply Chain Program is blooming year by year, especially in Asia. The buyer-supplier relationship is leveraged in the program. The exchange resource tie beneath this relationship is the customer normative legitimacy that these Asian firms seek for, especially the middle-size corporation. A lot of the attending firms are the OEM or suppliers of large corporations from the developed market. Gaining the normative legitimacy from their customer, large corporations, will gradually become crucial in gaining or retaining new orders. That makes the normative legitimacy resources very powerful on leveraging SMEs to reduce carbon emission. This influence strategy can be summarized in the Triple "Customer Normative Legitimacy, Export-Oriented Market, SMEs".

However, obviously this tie does not apply to all the companies in the emerging markets. For the large firms where governments have a large proportion of the share, the 'Capital' resource tie still applies, if the government has great intention/policies to reduce carbon emission . But for the companies which are neither public-listed, nor rely on foreign customers, other resource ties could be more effective/or have more influence, such as the social normative legitimacy.

Carbon Trust PCF (Product Carbon Footprint) standard relied on the end consumer power over firms. It is argued that consumer choice on low carbon product will place pressure on firms. This resource tie can take effect under two conditions: firstly, the end consumer's awareness of a low carbon product is high and they do take action in their choice; secondly, the firms are heavily reliant on the end consumer purchasing. It can be presented in the Triple "Social Normative Legitimacy, Low-Carbon-Aware market, Consumer Goods Firm". Obviously the firms in the non-consumer-goods sector, or at the upper stages of value chain, will be influenced directly from consumer pressures.

The Trucost &Newsweek Green Ranking applies media's publicity power over focal firms. In fact, due to the broad scope of the readers, multiple resource ties are leveraged in this case. All three types of normative legitimacy are involved. Firms would receive pressure from via social normative legitimacy, for readers are eventually an end consumer; Industry Normative legitimacy plays a role because firms are compared within the same sector in this Newsweek Green Ranking. Since the ranking is presented to the whole society, it also affects the social recognition towards focal firms, especially the ones in the poor performers' list. So the Cognitive legitimacy as well is the resource tie used by Green Ranking. But all these happen under the context of a carbon-issue-widely-aware society and the focal firms are large corporations who care about their brand image. It is as the Triple "Cognitive Legitimacy, Low-Carbon-Aware Market, Large Firms".

The focal firms, which attended WWF LCMP, aimed to gain Industry Normative legitimacy by carbon emission performance improvement practices. They are all OEMs which do not have competitive advantages over their rivals, so building up norms in industry will potentially have benefit and prepare them better for customer normative legitimacy if low carbon management is required by customers like Levi's in the future. The Triple in this case is "Industry Normative Legitimacy, Red Ocean Market, SMEs".

Greenpeace's 'Dirty Cloud' campaign leverages the same as the Trucost &Newsweek Green Ranking, as "Cognitive Legitimacy, Low-Carbon-Aware Market, Large Firms", though it takes destructive way of leveraging. Its direct-action campaign on the Germany coal-fuelled power station tries to stop the firm getting materials for production--blocking the coal transportation. In fact the campaign is only used as propaganda for its low carbon mission message, the inward material flow was not blocked permanently. This resource tie would only be successful if the material supplier is highly carbon-issue-concerned, and has a dominant position over focal firms, e.g. the inward material is scarce. It could be summarized as “Material, Low-Carbon-Aware Market, Resource dependent Firms”.

Taiwan IDB PCF Program starts from generating an industry standard to guide firms, which is a lever of industry normative legitimacy. However, the nature of IDB, government body on setting industry standards, represents the coercive influential power over Taiwan’s domestic manufacturing firms. To avoid potential regulation risk in the future, focal firms have a strong intention to attend the program and comply with its standard. In fact, as common sense suggests, the coercive legitimacy owns strong influential power in most cases, especially for the non-public-listed, non-consumer-goods firms in the emerging market where low-carbon-awareness is still absent. The obstacle is the regulation / legislation on carbon emission reduction which is both time-consuming and difficult to set up. This case can be presented by “Coercive Legitimacy, General Market, General Firms”.

For a summary of the relationship among “Resource Ties, Focal Firm Context, and Focal Firm Type” is as the following Table 4-9.

Table 4-9. Comparison of Triples “Resource Tie, Focal Firm Context, Focal Firm Type”

Case	Network Linkage	Market Context	Firm Type
CDP Investor	Capital	Developed Market	Public-Listed Firms
CDP Supply Chain	Customer Normative Legitimacy	Export-Oriented Market	SMEs
Carbon Trust PCF Standard	Social Normative Legitimacy	Low-Carbon-Aware market	Consumer Goods Firms
WWF LCMP	Industry Normative Legitimacy	Red Ocean Market	SMEs
Trucost &Newsweek Green Ranking	Cognitive Legitimacy	Low-Carbon-Aware Market	Large Firms
Greenpeace 'Dirty Cloud' Campaign	Cognitive Legitimacy	Low-Carbon-Aware Market	Large Firms
Greenpeace Direct Action	Material	Low-Carbon-Aware Market	Resource dependent Firms
Taiwan IDB PCF Program	Coercive Legitimacy	General Market	General Firms

From this table, some general findings can be concluded: SMEs are sensitive to normative legitimacy, while the large firms are more concerned about shareholders and social brand image; Both types of firms can be involved by coercive normative power; The more resources a focal firm relies on from external resource owners, the more sensitive it becomes concerning low carbon requirements. The further discussion on the constituents of context and effectiveness of resource ties, the implication to theory are presented in Chapter 7-Discussion and Conclusion.

4.5 A Framework of Influence Process

In this section, we conduct cross-case analysis to the influence processes of each case. The analysis firstly discussed the conditions that trigger organizations to generate their influence strategy. Then the influence process of each case is compared in order to summarize the common pattern in these processes, in which a typology of influence choice model emerge. Finally a general framework of influence is presented.

4.5.1 Triggers of Influence Strategy

In section 4.2 and 4.3 cases are presented in the three parts: 'how do they generate the influence method? What is the influence process? What is the influence result?' The underpinning conditions of influence strategy can help to explore the common themes which can trigger organizations to devise efficient strategy. From the Table 4.6 in section 4.4, we can perform further cross case analysis to explore the 'how to generate' from the idea generation category of each case.

It is found that the influencers, which are CDP, WWF, Trucost, Newsweek, Greenpeace, and Taiwan IDB in the context, generate their influence strategies partially due to the following four themes: their role in the business eco-system, their expertise, their origins and supports gained, and resources they have already obtained.

The role in the business eco-system

The role of the influencer determined the resources they could use to control the firms. Taiwan IDB, which is under the ministry of economic affairs, has the natural legitimate power to persuade firms. Though the carbon-related practices have not been in Taiwan's legislations or regulations, attending PCF program which is proposed by IDB will reduce the potential regulatory risk in future for Taiwan firms on product carbon footprint information disclosure and management. The guidelines, management system and the carbon footprint data in IDB's PCF program spontaneously attain the normative--being the industry standards in Taiwan. This linkage between these two actors, government and firms, in business system, existed intrinsically, while other actors in the system would not have such strong linkages.

WWF LCMP, supported by the Hong Kong productivity council, has a similar but much weaker normative power over firms, because WWF itself does not represent the HK government nor its legislation and regulation on the carbon issue, so WWF put forward a labelling system to strengthen its effect on giving normative to better-carbon-performance firms.

Due to the position in HK, WWF naturally targeted the HK companies which have plant facility in the PRD (Pearl River Delta) Area. Because most of the products produced in PRD are exported, certification will be a strong tool to defence firms' normative practices and even stand out from competitors. So the LCMP label become the choice of WWF officer, which also proved to be a great success later on. The Hong Kong productivity council, which was established from 1967, has built up strong connections with Hong Kong manufacturing and trading firms due to its nature functions in the business system---governmental body of technology consultancy. So via the HK productivity council WWF would get easy access to HK firms and introduce the LCMP program with a high level of trust from firms. However, the key striking point/benefits for firms to take part in LCMP was not the introduction from the HK productivity council but gaining the potential industry normative legitimacy with the LCMP label and the cost benefits from CO2 improvement.

Carbon Trust, as a half-government-funded organization, cooperating with BSI (British Standard Institute) and DEFRA (Department of Environmental, Food & Rural Affairs), has a better position on generating the carbon footprinting standard compared to organizations such as WWF. The carbon footprint measurement standard---PAS2050, becomes the industrial standard soon and owns its international impact as well. That it gains the acknowledgement from the end consumer and industry should be partially attributed to the governmental nature of the Carbon Trust, and partially to that it is the first publically available CO2 footprinting guideline. The 'CO2 measured' label on firms' website, communication materials, and especially products sends signals to end consumers, building up the green brand image of firms in the consumer's conception. This helps corporates greatly to gain social normative legitimacy from the consumer market. This legitimacy would potentially rack up a firms' competitive advantage over competitors and eventually, potentially more purchasing.

In fact the Carbon Trust have also published a corporate-level carbon management certification, named 'Carbon Trust Standard', to support firms on overall GHG emission measurement and continuous improvement. But the PAS2050 gains much more attention from the industry and consumers. The vision outlined for the Carbon Trust by Prime Minister Tony Blair in 2000 was that it would "take the lead on low-carbon technology and innovation in this country and put Britain in the lead internationally". The mission of the Carbon Trust was to help businesses and public organisations to reduce their emissions of carbon dioxide through improved energy efficiency and the development of commercial low-carbon technology. So the decision to launch carbon footprint measurement certification is partially due to this original mission, because Carbon Trust realized that in order to further reduce carbon emission, enterprises (firms) not only need to improve performance in the plants, but also need to have a clear view of their products' life cycle carbon footprint. The product carbon footprinting is the key milestone to achieve that. The second reason that the Carbon Trust comes up with this effective leveraging tool is that carbon labelling should be attributed to the situation of the UK's manufacturing sector. Except for the as-called 'high-value-added' manufacturing products such as Rolls Royce engine, a lot of UK's local manufacturing products are consumer products, which give more power of footprint labelling certification to serve influencing firms via customer pressure.

Newsweek Magazine, as the second most popular magazine after 'The Time' in US, has naturally the resource of having a large amount of readers (subscribed or not) who are in the business community and in the normal household. So making a Green Ranking for well-known US and global corporates are the typical media way of involving companies. Gaining the attention of consumers and citizens will eventually push the pressure to the corporations that are revealed in the Green Ranking, with benefits for the top performers but not for the poor performers who lose out. The role of Newsweek in the business system is as third-party actors which are not directly involved in the manufacturing flow but, however, they possess an influential power over the cognition of the society, especially the individual citizens towards corporations.

Expertise

The Trucost Company was started by three founding directors who all have extensive experience in the financial sector especially in responsible investment, using the financial model for evaluating a firm's environmental performances. The economic input-output model that was developed and continuously improved was formed by the founders' expertise. The original perspective as investors to scan firms was naturally brought into Trucost as the key business model, as one of the founders, Andrew Jacobs, worked as a professional stockbroker in a financial institution. The personal business network and resources brought by the founders also contribute to the development of involving more firms using Trucost services, while at the same time, constrains the ways Trucost can influence companies. The linkage between institutional investors and public-listed corporations, was explored spontaneously by Trucost due to inherited expertise from the founders. This happened the same as CDP had experienced initially. CDP founder Jeremy Smith works in clean energy investment fund, and Tessa Tennant, another founder has even co-founded the UK's first equity investment fund for sustainable development in as early as 1988. So the first idea of CDP founders to involve the firms was through the institutional investors.

Origin and supports

Greenpeace's action would fall into this category due to its funding support and evolution history.

The reason Greenpeace can perform a direct action and blame the MNCs/Governments was due to its independent funding source and accountability--this global organization does not accept funding from governments, corporations or political parties, relying on 2.9 million individual supporters and foundation grants, charity, etc.. Since the organization is supported by individuals, so naturally one of key audiences that Greenpeace will pick up is the public individuals, who are the end consumers in the business system, raising the public awareness to MNC's green performance.

On the other hand, Greenpeace has been famous for using direct action, lobbying and research to achieve its goals, especially the direct action, compared to other NGO, e.g. Friends of the Earth. The organization had raised many issues over the decades with protesting and campaigning on worldwide issues such as deforestation, overfishing, commercial whaling, genetic engineering, and anti-nuclear issues. And its great success on campaigning on issues historically has provided them with a pathway and tactics to follow when it comes to new issues such as green electronics and coal-fuelled power station. They also make use of research reports due to the support from a lot of scientists who work for Greenpeace. And this choice could give Greenpeace more credits on leveraging the individuals.

Dynamic Resources

CDP supply chain program is an example of this type. The program was triggered by the action of Walmart---the giant retailer required over 100 thousands suppliers to participate in carbon emission revealing, via a CDP questionnaire. Flagging the message to better understand carbon emission of their supply chains, CDP targeted some of corporations, which has a large supply network, to take part in the CDP Supply Chain Program. Most of these corporations that attend the program as members, are all public-listed MNCs which are as of now revealing their own carbon management information to CDP via the Investor Program. They are accessible by CDP compared to those who have not attended the investor program and also are better convinced of the benefits of carbon management. It is also a spontaneous strategy to involve the smaller-size, non-public-listed companies that are the suppliers, as the larger ones are involved already. And these are regarded as resources that CDP can leverage after the investor program.

From these cases we could summarize that in the mission to persuade/engage firms to take carbon management action, the network of business where the firm sits currently should also be considered. Different ties and links exist to spread the information and pressure of carbon reduction. These linkages links organizations together and form the business system. Some of the linkages could only perform as an access to firms, while others are compelling links that could apply the influential power over firms. These links, being used by the-above institutions or companies, are part of their influence strategy. Summarized above, different actors generated the influence strategy ideas---exploring different links, due to different reasons. It helps to explain one question--a systematic way of designing/devising the influence strategy to engage firms on the carbon emission management issue.

The following section describes the detail comparison of the influence process of each case in order to answer the question of "how to influence firms to take action on carbon management" which could be applied to various linkages, no matter what types of links are utilized. In section 4.5, detail of the influential linkages of firms and the typology between linkages' effectiveness and context will be discussed.

4.5.2 Process Comparison Between Cases

Before coming to the proposed framework of influence process, the separate process of each case is illustrated in Table 4.10 in order to perform cross case analysis.

Table 4.10. Summary of Case Programs' Influence Processes

Case		Influence Stages							
CDP Investor Programme	Mode I	CDP founders have special concern on sustainable investment	Building up Questionnaire	Present to Institutional Investor	Gaining Support from Investor (Investors' Signatory)	Send to focal firms via investors or business network	Supports to focal firms	Collect Questionnaire, Analysis and Report	Publicize excellent focal firm's practices and quos
CDP Supply Chain Program	Mode I	Stimulated by Walmart Case	Building up Questionnaire	Talk to large Corporations with a lot of suppliers	Gaining Support from corporations (being members of SC Program)	Send to suppliers via members or directly by CDP	Supports to Suppliers	Collect Questionnaire, Analysis and Report	Excellent supplier experience sharing workshop
WWF LCMP	Mode II	Supported by Hong Kong Productivity Council, targeting HK firms	Building label system and Supportive Tools during the program	Seek for pilot firms via the Hong Kong Business Association	Get the engagement from pilot firms	Implement the GHG Management and Improvement Practices	Supports on using the online management system	Rating and certify the firms with LCMP logo	Organize workshops of pilot firms experience sharing
Carbon Trust PCF Standard	Mode II		Building up the PAS2050 standard and guide	Advertise its carbon footprint and management services	Corporations agree to participate	Implement the carbon footprinting process	Support on PCF process	Certify the carbon label to corporations	Workshop on excellent focal firms experience sharing
Trucost/Newsweek Green Ranking	Mode II	Media organize different types of ranking to expand its publicity	Building up the tools of Economical Input Output Model	Invite firms to provide detail information	Gaining support from some firms	Evaluate firms with public and given information		Publish the ranking report with top performers	
Greenpeace Greener Electronic Report	Mode II	Generating report is a regular practice of Greenpeace	Building up the evaluation criteria			Step 1:Evaluate firms with public and given information Step 2:Publish the ranking report emphasize the poor performer		Campaign type 1: Demonstrate/Strike near the firms' facility Campaign type 2: Online advert	Communicate with the evaluated firms for future report
Greenpeace Direct Action	Mode II	Direct action is a regular practice of Greenpeace	Building up the evaluation criteria			Evaluate firms with public and given information		Strike on the firms' facility	Communicate with the firms
Taiwan IDB PCF Program	Mode III	It is IDB's tradition to generate industry-applicable guideline	Building the government guideline on PCF	Advertise the program via consultancy and training courses	Get Application and select pilot firms	Implement the PCF Practices using certified consultants		Certify the firms with logo and advertise to public	
		Explore and choose effective resource tie and influence process choice	**Construct the reasoning points and influencing tool**	**Approach Resource Owner or Focal Firm**	**Get Involvement**	**Apply the tools**	**Support firms to implement**	**Generate result, publicize result**	**Prepare for next-round influence**
		Exploration	**Preparation**	**Accessing**		**Implementation**			

From these influence processes, it can be found that if an organization, which could be NGO, government, consultancy, media, or a manufacturing firm, intends to involve other firms in the network to take actions of reducing carbon emission, it could start from firstly influencing another organization or individual (such as end consumer), then the focal firm, or directly to the focal firm. In the first situation, this external organization or individual should have stronger influential power towards target firms, so firms have to react to their requirements. In the above cases all these external organizations and individuals have critical resources to the target firm. These resources include capital, orders, consumer recognition, etc. In the second situation, the involvement is carried out only between the organization and target firm. But it also splits into two situations: the organization owns the resources which target firm needs, e.g. Taiwan IDB PCF Program; and the organization does not own the resources. We define the organization that releases influence power as the "Influencer", the external organization/individual as "resource owner", and target company as "focal firm". The above three pathways of influencing are shown in Figure 4.22.

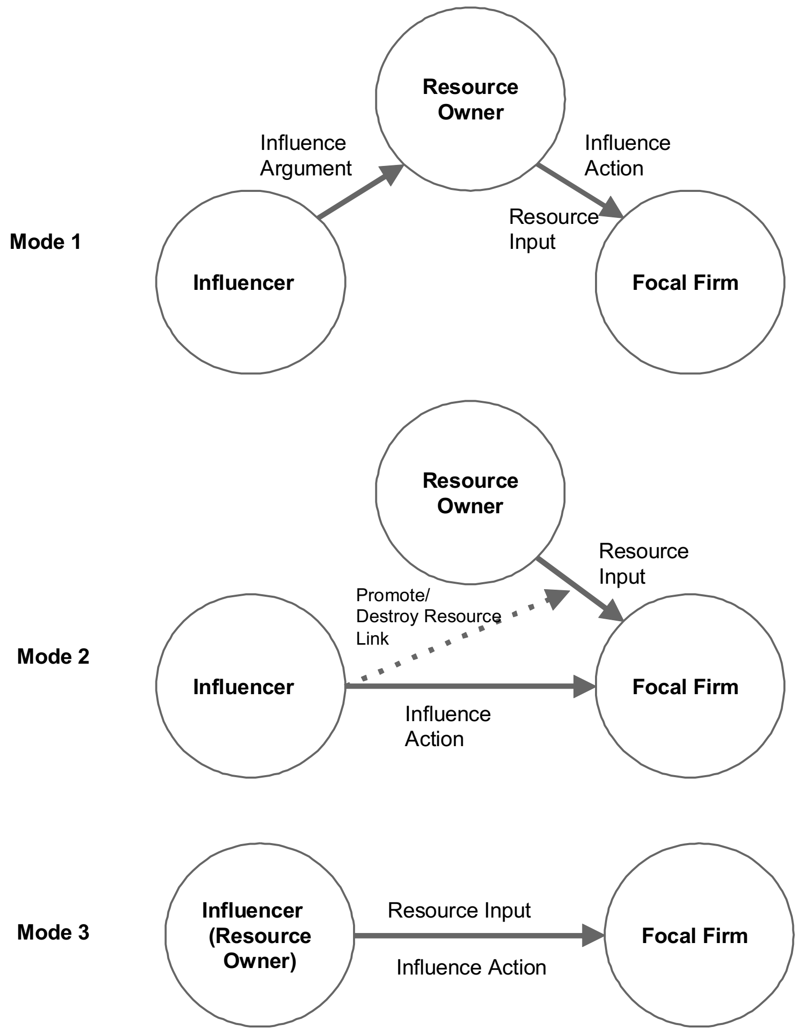


Figure 4.22. Influence Process Mode

In the Mode 1, the influencer does not directly approach the target firm, but to the resource owners of the focal firm. After presenting the argument of "why a focal firm should be urged to take action" to a resource owner, the actual influencing action is taken by resource owner (or influencer) to the focal firm. In the cases we presented, Institutional Investors are persuaded by CDP to consider embedded climate change risk of their portfolio, so they passed the message to the focal firms requiring them to fill in a CDP questionnaire and reveal their carbon management information; Large corporations are persuaded by CDP Supply Chain Program team to consider further management of their carbon performance along the supply chain, so they asked the suppliers to engage with them. Both of the resource owners, investors and large corporation, possess the critical resources that firms need, investment capital to public-listed companies, and purchasing order which stands for income for suppliers. Trucost & Newsweek evaluate the green performance of large corporations publishing the green ranking. This Green Ranking Report reveals the top performers and poor performers in basically every industry. The report sent out messages to the readers, including business readers and household readers, about the focal firms' performance. The top firms would gain normative legitimacy and cognitive legitimacy because that the audience are eventually the businessman in customer companies or end consumer, depending on the reader nature to be business readers or household readers. On the other hand the bottom performer suffers the loss of their legitimacy and eventually risk losing orders. Greenpeace as well tries to publish reports to influence the individual first and then urging the focal firm to action, with bolder emphasis on the bad performers. Greenpeace's report on the data-centre that are using coal-fuelled power stimulates readers' concern on their IT-support Cloud services provided by Apple and Amazon. Then these companies suffer more pressure from the individual, due to the losing of social normative legitimacy from the consumers.

In the Mode 2, the influencer approaches the focal firms directly, with the influence action to increase / decrease firm's advantage on getting the resource from the resource owner. This action is focus on the resource exchange between owner and focal firm. Carbon Trust built up the carbon footprint measurement and labelling system and promoted the labelling certificate to firms by arguing that end consumers, as individuals, will become more concerned about the low carbon label on products. So the firms with the label will potentially gain better recognition from consumers, and as a result it will benefit product sale. The WWF LCMP label marks the focal firms' greener performance compared to their rivals, marking them to gain industry normative legitimacy in industry. So this LCMP label increases a firm's advantage on gaining new orders or retaining orders from their customer, because the focal firm achieves the normative legitimacy by labelling. Greenpeace's direct action is the example of decreasing / blocking resources inflow by an approaching directly method. Though not necessary to be successful eventually, the strikes and campaigns on the railway tracks of coal-fuelled power station are decreasing the focal firms' advantage to get resources. In Greenpeace's specific case, coal, as the material needed to generate power, is the resource. In common sense, the resource owner is the one who can use this blockage strategy with a successful result, compared to Greenpeace who does not own the resource.

In the Mode 3, the influencer itself is the resource owner, so that it can easily release the pressure towards the focal firm, either by giving out incentives or by punishing the focal firm for lacking carbon management action. Taiwan IDB PCF program is the exact sample to demonstrate that. The same mode can be also seen between investor and focal firm in the CDP Investor Program, between large corporation and suppliers in the CDP Supply Chain Program.

So the above cases can be gridded into two dimensions: Influence target, or 'Who is primarily influenced?', and influence option, or 'Carrots or Sticks?'. Influence target refers to whether the resource owner or focal firm is firstly approached", and influence option refers to whether to increase or decrease the focal firm's advantage to gain resources. The four categories of influence process choices are shown in Figure 4.23.

		Who is initially influenced?	
		Resource Owner	**Focal Firm**
"Carrots or Sticks?"	**"Carrots"**	Approach Resource Owner Increase Resource Potential **-CDP Investor Program** **-CDP Supply Chain Program** **-Trucost Green Ranking**	Approach Focal Firm Increase Resource Potential **-Taiwan IDB PCF Program** **-Carbon Trust PCF Standard** **-WWF LCMP**
	"Sticks"	Approach Resource Owner Damage Resource Potential **-Trucos Green Ranking** **-Greenpeace coal-fuelled Datacentre**	Approach Focal Firm Decrease Resource Potential **-Greenpeace Direct Action**

Figure 4.23. Typology of Influence Process Choice

The decisions affecting influence process choice have a great impact on its effectiveness. It makes common sense for the influencer to make the most effective choices. The impact factors that affect the effectiveness of influence process choice include many aspects: first, internally, the criticalness of resources of focal firms, focal firm's corporate culture, firm size, ownership structure (privately owned, state-owned, or public-listed), scope of firm (domestic or MNC); secondly, externally, the institutional environment of focal firms, industry standards, scarcity of resources, and degree of control of the resource owner (whether the resource owner can be persuaded), etc. The influencer's control over the degree of critical resources, including their ability to approach the focal firm, to persuade the resource owner, or own the resources itself, is the most important impact factor on influence process choice. This degree of control can be interpreted as 'feasibility' of choice. Logically the influencer should choose the one that it has the largest impact on. CDP Supply Chain Team can directly approach the suppliers of large corporations, but obviously the influential power is much weaker without the request coming first from these large corporations. And CDP has gained this type of resources through the previous Investor Program. WWF LCMP will potentially obtain even better results if the customers of SMEs in PRD, such as Levi's, are urging their suppliers to take part in LCMP. However, WWF only have the business network of the Hong Kong Business Association at hand to leverage this, without first building up a solid trust and cooperation relationship with large retailers, such as Levi's and Walmart.

For Mode 3, the influencer needs to have the critical resources of the focal firm. It is not related to any of the above-mentioned factors. For a focal firm with a highly complex product, the complexity of the product usually requires a complex supply of sub-components, more suppliers and advanced technology partners. Therefore if there are more critical resources ties from the external environment then Mode 1 for influence would be a more suitable choice. In terms of company size, smaller size companies, in most situations, heavily rely on several critical resources, such as critical clients, or critical partners. In this case the Mode 1 influence strategy will be the most powerful choice. For large size companies, they normally have a huge number of resources owners, such as end customers for Dell, and this makes the Mode 2 strategy the best solution.

The fundamental reason that urged focal firms to take action is the critical resources tie. The effectiveness of this resource tie is subject to even more impact factors. The further discussion on the effectiveness of resource ties under different context will be discussed in Chapter 7-Discussion and Conclusion. The resources tie that is picked to leverage on also contributes to the influence process choice. Greenpeace decides to reveal the poor performance of Electronics Manufacturers, which seems to be bolder than the Trucost &Newsweek Green Ranking, in terms of affecting focal firm's cognitive legitimacy. This is because the legitimacy is easier to damage but more difficult to recover, the same as a brand name.

Both the decision on leveraging the resource tie and influence process choice will affect the effectiveness of influence. But the impact of the two decisions is different: leveraging resource tie is more fundamental while the influence process choice is secondary.

4.5.3 A Process Framework for Influence Process

Combining the cross-case analysis shown in Table 4.10 and typology of influence choice, a general influence process is proposed, which includes four main steps: Exploration, Preparation, Accessing, and Implementation. It is shown in the Figure 4.24.

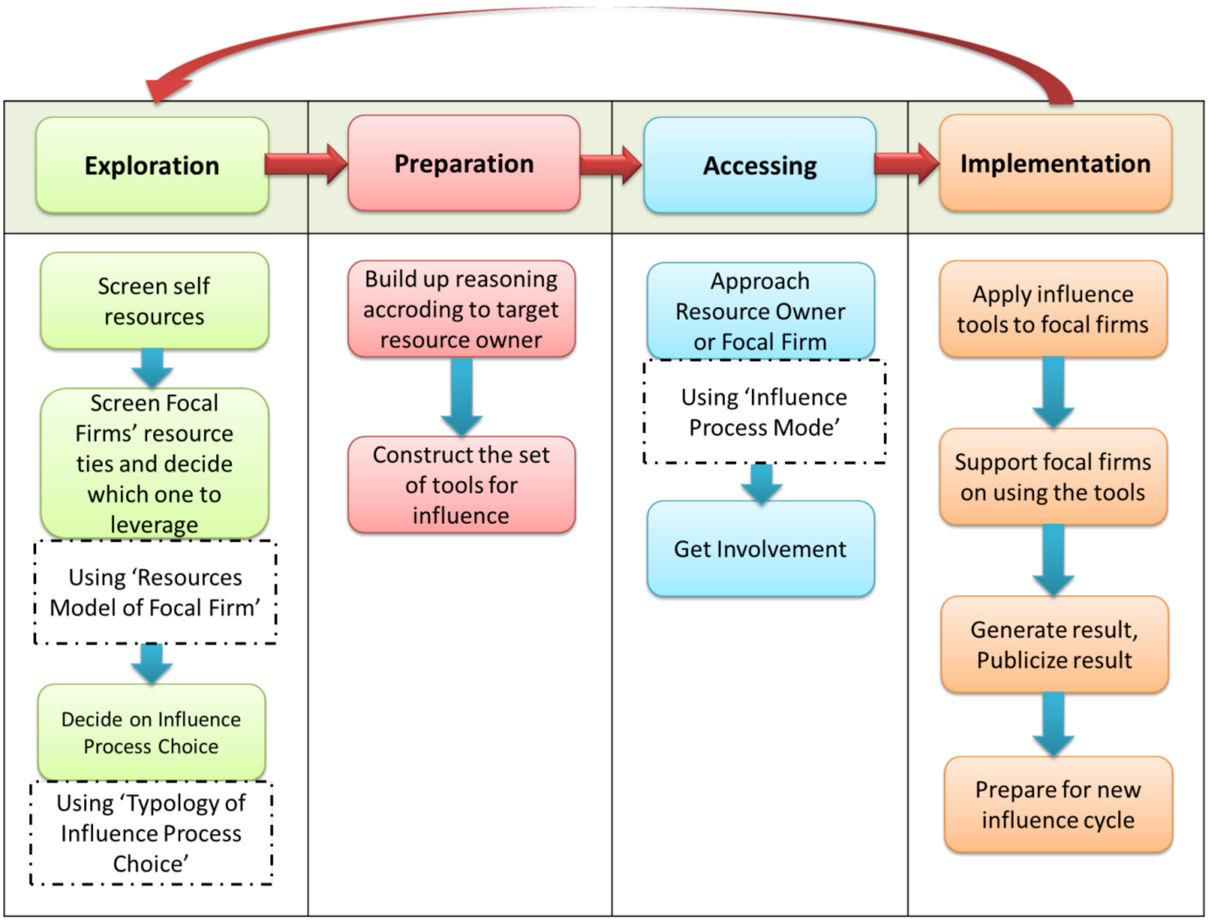


Figure 4-24. The Influence Process Framework

Exploration: The first step to start an influence process is exploration, to consider all factors that have impact to the effect of influence. The Influencer should firstly screen its resources, business network, and capability. The Influencer then can have an idea on the range of resource tie that it has leverage on. A decision made on leveraging which resource tie is the fundamental one. This is because the more critical and scarce the resource tie is to focal firm, the more effective its influence will be. Spontaneously the influencer will pick the resource tie according to its own capability, strength of the resource tie, and the overall external environment, then a decision on using which type of influence process in Figure 4.24. comes up. However, in the actual cases, rather than with intention, the exploration step is conducted unconsciously by influencers, due to their instinctive business sense and their depth of experience. So in a practical guideline for designing influence process, this step should be intentionally conducted so as to ensure effectiveness of influence.

Preparation: With a clear understanding of the influence process choice, a set of tools should be prepared to support the implement of influence. This set of tools should be the message carrier about the importance of low carbon issue, to the resource owner and focal firm. This message should be tailored according to the target. In CDP Investor Program the questionnaire is focus on revealing the embedded carbon-related risk in an investor's portfolio, while the WWF LCMP label system emphasizes the excellency of a firm's green performance which help firms gain a stronger customer normative legitimacy from the customer. And this set of tools should be in a proper format in order to sufficiently reflect the nature of the resource tie. It could be questionnaire, label, ranking list, or report, depending on which resource owner is the target and which format can mostly present messages they care about.

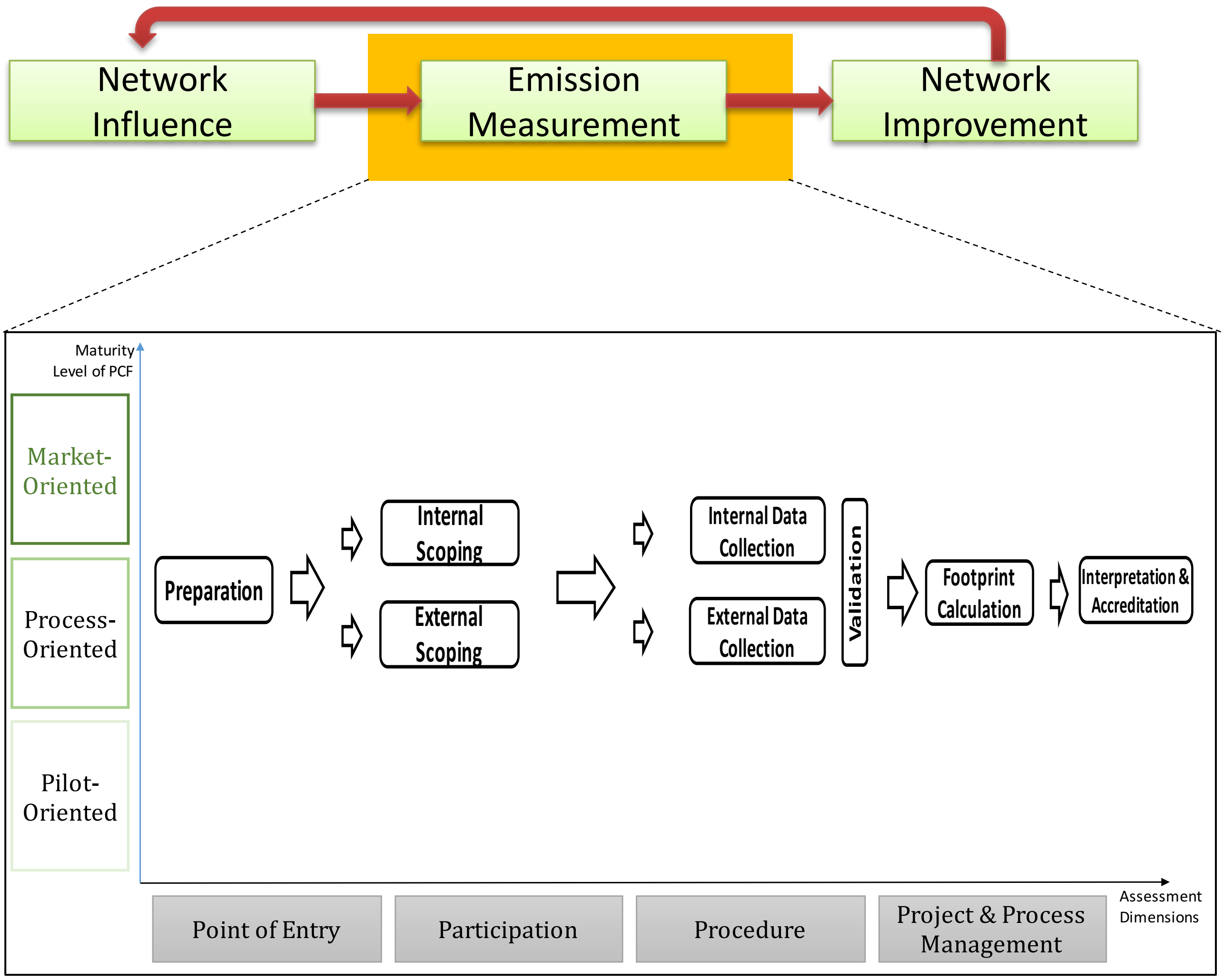
Accessing: After all preparation is done, the resource owner or focal firm should be approached. A well design accessing mechanism can enlarge the scope of influence, forming a stronger influential power towards the focal firm. The resources of influencer, such as the business connection with resources owner, its expertise, as well have significant impact on the result of accessing, reflecting on the amount and strength that influencer get from resource owner.

Implementation: The final step is to implement the actual influence to focal firm. Influencers should apply the tools developed in the Construction stage and support the focal firm on using the tool. This support is critical to some type of the influence strategy, especially to those targeted on SMEs, because the smaller firms do not have enough skilful staff and time to develop its own capability of tools utilization, and if this kind of support is absent, they are more reluctant to comply. The results, after tools are applied, can be collected and analysed as the project carries on. Publicizing this result further expands the impact of influence, it is one key part of the jigsaw to finish the influence process as whole. This result is shown to the resource owner, and this result completes the original reasoning arguments presented to them. As starting the new influence cycle, showcases of successful performance of participated focal firm, such as workshops in CDP Supply Chain Program and award ceremony in WWF LCMP, are the final piece of first-round influence process, but also the basic for second-round activities.

4.6 Chapter Summary

Engaging more firms to take actions on carbon emission reduction is the first step in improving industry performance. And it is a crucial and starting point of the transition to a low carbon industrial system, because without the intention to participate, firms rarely care for the carbon footprint measurement and further improvement. The cases and discussion in this chapter aim to draft a practical process to influence more and more firms. The key step of the influence is to screen feasible, effective relationships in order to exert impact. Depending on the influence target and options, a typology of influence process choice is identified. Organizations have to decide the leveraging relationship and influence choice, then produce relevant tools to support the process, access focal firms, and eventually release the influence power. The four-step procedure produce a cycle, spinning up the impacts to more and more companies. The success of influence relies fundamentally on the resources ties that are picked. Effectiveness of these ties varies due to its criticalness, focal firm's context and the nature of the focal firm. Through cases an initial answer is given: large firms are sensitive to social recognition while SMEs to customer pressures, regulatory pressures are most influential, but this rough answer will be further discussed later. These models lay their roots in the field of organization response to external control. By applying institutional theory, stakeholder theory and resource dependence theory, the models gridded by cases have implications to both these practices and these theories. As seen from the later chapter, how the firms react and improve link to the influence strategies as well.

CHAPTER 5 MEASURING CARBON FOOTPRINT IN SUPPLY NETWORK



5.1 Introduction

In the IMI model, after the focal companies have been engaged to take action to participate in the carbon issue, the next step is to measure the carbon footprint. As one of the basic management principle is, “What gets measured gets managed”, probably earliest stated by William Thomson, the Scottish physicist, in his lecture on “Electrical Units of Measurement” (Popular Lectures, Vol. 1, page 73) at 1883, it then becomes a logical step to measure the carbon footprint in order to reduce it.

The Carbon emission of firms can be simply categorized into two levels: corporate level and product level. As reviewed in Chapter 2, the product level carbon footprint is examined during the life cycle of the emission of the product, linking the carbon emission naturally along the supply chain naturally. There has been a complete study of the corporate level carbon footprint during the early years of last decade, and this has been extensively practised in firms during 2005-2006. The product level carbon footprint has become the new focus at the arena from 2008 with limited research and practices and it has had a large impact on reducing carbon emission in the industrial system, compared to corporate level carbon footprinting. Also the still, corporate carbon footprint is the base of PCF.

In this chapter based on the case data, a framework for PCF process is proposed. , serving as a practical guideline. It can serve as a practical guideline for businesses practitioners that are inexperienced in relation to the carbon issues. . Three types of tailored PCF are summarized, according to the goals of conducting PCF. A Process Measurement Model (Mills et al., 1995) is applied to the analysed PCF process in the case companies.

5.2 Product Carbon Footprinting Process with Cases

5.2.1 Case Pool in Measurement Analysis

In this chapter we trim the cases pool as shown in Table 5.1.

Table 5.1 Cases with PCF process illustrated

Region	Case Name	Measurement Practices Highlights
Mainland China	Lenovo	Product: Desktops. Lenovo's PCF (Product Carbon Footprinting) started from 2008 and it conducted the first desktop product carbon footprint in mainland China. Lenovo implemented two other footprint measurement projects in 2009 and 2010 with more rigorous standards. Lenovo is also actively involved in the Chinese electronic carbon standard formation and cooperates with international standard organizations as well as footprint relevant research institutes such as MIT Life Cycle Assessment Lab.
	Tsingtao Brewery	Product: Beer in 330ml-bottle exported to UK. Both corporate level and product level carbon emission are measured in Tsingtao. Tsingtao is the first beverage brand to measure the carbon footprint in mainland China. Tsingtao invited a special consultancy to tutor the carbon footprinting process.
	ZTE	Product: Mobile. ZTE conducted the PCF due to the request of a European customer. ZTE has not measured the corporate-level carbon emission. The measurement team is positioned in the product quality department.
China Taiwan	Acer	Product: PCs. Acer as the leading brand in personal electronic products has therefore received higher pressure from consumer and the media on environmental issues. Because most of the production is outsourced to OEM and suppliers, Acer has set up a detailed plan to engage and tutor supply chain partners into this carbon measurement project.
	AUO	Product: LED panel. AUO LCD TV is at the time (2009) had the most complicated products to conduct footprint measurement due to the large number of sub-components and suppliers. AUO generates its own carbon footprint calculation e-system in 2011 for suppliers to fill in footprint-relevant information
	Tungho Steel	Product: 'H' shape steel. Tungho steel and its over 10 of its suppliers were grouped together to participate in the Taiwan IDB PCF program.
	BenQ	Product: LCD TV, Monitor, Projector. Because BenQ does not produce most of the products and outsources to OEM, BenQ developed a detailed plan to coach suppliers. One to one tuition for suppliers were conducted in order to ensure data quality
U.S.	Dell US	Product: Laptops. Dell calculated the Laptop carbon footprint using all secondary activity data in LCA software rather than from primary data. It is shown that the manufacturing and user phrase take up the two largest portions of total carbon footprint profile.
U.K.	British Sugar	Product: Granulated Sugar. British Sugar is one of the first six companies that have been involved in the trail practices of PAS2050. The footprint measurement process in British Sugar focuses on the internal production processes.

5.2.2 Brief of Cases

Lenovo (Appendix I-1)

In 2006 Lenovo assigned its first ever Chief Environmental Officer (CEO) to manage Lenovo's strategy on sustainability issues. Starting from 2008, Lenovo began to conduct product carbon footprint measurements internally within the corporation scope. Via a national database from the bureau of ICT industry, in 2009 Lenovo conducted another carbon footprinting applying these second-hand datasets. However, the footprint result contains the phases from suppliers, production (ODM data), distributors, usage and recycle. At 2010, Lenovo applied the first carbon footprint using primary data, which is partially collected by Lenovo's internal departments.

The carbon footprinting is designed by a special group in the Product Certification Team of Lenovo, because originally Lenovo received the European customer requirement for revealing their product carbon footprint, which is similar to requests for an Environmental Certificate that was usually dealt with by the product certification team.

Starting from material and raw components, Lenovo traced the carbon emissions from these parts via its first-tier suppliers. The suppliers of the raw components to the 1st tier supplier are asked to provide the bill of materials (BOM). According to the BOM, emissions can be calculated with the data from the National Basic Component Database. Since Lenovo does not have direct impact over upper tier suppliers, the basic data collection process for raw components is actually implemented by the 1st tier suppliers. Material, production and distribution are the three main categories that Lenovo have focused on. The carbon emission during production needs to be calculated using the power operation data. For the suppliers certificated with ISO14064, which is the international standard of corporate level CO2 emissions auditing system, the data collection is relatively easy. For the suppliers that do not have the data collection capability, Lenovo will send out information collection forms to the suppliers to gain operating data including: the energy usage data, equipment types, energy usage per unit, operating time allocated to Lenovo orders, etc. To all the suppliers and OEM, the Lenovo product certification team served as an audit role and performed site-visits to check the accuracy of data. With these elemental statistics renewed, the Lenovo team could then conduct the calculation. Distribution and logistics, user phase, recycling statistics can be obtained from the internal logistics and product design (R&D) departments of Lenovo. The flow of the emission data collection process is demonstrated in Figure 5.1.

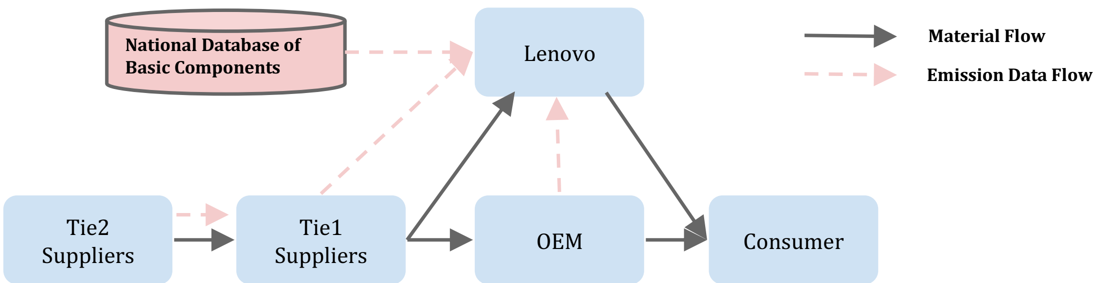


Figure 5.1 Lenovo Product Carbon Footprinting Process

Lenovo's experts suggested that for data accuracy, measurement meters should be installed in the production lines to get a full picture the of energy usage. Some of the large suppliers had already built up the capability to implement it, while most of the small & middle size suppliers are lacking of these skills. So the development of an industry standard on carbon footprint disclosure is very important, because this standard would exert influence and deliver knowledge to the smaller players in the field.

Tsingtao Brewery (Appendix I-2)

As the market leader, Tsingtao spotted the new trend of carbon footprinting requirement in the industry, partially due to their exporting business to Europe, especially to the UK. Mr. Zhiguo Jin proposed the carbon emission strategy for Tsingtao Beer : "Carbon Emission could be asset or debt of corporation, depending on how it is managed. The carbon emission management is part of corporate strategy". During the brewery process of beer, the chemical reaction of the wheat releases large amounts of CO2 emissions, as is the case in the other production processes of beer. It is significant that at the end of production, CO_2 has to be pumped into the liquid in order to generate foam in beer. So the reusing of carbon emission in previous stages can bring in cost reduction and carbon emission reductions at the same time, because originally the pumped-in CO_2 need to brought from suppliers. Other similar examples also show that good management of CO_2 emission can generate better profits, making it a 'Carbon Asset'. Tsingtao Brewery have therefore, made it an action guideline that "The earlier to consider carbon issue into strategy and take action, the more benefits we can make".

Tsingtao brewery started their carbon footprint measurement on both corporate-level and product-level at the same time. The corporate GHG emissions was supported by the China Quality Certification Centre (CQC) which is a national third-party validation service provider. And the product-level carbon footprinting was counselled by the Taiwan Environmental Science Technology Consultants Corporation (ESTC), which is one of the Top 3 carbon footprinting consulting service firms at Taiwan.

The carbon footprinting project began in August of 2010 in the Plant One of the Tsingtao brewery. This plant was chosen because the main product produced in it is the 330ml beer exported to the UK. Tsingtao brewery was the first brewer to measure the CO_2 footprint in the brewing industry within China. Starting from August, the carbon measurement team was trained during several workshops from the consultant ESTC. There were 6 Tsingtao staff who directly involved in the carbon footprinting project team, excluding the senior management staff and plant-level environmental specialists. The process can be divided into 5 steps, as showed in Figure 5.2.

Figure 5.2 Product Carbon Footprinting Process in Tsingtao Brewery

(Source: "Carbon Footprint Project Review Report of Tsingtao Brewery", ERIT, 2011)

The measurement process was focused into three parts: supply of material, production, and distribution. The material emission data comes from the suppliers, so the data collection process starts from suppliers. After the training was given to Tsingtao is internal staff, a supplier's general meeting was conducted to give overall training to them. Afterwards, forms were sent to suppliers to collect related information. These forms contain the emission factors as well. On-site training was provided by both Tsingtao staffs and the ESTC. Suppliers provided an overall footprint of the material, including a footprint from earlier stages of the material flow, the production in the suppliers' plant, and the transportation to Tsingtao's Plant One. It is an iterative process of data collection as the Tsingtao Footprint team controls the data quality from suppliers, and if the data submitted by suppliers is in poor condition. They are returned for re-collection. The production part of data gathering was executed by Tsingtao's internal team. Since Tsingtao has implemented the corporate-level carbon emission auditing, they were already equipped with basic data of fuel, electricity, and water use. One of key part of the work went to the allocation of emissions. The involved allocation types include the yield, number of bottles, and the economic outcome.

The distribution part has a large portion in the total carbon footprint. Because one of the raw materials, wheat, is imported from Canada, Australia, France etc. The long distance transportation from overseas to Tsingtao and also the long way it is distributed to the UK market generates the majority of the emissions. The detailed distribution data was gathered from the wheat suppliers and distributors in the UK. Compared to some of the local packaging suppliers, these suppliers have the capability to provide high-quality activity data. Distributors in the UK can provide the detailed sales data for each sales points as much as the second tier distributors. The final data of distribution is a weighted average result for all the bottles sold in the UK. The final step in the life cycle, the recycle of packaging, is not included in the calculation.

The whole time span for the project is nearly 8 months. The main difficulty of the carbon footprinting project in Tsingtao lays in the data gathering part. Data accuracy and validity of suppliers' data should be strictly controlled by the focal firm. Due to the 95% coverage requirement from PAS2050, an estimation of the total footprint should be conducted, and how many suppliers should be asked to collect data should be determined. In the Tsingtao brewery case, as there are over 10 suppliers for glass bottles, of which 95% is provided by three suppliers. Due to the time and resource constraints, only these three suppliers are picked to the involved in the measurement project. The internal management system and the capability for data collection vary from firm to firm. So more time and effort is needed to look into the data quality control. Also, as the suppliers are not part of the Tsingtao brewery, so the request for high-quality data is not feasible, compared to the requests to internal departments.

One of the key factors to success is the support from senior management. There are special offers in the management board to cover environmental issues in Tsingtao. Also, the head of the relevant department in the project, such as manufacturing and logistics, attended each training session from Taiwan ESTC. Every department had allocated 2 staff to assist in the training and data gathering.

Several policies were set up to ensure the higher priority of carbon management projects: Priority in job orders, funding, human resources, etc. The involved staff were even promised a promotion to become a 'Carbon Specialist'.

ZTE (Appendix I-3)

ZET, different from other companies, conducted the product carbon footprinting earlier than the corporate level emissions measurement. The PCF is triggered by the customer request for ZTE from Europe. A telecom carrier customer asks for the product carbon footprint of the ZTE mobile. ZTE started its green issue management from 2006, due to the requirement from the European Union's recycle, hazardous material control, etc.

ZTE has chosen the LCA software to complete the carbon footprint measurement, which relies more on the secondary data from the software rather than from the primary data collected along the supply chain. The software—EIME, developed by Bureau Veritas (BV) CODDE, which is the globally leading firm in certification. The EIME is a tool that was originally developed by 6 major companies of the Electric and Electronic sector. It has embedded several hundreds of modules of Electronic and Electrical product categories.

The measurement process is implemented by the product quality department, which is responsible for the product safety, survivability, and environmental performance etc. The first step of the calculation process is to decide which products are to be included to conduct the footprinting measurement. ZTE decided to choose the best sellers and those with clear customer requirements. The process map is embedded in the software. It mainly follows the fundamental steps of the product life cycle: Manufacturing (including raw materials, design, procurement, and production), distribution, use phase, and recycle. A special team was assigned for data collection. For most of the raw material (in ZTE case raw materials are referred to the semi-finished parts from suppliers), suppliers did not provided the detailed product specifications. Therefore, the ZTE teams needed to decompose these parts and analyse the manufacturing process of these parts. The raw material of these parts, mainly metals, and the possible manufacturing processes, can be traced in the internal database of EIME, according to their module. Because the internal dataset comes from the European sample data, so the data accuracy is under challenge. But a basic continuous improvement policy is already laid down in ZTE, so the LCA result can still help to improve the performance year by year. According to the provided product specifications, structures, product markets, distribution methods, distribution journeys, user phase, the data from these areas is then imported to the software. And this data comes from the product team, because they have the detailed specification of the product groups. But the product quality control department also works on building up the common database such as battery modules. The distribution part of the products is a related fixed variable, and this variance usually comes from the production phase and user phase. ZTE has arbitrated the distance, transportation methods, and the vehicle of recycle transportation. Because of the data quality, the measurement result can't be publicly released, so that the internal resource has not been incorporated much into the carbon footprint management.

This special team for the carbon footprint measurement consists of two staff. It takes about 2 months for the mobile product measurement and 3-4 months for network equipments. The working model is between the footprint team and the product line teams. The data request is sent to the product line teams and their answer is sent back to the footprint team, who are then responsible for filling in the software tool.

After the footprint measurement, a report then will be generated and sent to the R&D department. Combining the requirements from the customer and the information in the report, the R&D department would then consider some measures to reduce carbon emission, including raw material substitution, and the use of recyclable materials. The potential improvement focus could be mapped out by the result chart for the footprint. The high emission source of the life cycle of the whole product life cycle will show clearly on the result chart, sourcing from raw material or production, or sourcing from one special type of production technologies. A guideline generated by the product control department has been circulated round to the departments of production, and R&D. Four principles have been advertised in order to improve the product carbon performances: design for using less, recycle, general-fit materials, and circular usage design.

The carbon footprint issue started from 2008, while the driving force comes directly from the senior management. A committee named "Energy efficiency and carbon emission reduction" was formed. However, a complete strategy is not formed and advertised publicly. The next step of ZTE was to expand the measurement process to other products, making the practices a routine. The measurement process could be monitored by the quality control department, an overall response to the external requirements. The quality department builds up the basic data from the supply chain and production. The footprint calculation of a specific product will be conducted by these operation departments, rather than from the quality control department, which will perform as the monitor of methodology.

Acer (Appendix I-4)

Acer found that for their electronic products, the usage phase and manufacturing contribute nearly 80% of the carbon footprint, while the distribution and design take up more or less the same portion, with the recycle being the least part.

Acer outsources their manufacturing to OEMs, so the carbon footprinting process is mainly conducted through collecting data from suppliers, OEM and distributors. From 2009 during the third quarter, Acer started to measure its product carbon footprint with its suppliers. Acer follows the PAS2050 common life cycle of products: raw material acquisition, production, distribution & retail, use and end of life. The process is illustrated in Figure 5.3.

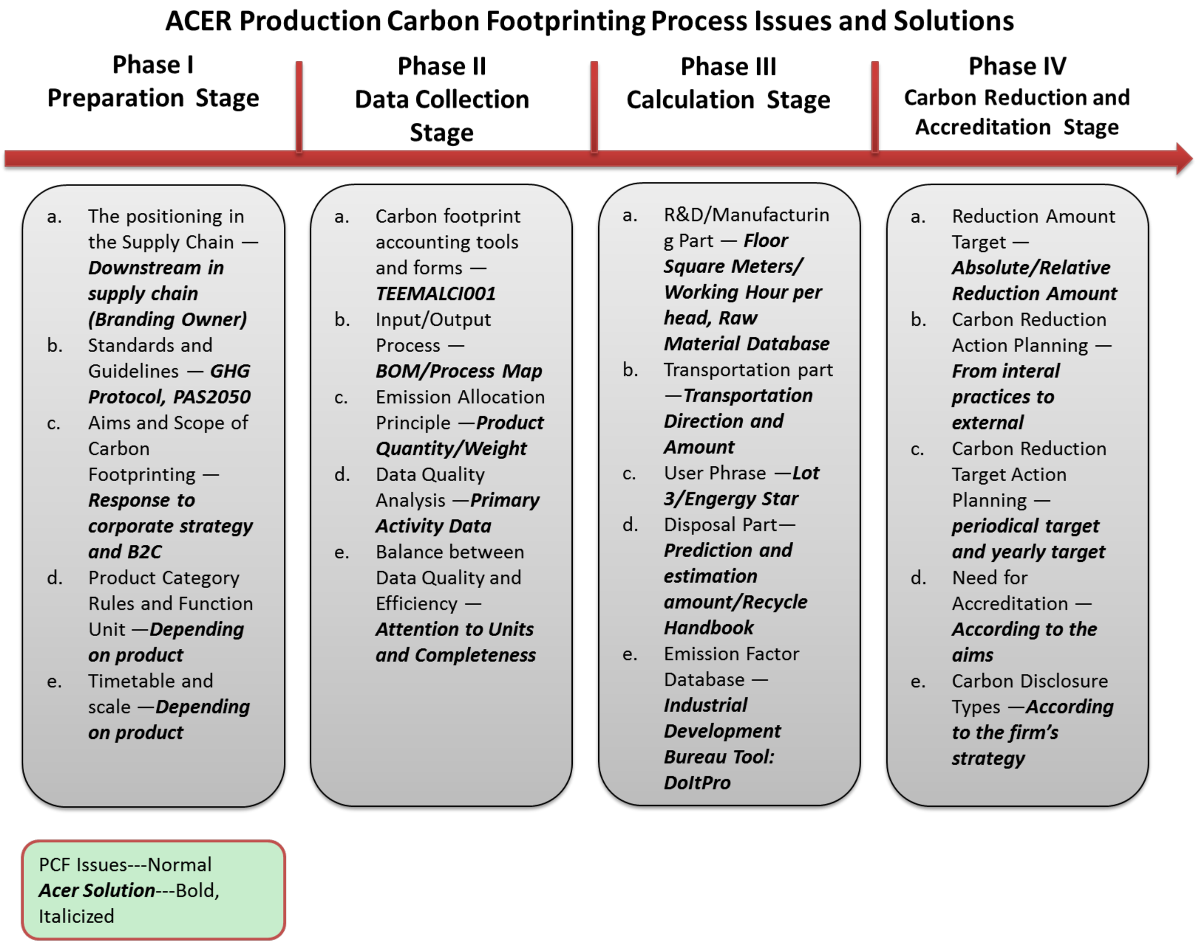


Figure 5.3 Acer Product Carbon Footprinting Process Issues and Its Solution

From 2009, Acer has formed the group called Acer Product GHG Working Group aligning with most of the first-tier suppliers. Setting 2008 as the baseline year, they implemented the Scope 3 Accounting & Reporting and Product Carbon Footprinting & Reporting.

AUO (Appendix I-7)

The AUO 32'inch LCD TV was at the time in 2009, one of the most complicated products in the processes that has conducted the carbon footprinting. This is due to the numbers of sub-parts of the LCD TV and their being over 500 suppliers. And the product is the first electric one in the global projects led by the UK Accreditation Service Pilot Programmes. AUO organized the suppliers briefing and training meeting particularly to gather data, examine the processes including raw materials, manufacturing, distribution, usage, disposal and recycling.

AUO generated its own product carbon footprint calculation e-system (PCF System) in 2011, which could not only measure but was also able to provide the longitudinal data of the same product and comparison between products in different sizes.

In 2009 AUO was the first one to attend the UK accreditation system in Taiwan, and the first one to get products labelled with a carbon footprint declaration. The process is shown in Figure 5.4.

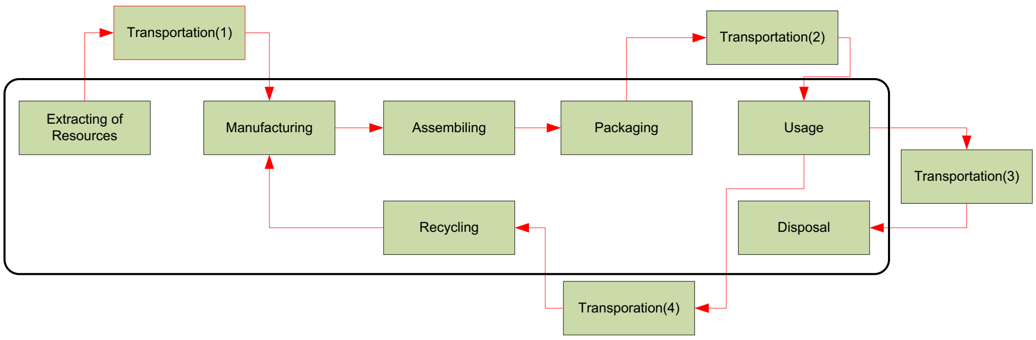


Figure 5.4 PCF process mapping of AUO TV product

Tungho Steel (Appendix I-9)

Plotting the processes map, determines the boundaries and priorities, and collecting data, allocating the emission according to the weight, calculation and uncertainty analysis are identified as the key five steps.

Since this PCF involves over 10 suppliers in the upstream supply chain, the supplier firms are reluctant to reveal their data on electricity/gas usage because they think it links to their operating cost. Tungho gives two points to suppliers to persuade them. The first one is that the verification of the PCF would be limited to Tungho rather than to all the suppliers, so the supplier firms would only need to provide the data without verification files. Secondly, low carbon is the trend of the industry, and suppliers could take advantage of the government support for free tutorial and carbon reduction advice in this case rather than conduct PCF later without support.

The auditing process lasts for 7 months as a whole, and 3 tutorial workshops are conducted for the suppliers together with Tung Ho. The tutorial team also conduct the site-visit to the supplier plants to coach the data collection procedure.

The product carbon footprint accreditation enforces a strict verification requirement on the data sources, which are the paper sheets and tables, as the proof of data credibility.

BenQ (Appendix I-8)

From 2009, BenQ started its journey of measuring the carbon footprint of its products. In 2010, BenQ got the BSI PAS2050 label for its LCD TV and LCD Monitor, which was the most complex product certified by then. And then in 2011, BenQ's E-book, Camera and Projector all have been certified by the Carbon Trust with the PAS2050 standard.

The first footprinting process of BenQ's LCD TV took around 9 months to complete. Multiple business functions are involved in the process, including product certification, product R&D management, logistics and supplier management departments. BenQ was supported by 7-8 consultants from the Taiwan Industrial Bureau and from the Institute of Industrial Research.

The overall timeline of BenQ PCF is shown in Figure 5.5.

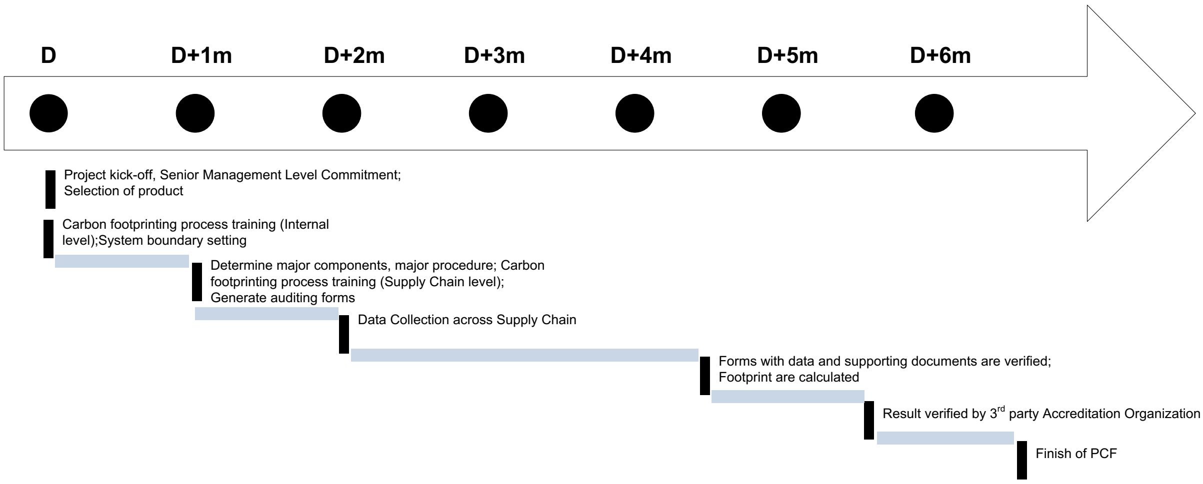


Figure 5.5. BenQ LCD TV Product Carbon Footprinting Timeline

The key focus of BenQ's PCF team is in supplier tuition. A process of engagement is proposed in Figure 5.6.

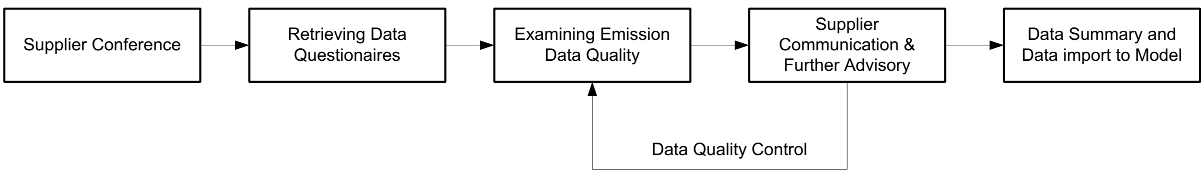


Figure 5.6. Supplier Engagement Procedure of BenQ carbon footprinting

Forms that were designed by consultants were sent to suppliers by BenQ. A conference attended by selected suppliers, BenQ and consultants was organized. Reasons and benefits of conducting PCF, measurement tools & process are introduced at this meeting. After the meeting suppliers were given 2 months to collect relevant data according to the information requested on the forms. As it was the first footprinting process, errors and faults are predicable in the suppliers' data. A second conference with these stakeholders was held providing communication and an explanation on how to fulfil the data collection requirements. Separated and one-to-one tuition for suppliers was also conducted based on their data quality. And BenQ's special team also visited some of the key suppliers to check the suppliers' data gathering procedure.

There are other issues that could also be covered to, such as the emission allocation criteria. Instead of focusing on product amounts, bulk and price, the emission is allocated according to length of working hours.

One of the interesting thing is that before the products re-design, the footprint of the projector would be 800kg, but become 433.38kg after the product redesign. Therefore, it can be concluded that product design is a very important part of carbon reduction, and not only the auditing.

Dell US (Appendix I-11)

Since most of Dell's production is outsourced to the OEMs which are located in the East, South East of Asia, and South America, the suppliers management is conducted by the local teams in these areas while the carbon footprinting is implemented at the headquarter at Dallas, Texas, USA. In the global scope, Dell took part in the CDP Supply Chain Project to help manage the carbon emission along its supply chain. From 2010 Dell's headquarters started to calculate the carbon footprint of its laptop products. As shown previously the four parts of the product life cycle are the focus of the calculation: which are the raw material consumption, manufacturing, logistics, and product use and end-of-life management. The detail measurement process was conducted by the Dell Environmental Affairs Department. Dell Latitude E6400 was chosen as the functional unit for this study. This model was selected because it is typical high-volume, mainstream business laptop and therefore representative for a range of similar laptop products.

The system boundaries of the measurement includes:

1. Material (=components, parts) and product manufacturing in Asia;

2. Transport to final assembly;

3. Final assembly in Asia and Europe;

4. Transport to customers in the USA, Germany, and China respectively;

5. Use in the US, Europe, and China for four years;

6. Transport to recycling;

7. End of life disposal and recycling.

The software Gabi from PE international was used to assist the measurement process, the data from Gabi replaced all the data from the actual data acquisition in factories and assembly plants. This specifically is the case for electronic components like integrated circuits (ICs), active and passive components, as well as printed wiring boards. Also generic energy mixes both for manufacturing and use were used. Further generic end of life processes were used to determine their impacts at the end of their life. So the Dell product's PCF is a secondary data result.

It is shown in the result that the manufacturing and user phase take up the two largest portions of the total carbon footprint of Dell's laptop. Within the manufacturing part, most of the carbon emission comes from the parts components manufacturing, rather than from the assembly and transportation. And the mainboard within the components contributes to the biggest part.

British Sugar (Appendix I-10)

British Sugar is recognised internationally as one of the most efficient and progressive sugar manufacturers in Europe. In December 2008, British Sugar with its branding arm Silver Spoon became the first sugar manufacturer to calculate, certify and publish the carbon footprint of its sugar, using the new PAS 2050 method. British Sugar worked as a partner using the standard as a trial, and completed a detailed assessment of each stage of its 'total supply chain'. The measurement process lasted for 9 months.

The working group was combined with the British sugar internal energy expert and the UK consultancy North Energy. They conducted the measurement process as follow:

1. An analysis of British Sugar's process flow to draw process flow charts and establish the detailed data requirement;
2. They allocated the GHG Emission between products (granulated sugar, Topsoil and LimeX) based on their separated values;
3. They calculated the weighting of GHGs from electricity exported to the grid from the Combined Heat and Power (CHP) plants;
4. Each plant that produced the granulated sugar were examined in order to calculate the overall energy consumption of production;

The full life cycle of the product "cradle-to-factory gate" was assessed, including all the products produced. The process consisted of: cultivation, transportation of all inputs, and process stages within the British Sugar's four British plants. These four plants are at: Wissington, Bury St Edmunds, Cantley, and Newark. The final GHG emission of products were calculated with the weighted average of all plants.

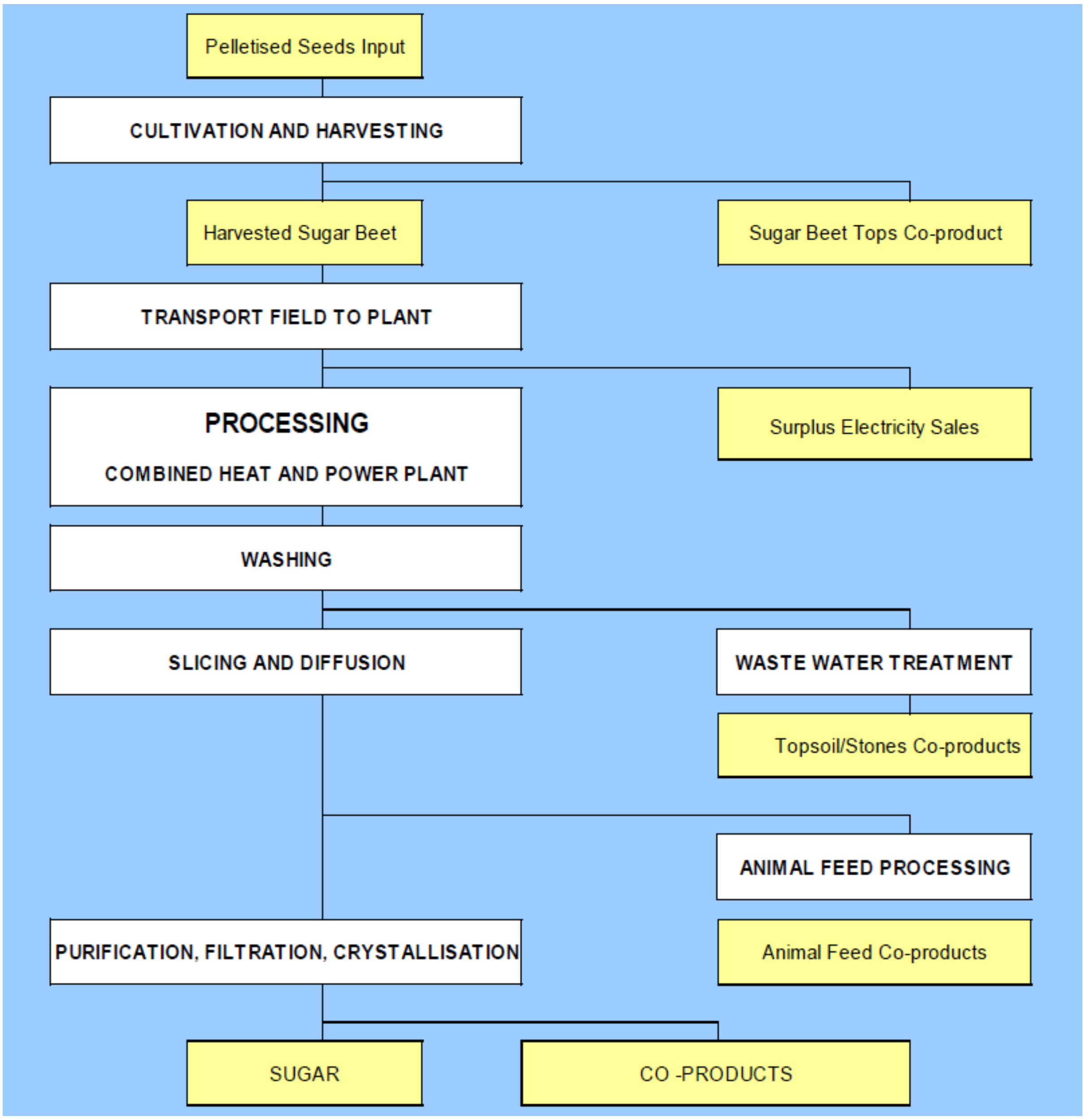


Figure 5.7 British Sugar Granulated Sugar Cradle-to-Gate Processes

5.2.3 Summary of Cases

The PCF processes in these cases can be summarized in the following Table 5. 2. The detail analysis will be presented in next section.

Table 5.2 Summary of PCF Process in Selected Cases

Case	Product Carbon Footprinting Processes				
ZTE	1. Setting the goal of PCF—Only to response to customer request 2. Determine the product for PCF 3. Obtain product specification & bill of material 4. Design data collection forms for internal departments 5. Analysed the components of raw material	1. Obtain data from internal departments	1. Input data to software and calculate the footprint		Pilot-Oriented Goals
Dell US	1. Determine the goal of the carbon footprint study—Dell have customer inquiring about carbon information so to make a pilot for it 2. Determine the product and scope of the study 3. Determine the system boundaries 4. Use bill of materials	1. Extract data from Database Gabi	1. Calculate the life cycle carbon footprint	1. Conduct life cycle impact analysis to the result	
Lenovo	1. Setting the goal of PCF—Not to disclose to public but for internal information sharing and continuous improvement 2. Determine the product for PCF 3. Allocate PCF task according to BOM 4. Select Involved Suppliers	1. Design Data Collection Forms for Internal & External user 2. Engaging Suppliers to Complete Data Form 3. Engaging Internal Department to Complete Data Form 4. Obtain Data from Suppliers 5. Obtain Data from Internal Departments 6. Site-visit to Check Data Validity	1. Calculate the footprint	1. Setting Reduction Action Plan	Process-Oriented Goals
Tsingtao	1. Determine the goal and priority of PCF—Tsingtao has integrated carbon issues into strategic decisions, and use it for operation improvement 2. Select PCF product 3. Internal workshop on PCF Action Plan 4. Draw Process Map and Task Allocation 5. Select Involved Suppliers	1. 1st Training Workshop for Suppliers 2. Obtain Data from Less Capable Suppliers 3. Obtain Data From capable suppliers 4. Site-Visit Consulting to support data collection 5. Obtain data from internal departments	1. Calculate the footprint		
Acer	1. Project Kick-off, Support from Senior Management 2. Position company in the supply chain 3. Determine standards & guidelines 4. Aims & Scope of Carbon Footprinting—To response to customer and NGO requirement, and gain certification 5. Determine Product Category Rules & Function Unit 6. Set Timetable & Scale	1. Design/Choose Carbon Footprint accounting tools & forms 2. Drawing Input/output Process 3. Emission Allocation Principle 4. Conduct Data Quality Analysis 5. Balance between Data Quality & Efficiency	1. Calculate R&D/Manufacturing Part 2. Transportation Part 3. User Phrase Part 4. Disposal Part 5. Emission Factor Database	1. Setting Reduction Amount Target 2. Set carbon reduction action planning 3. Accreditation of PCF result 4. Determine Carbon Disclosure Types	Market-Oriented Goals
BenQ	1. Project Kick-off, Support from Senior management, and goal—To gain certification in order to compete with rival products 2. Determine the product for PCF 3. Setting Product Category Rules (PCR) and System Boundary 4. PCF Training Workshop (Internal) 5. Draw Process Map and Determine Key Components & Processes 6. PCF Training Workshop (Suppliers) and Generate Forms	1. Obtain Data from Suppliers 2. Obtain Data from Internal Departments 3. Validate Data with Forms & Supporting Documents	1. Calculate the footprint	1. 3rd Party Accreditation	
AUO	1. Determine the goal for PCF—To gain the first PCF certification in its kind for the competitive advantage 2. Organize the Project Team 3. Determine system boundary, bill of material, list of suppliers	1. Design data collection forms 2. Distribute forms and retrieve filled forms	1. Integrate data and calculate the carbon footprint 2. Validate the files and site-visit to factories (including suppliers)	1. Generating the carbon footprint report 2. Setting the carbon reduction strategy 3. Certify carbon footprint result	
Tungho Steel	1. Determine the goal of PCF—Get involved in the Taiwan IDB programme and to be certified by the Taiwan standard 2. Plotting the processes map 3. determine the boundaries and priorities	1. Collecting Data	1. Allocation the emission according to the weight 2. Calculating the footprint 3. Uncertainty Analysis	1. Certified by 3rd party organization	
China Steel	1. Setting target—To be certified by Taiwan standard 2. Select Product 3. Determine the suppliers involved in the project 4. Drawing Process Map 5. Checking boundary and priority	1. Collecting data	1. Calculate the carbon footprint 2. Uncertainty validation	1. Declare the carbon footprint report	
British Sugar	1. Setting the goal—To assist in the PAS2050 pilot to develop the methodology 2. Analysis process flow 3. Draw the process flow map of British Sugar's procedures 4. Established detailed data collection requirement	1. Produced a series of MS Excel workbooks for each plant to collect data 2. Calculated the weighting of GHGs to electricity exported to the grid from CHP	1. Allocated GHG emission between products based on their market value 2. Produced a cradle-to-factory gate assessment of all products produced, including processes of cultivation, transportation of inputs and inside-plant processing		
	Preparation for scoping and engaging relevant stakeholders	Collecting Data from Internal Department and External Supply Chain Partners	Calculate the Footprint in sub-processes and allocate emissions	Post PCF Validation, Certification and Set up Reduction Action Plan	

5.3 Findings and Implications

5.3.1 Three Goal-oriented Scenarios of Product Carbon Footprinting

In the summary Table 5.2., we could categorize the PCF projects according to their goals and targets. Different level of time and effort are devoted to footprinting depending on the carbon-related targets that firms are pursuing. The quality of activity data (explained in Literature Review Section 2.X) collected in the process marks the difference between the PCF projects. The more the primary data was collected from the firm's actual operation, the more valid was the footprint result, which is an estimation to the emission in reality. Consequently more time and effort is needed in order to gain more primary data, compared to using secondary data. These three types of PCF are explained as follow:

- Pilot-oriented PCF: aiming to make an attempt on carbon footprint measurement. This is a brief examination of the product carbon emission performance, and usually it is the firm's first attempt to measure the carbon footprint. The main aim for firms is to initially understand the new carbon footprint requirement, and prepare itself for a more detailed measurement in the future. The PCF can be conducted by software or even MS-Excel based models. The primary activity data is not required because secondary source data is sufficient enough for the task space. It limits the project's system scope to the main stages of the product, and only uses secondary activity data. External supply chain partners do not provide any data;

- Process-oriented PCF: The Firm's intent is to have a clear mapping of its product's carbon footprint, which will trigger the improvement of the firm's supply chain carbon emission. Hot-spot analysis to the carbon footprint can be analysed so the improvement practices can be focused. And after the first PCF, a footprint can be set as a baseline to enable continuous improvements. To achieve this goal, primary activity data from multi-tiers suppliers, OEMs (for ICT industry), internal production plants, logistics and product design (for user phase and end-of-life phase) should be collected as much as possible. The use of secondary source data undermines the creditability and validity of the result. Because certificates are not granted after PCF so the collected data does not require verification;

- Market-oriented PCF: The firm aims to achieve carbon footprint labels which may benefit the firm's brand. With the purpose being not only for continuous improvement internally but also for external claims and communications. The result of carbon footprinting needs to be verified by an independent 3rd party organization. In this type of PCF, firms should ensure that the data collection and calculation procedures are solid, activity data are of the appropriate quality, the reported footprint claims have reflected what has been undertaken with sufficient document proof, and that they are delivered in the given reporting period. These above need to be reviewed and tested by the 3rd party accreditation organizations. So the PCF process should be conducted under a strict mode following standards and to achieves primary activity data as much as possible. Certificates are granted afterwards.

The data used in the assessment includes activity data and emission factors (the emission per unit of energy, material, waste, etc.). The emission factors are basically all secondary data. The activity data can be collected primarily from the firm or substituted by secondary sources. Therefore, the quality of these three types are gradually improved—the activity data used in 'Pilot-oriented PCF' are mainly from a database embedded in LCA software such as Gabi, SIMAPRO, and activity data in 'Process-oriented PCF' is collected in the actual business, while the data in 'Market-oriented PCF' is not only primarily collected but also verified by third-party accreditation organizations. A summary of these three PCF types are illustrated in Table 5.3.

Table 5.3. Three types of PCF Process

PCF Types	Target	System Scope	Data Source	Data Quality
Pilot-Oriented	An attempt to measure carbon emission. To initially understand the new carbon footprint requirement, and prepare for a more detailed measurement in the future	Covers the main stages of the product	Secondary data from database	The quality depends on the database applied.
Process-Oriented	To have a clear mapping of its product carbon profile for continuous improvement, but not aiming to publicly advertise the result	The system scope covers the full life cycle of the product. The firm can expand to a larger scope if the continuous improvement need to cover more aspects of the product.	Secondary data from database and primary activity data from the firm's actual business	There is no strict requirement for primary data. Secondary data depends on the database applied
Market-Oriented	To certify the carbon footprint result as a part of a marketing tool	The scope has to cover over 95% of a product's total carbon footprint	Secondary data from database and over 30% of data is primary activity data from firm's actual business	The primary activity data has to be internally and externally validated.

The detailed difference of these types in implementing PCF projects will be illustrated in the proposed PCF framework in the next section.

5.3.2 Product Carbon Footprinting Framework

Based on the cross-case analysis, a general process for PCF is proposed in Figure 5.8(next page).

Preparation

The preparation stage (Table 5.4) is the key stage in the project because it sets up the overall planning. Aims, targets, and priorities have significant impact to the strategy of the footprint measurement process, so these issues have to be considered at the beginning of the project. Also the function unit of footprinting, which is the targeted product or service, has to be determined at this stage.

Scoping Stage

In the 'Scoping' stage, it includes a scoping task internally (Table 5.5) and scoping for external supply chain partners (Table 5.6). These two parts have similar steps, the difference is that the first one focuses on the internal departments while the external one covers the supply chain partners, who are mainly upstream suppliers. There are several steps in the 'Internal Scoping' stage, which are:

1. Describe the product to be assessed and the unit of analysis;

2. Draw the 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. In this step there are sub-steps to do as well:

• provide a description of the activity to aid with data collection

• identify the geographic location of each distinct step where possible

• include all transport and storage steps between stages.

3. Determine the system boundary: the boundary should be documented with (1)a list of all that is included in the life cycle stages; (2) a list of all included activities and processes within each life cycle stage; (3) a list of all excluded activities and processes, and the steps taken to determine their exclusion. Drawing the system boundary, BOM can help to generate the list but it is not sufficient enough, the following elements should be considered: Production materials, Energy, Production processes and service provision, Operation of premises, Transport, Storage, Use phase, End-of-life.

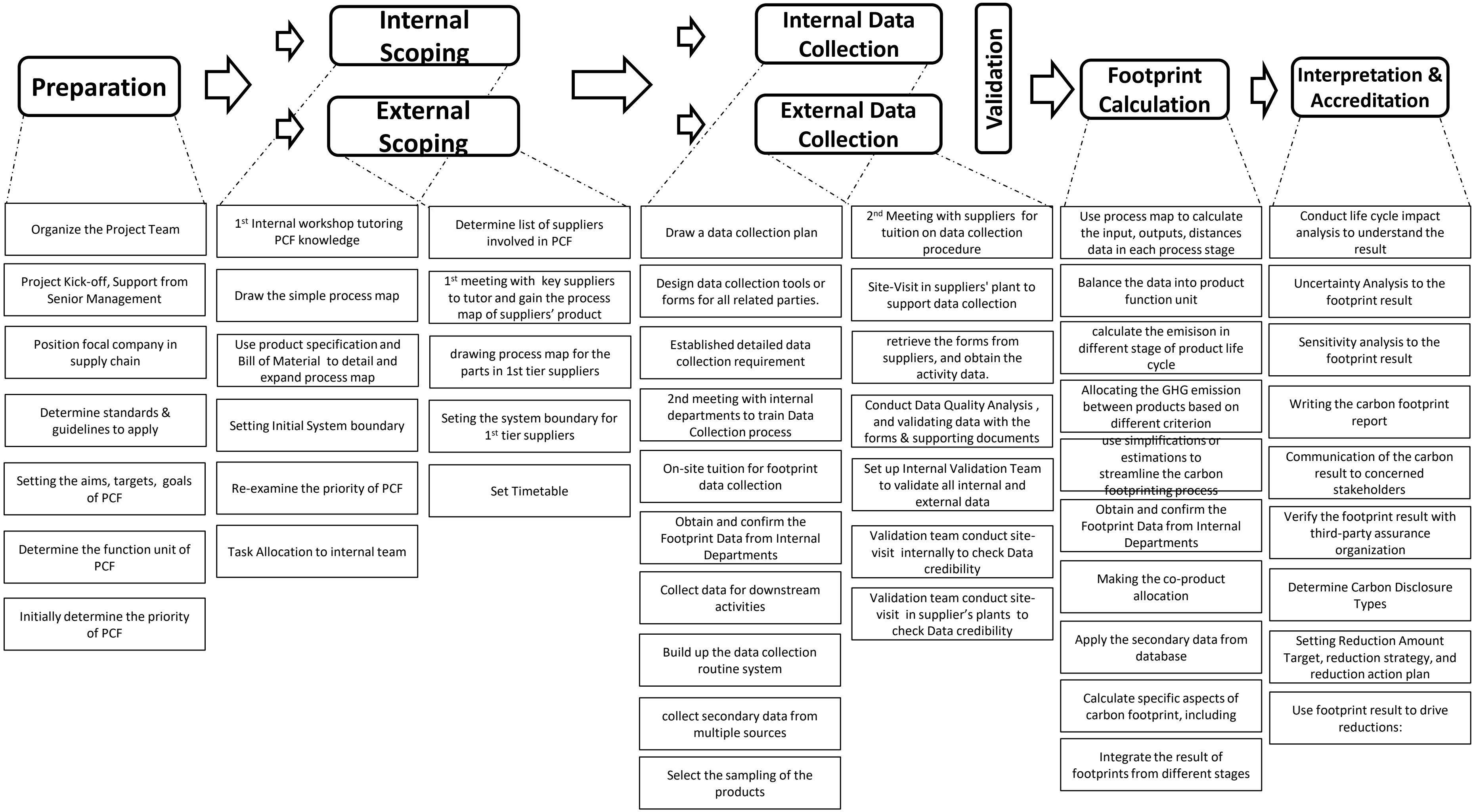


Figure 5.8. Product Carbon Footprinting Process Framework

Table 5.4 Preparation Stage of PCF

		Steps	Explanation	Pilot-Oriented	Process-Oriented	Market-Oriented
Preparation	Project Initiation, Aims and Targets	Organize the Project Team	To set the project team, allocate sufficient number of staffs and resources into the team	a small team of PCF expert	PCF team and representatives from other business functions	PCF team, representatives from other business functions, and a separated internal validation team
		Project Kick-off, gaining Support from Senior Management	The start of the project. The support level from senior management has a significant impact on the project	Senior management support is not very critical. The operation can be conducted by pure desk research	senior management support is critical because the cooperation is needed between PCF team and other business functions	senior management support is critical because the cooperation is needed between PCF team and other business functions
		Position the focal firm in the supply chain	The position of focal firm in supply chain will reflect the pressures they received. That will be taken into consideration when focal firm determine PCF strategy.	Because the primary activity data is not collected, so this issue is not critical	The focal firm in upper position of supply chain usually cover fewer suppliers, and focuses on the internal production: the ones in downstream of supply chain usually cover more suppliers. But it depends on the industry category as well.	The focal firm in upper position of supply chain usually cover fewer suppliers, and focuses on the internal production: the ones in downstream of supply chain usually cover more suppliers. But it depends on the industry category as well.
		Determine which standards & guidelines to use	PAS2050 is only one of the standards for product carbon footprinting. The other options include ISO14067.	It is usually embedded in the software	Life cycle assessment	Life cycle assessment
		Setting the aims, targets, goals of PCF	The aims, targets, and goals of PCF determine the procedure of PCF and resources which are allocated to the project	A quick-scan to the product carbon emission profile, mainly focuses on the result. So secondary data will be used without primary activity data	Internal communication and continuous improvement. So primary activity data will be used	Carbon footprint accreditation & labelling. So high quality & validated primary activity data will be used.
	Function Unit	Determine the function unit for PCF	Check whether PCR (product category rules) exists, if not, then the function unit has to be set.	Selected product is required by customer	Mainstream products	Mainstream products
		Initially determine the priority of PCF	(according to the PCF aims and the product characteristics, and company's position in the supply chain, to decide focus / priority of PCF, the focus / priority is just an initial decision, not as detailed as setting the system boundary), this determines whether the priority should be in the production part or the supply chain part	It is not needed to consider PCF priority	The PCF team should make up an initial decision on the focus of the project: the production stages or supply chain	The PCF team should make up an initial decision on the focus of the project: the production stages or supply chain

Table 5.5. Internal Scoping Stage of PCF

		Steps	Explanation	Pilot-Oriented	Process-Oriented	Market-Oriented
Internal Scoping	**Map of Product Life Cycle**	1st Internal Workshop tutoring PCF knowledge	The first meeting should be organized within internal departments, in order to get a good idea of what is the process map and what are the related parts and input flows, because the PCF team may not be the expert of each team, so may not be well aware of all the related information of the product. But the internal meeting should be the training to different departments, because they may not be prepared in the knowledge of PCF. The tuition content of the workshop should include: 1. Introduction to international corporate carbon management practices; 2. PAS2050 standards, system boundary, data collection/calculation and quality assessment; 3. Emission allocation principles; 4. How to complete data collection template forms; 5. Overall process of calculating carbon footprint; 6. Footprinting routine report and overall carbon footprint report; 7. Training to internal validation	This meeting is not applicable for this strategy.	PCF team and representatives from other business functions need to attend the training.	PCF team, representatives from other business functions need to attend the training.
		use product specification and BOM to detail and expand process map	The product specification and BOM (Bill of Material) can give a clear information list of product's components.	Obtain from product management department	Obtain from product management department	Obtain from product management department
		draw the initial process map	The map of linked processes to make the product	the process map can be simply divided into several stages: R&D, manufacturing, transportation, usage and disposal	Draw the proces map with detailed stages	Draw the proces map with detailed stages
	System Boundary	Setting initial system boundary	After drawing the initial process map, according to the goal of PCF, the focal firm can decide how wide to involve suppliers, if yes, what are the involved components. Suppliers to involve? As well, use PCR to help to determine the system boundaries, but in many situation there are not PCR to reference from	covers partial product life cycle	covers full or partial product life cycle	covers full product life cycle; include 95% of the total carbon emissions
		Re-examine the priority of PCF	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 and priorities should also be linked to the intended purpose of the study. It is suggested to identify potential emissions 'hotspots' at a high level early on in the process, and focus your efforts.	Not applicable	Determine the focus of PCF to ensure sufficient effort into the emission factors with significant impacts	Determine the focus of PCF to ensure sufficient effort into the emission factors with significant impacts
		Determine primary activity data collection scope	The general rule in PAS2050 is that primary activity data are preferred. So it has to be considered whether supply chain partners' primary data should be covered	Only secondary data applied	Primary data and secondary data	Primary data in most case; supplemented by secondary data
		Task Allocation to internal team, including PCF team and other function units	The detailed tasks to collect data from different processes are allocated to relevant departments.	Tasks are only allocated to PCF team	Data collection tasks are allocated to other internal business functions	Data collection tasks are allocated to other internal business functions and internal validation team

Table 5.6. External Scoping Stage of PCF

		Steps	Explanation	Pilot-Oriented	Process-Oriented	Market-Oriented
External Scoping	Supplier Process Map & System	Determine list of suppliers involved in the project	According to the process map and decision on system boundary, a list of suppliers which make the raw material for the focal firm can be generated	Not applicable	Select key raw/materials/components	Select key raw/materials/components
		1st meeting with key suppliers to tutor and gain the process map of suppliers' product	The second meeting should be organized with key suppliers to tutor or directly get the process map from the supplier's site. This meeting aims to help the focal firm to get a clear idea about the product life cycle map of the component parts produced from suppliers. Because the focal firm may already have a clear idea of suppliers' product life cycle, this can be finished directly by the focal firm without discussion with suppliers.	Not applicable	Tutor suppliers with basic knowledge of PCF	Tutor suppliers with basic knowledge of PCF
		Drawing process map for the parts in 1st tier suppliers	The process map of the producing procedure for the specific raw material	Not applicable	Get the process map of supplier's key product which are inputs to focus firm	Get the process map of supplier's key product which are inputs to focus firm
		Setting the system boundary for 1st tier suppliers	System boundary for the components that is made in suppliers' plant	Not Applicable	Setting boundary for suppliers' products. In most situation it only considers the raw material and its production stage	Setting boundary for suppliers' products. In most situation it only considers the raw material and its production stage
	Overall	Set Timetable	The timetable and milestones for the whole project, including the data collection, footprint calculation procedure, internal validation and result verification by 3^{rd} party.	2-4 months for first-time PCF	4-7 months for first-time PCF	6-8 months for first-time PCF

4. Prioritize data collection activities: to identify the hotspots of the emissions and skip collecting data with little impact.

These four steps can also apply to external scoping, only changing the target to external partners. But Engaging suppliers may be very difficult because they are very sensitive about sharing their data.

Data Collection

In the data collection section, footprinting standards requires that the company should collect primary activity data for its own operations and the operations under its control (for example product distribution). And there should be a minimum percentage of the total cradle-to-gate emissions (10% in the PAS2050) which must be calculated from primary data. For manufacturing companies, this 10% threshold will probably be reached with the companies' emission alone. For companies in other industries, they need to collect primary activity data from their supply chain. So the data collection can be divided into two parallel stages: internal data collection (Table 5.7) which focus on the primary data collected within the focal firm's own operation; and the external data collection (Table 5.8) working with supply chain partners (mainly suppliers).

Internal data quality assessment and validation (Table 5.9) are important for a 'Market-Oriented' type PCF because the internal assessment team can assure data validity and adequacy of the PCF procedure (the PCF has been conducted in an adequate way), and therefore enhance the possibility to get 3rd party verification for the footprint result.

Table 5.7 Data Collection Stage of PCF Framework

		Steps	Explanation of Steps	Pilot-Oriented	Process-Oriented	Market-Oriented
Internal Data Collection	Data Collection Plan	Draw a data collection plan	Draw a data collection plan	Rough collection plan	Data collection plan involves multiple internal and external partners	Data collection plan involves multiple internal and external partners
		Design data collection tools or forms for all related parties	Design data collection tools or forms for internal departments and suppliers, and downstream logistics providers.	generated from software	According to PCF standards (e.g. PAS2050) and external consultancy advice if provided	According to PCF standards (e.g. PAS2050) and external consultancy advice if provided
		Established detailed data collection requirement	choosing between primary data and secondary data, following the principles: •relevance – selection of appropriate data and methods for the specific products •completeness – inclusion of all GHG emissions and removals arising within the system boundary that provide a material contribution •consistency – applying assumptions, methods and data in the same way throughout the assessment •accuracy – reducing bias and uncertainty as far as practical •transparency – where communicating externally, provide sufficient information.	using secondary data	supported by standards or external consultancy	supported by standards and external consultancy
	Collect Internal Data	2nd meeting with internal departments to train data collection process and on-site tuition	2nd meeting with internal departments, focus on the Data Collection Training, engaging these internal departments to complete data collection forms. The collection process follows the process map in the scoping stage. These tasks are allocated across internal departments	This type does not need to collect primary data so no need to train representatives from internal departments	Training to representatives of internal departments (R&D, procurement, production, logistics, etc.) and on-site tuition for data collection	Training to representatives of internal departments (R&D, procurement, production, logistics, etc.) and on-site tuition for data collection
		Obtain and confirm the Data from Internal Departments	Collect data through the representatives from internal departments. Communication between PCF team and representative can be quite frequent.	Not applicable	Collect data from multiple departments	Collect data from multiple departments
		Collect data for downstream activities	These data include distribution to customer, usage and end-of-use phrase of product. These tasks should be conducted by transportation/ distribution department, and product R&D department, and the PCF team	collect downstream data from software	Collect downstream data from internal departments	collect downstream data from internal departments
		Build up the data collection routine system	Build up the data collection routine system, which can support the business for future footprint collection and good traceability of data source	Not necessary for Pilot-oriented PCF	The data collection routine can save time for new PCF project and easily scale up to cover other product's PCF profile. And it can help on product-level carbon continuous improvement.	The data collection routine can save time for new PCF project and easily scale up to cover other product's PCF profile. It makes PCF validation process more efficient in the future
		Collect secondary data from multiple sources	The source of secondary data include aggregated data such as emission factor and disaggregated data such as inventory data sources	Secondary data is usually embedded in software	use secondary data embedded in software or other sources	use secondary data embedded in software or other sources

Table 5.8. External Data Collection Stage

	Steps	Explanation of Steps	Pilot-Oriented	Process-Oriented	Market-Oriented
External Data Collection	Select the sampling of the products	Selected average from upstream source. Not every supplier is needed to be involved in data collection. The result can be sampled from typical or selected suppliers	Not necessary	select some suppliers that supply key components	cover the majority of suppliers
	2nd meeting with suppliers for tuition on data collection procedure, and distribute forms to suppliers	This meeting should be organized with suppliers to tutor them with the data collection forms, and the procedure of how to collect data. Also the data collection templates forms are distributed to suppliers.	Not applicable	Organize suppliers conference to tutor suppliers on detailed procedure of data collection, the requirement and related forms which have been designed by PCF team or external consultancy	Organize suppliers conference to tutor suppliers on detailed procedure of data collection, the requirement and related forms which have been designed by PCF team or external consultancy
	Site-visit suppliers' plant to support data collection	Site-Visit in suppliers' plant to support data collection	Not applicable	For some of the suppliers, PCF team visit their plants to tutor data collection method	For some of the suppliers, PCF team visit their plants to tutor data collection method
	Retrieve the forms from suppliers, and obtain the activity data	Retrieve the forms from suppliers, and obtain the activity data. This process and the previous tuition step can iterate several times because the suppliers may not be well trained to collect data, so the data quality is not as good as required	Not applicable	collect the forms with primary activity data	collect the forms with primary activity data

Table 5.9. Data Validation Stage

		Steps	Explanation of Steps	Pilot-Oriented	Process-Oriented	Market-Oriented
Data Validation	Internal Validation	Conduct data quality analysis, and validating data with the forms & supporting documents	These data are collected by both internal business units and suppliers. These data are validated with the forms & supporting documents provided by internal departments and suppliers. The data quality should follow the underlying PAS 2050 principles: relevance, completeness, consistency, accuracy and transparency. And there are multiple data quality assessment methods	Not applicable	Check and confirm the quality of primary activity data & secondary data. This process includes examining the rationality of data with background documents from internal departments and suppliers	Check and confirm the quality of primary activity data & secondary data. This process includes examining the rationality of data with background documents from internal departments and suppliers
	Data Quality Assessment	Set up Internal Validation Team to validate all internal and external data	Internal Validation Team is set up for the purpose of internal check before applying for the 3rd party accreditation.	Not applicable	For the process-oriented type PCF it is not necessary to set up the internal validation team	Internal validation team is for the purpose to double check the accuracy of the data, and ensure procedural accuracy of PCF
		Validation team conduct site-visit internally to check data credibility	Internal validation to the data collected from internal departments	Not applicable	Not necessary	Check data credibility of internal data
		Validation team conduct site-visits in suppliers' plants to check data credibility	The internal validation team need to conduct site-visit to suppliers to check Data credibility	Not applicable	Not necessary	Check credibility of external supply chain data

Footprint Calculation

The footprint calculation stage is to integrate the emission data in different stages of a product's life cycle. The emission result can be simplified as the equation:

$$Emission = \frac{Activity * Emission\,Factor}{Allocation\,Factor}$$

Taking distribution of a bottle of Tsingtao beer from the plant to Tsingtao Port as an example, the carbon emission of this single process is equal to: '100km'—the distance, times '0.03 kg/km'—the emission amount per kilometres of fuel usage that a truck consumes in transporting goods, and it is divided by '5,000'—the number of bottles in each haul.

The general steps of calculation can be summarized as follow: Firstly the emission is calculated according the above-mentioned general equation, and balances the data into a product function unit; Secondly simplifying assumptions can be made, which is detailed in Table 5. 10. ; Thirdly it is to make the allocation of the co-products which is produced together with the main product, such as Topsoil when making sugar in the British Sugar case. As well the specific aspects of emission has to be considered, which is also detailed in the following table.

Table 5.10 Footprint Calculation Stage of PCF

	Steps	Explanation of Steps	Pilot-Oriented	Process-Oriented	Market-Oriented
Calculate Footprint Stage	General calculation process	Use the process map which already map out all of the inputs, outputs, distances and other useful 'activity' data for each process stage. It can be used to calculate the emission quantities	executed in software or Excel worksheet	executed in software or Excel worksheet	executed in software or Excel worksheet
	Balance the data into product function unit (calculate the provision of functional unit of product to the overall process)	Because Activity data are often collected in many different formats and relating to different units, so the important step is to balance the data into a function unit	executed by software	The allocation method of primary activity data needs to be discussed with PCF team and internal departments. Some of the typical allocation units are weight, monetary value, per working hour, etc.	The allocation method of primary activity data needs to be discussed with PCF team and internal departments. Some of the typical allocation units are weight, monetary value, per working hour, etc.
Simply and Consider the specific aspects of footprint	Making simplifying assumptions	Use simplifications or estimations to streamline the carbon footprinting process, including a generic emission factor for a group of similar chemicals, and to assign a set of general assumptions for transportation calculation.	software dataset has embedded the simplified assumptions	make these assumptions on less-impact emissions activities but make sure the high-impact activities are carefully examined	strictly follows the requirements of footprinting standards
	Making the co-product allocation	split/divide the emission footprint between the main product and the co-product	this issue is usually omitted by software	conducted by PCF team according to product production process	conducted by PCF team according to product production process
	Apply the secondary data	The secondary data were collected in the data collection stage, including the emission factor database	Data in software are all secondary type	apply the secondary data	apply the secondary data but ensure it complies with the PCF standards requirement on usage of primary data
	Calculate specific aspects of carbon footprint	Including: biogenic carbon accounting and carbon storage, energy and combined heat & power (CHP), grid electricity, renewable energy and renewable electricity tariffs, on-site electricity production, agriculture, land use change, refrigeration, transport emissions, storage emissions, recycling, residual waste disposal	this issue is usually omitted by software	special aspects should be carefully considered by PCF team	special aspects should be carefully considered by PCF team and make sure it complies with standard requirement
Result	Integrate the result of footprints from different stages	Summarize the emission results in different stages of product life cycle	Automatic conducted by software	integrate the footprint result	integrate the footprint result

Interpretation and Accreditation

The interpretation stage (Table 5.11) represents the firm's reflection on their product carbon profile. The result sets the baseline of the firm's current carbon performance and, therefore, the targets and action plan for improvement can be generated. Also the 'hot-spots' that are shown in the footprint profile can be targeted as the priority of improvement actions, but the feasibility and other decision factors have to be taken into consideration. Therefore, the high-emission stage of product carbon footprint is not necessarily the focus of a firm's reduction activity.

Accreditation of the footprinting result is the aim of the 'Market-oriented' PCF, hence the result has to be verified by a 3rd party assurance organization, such as the Carbon Trust. But for the other two types of PCF, the results serve as an internal communication or are used to respond exclusively to a customer request.

Table 5.11. Interpretation & Accreditation Stage of PCF Framework

	Steps	Explanation of Steps	Pilot-Oriented	Process-Oriented	Market-Oriented
Footprint Result Impact Assessment	Understand the carbon footprint results	Conduct life cycle impact analysis to the result, which shows the emissions hotspots across the life cycle	Hot spot' analysis, but due to using the secondary data, the analysis may not be accurate	Hot spot' analysis	Hot spot' analysis
	Uncertainty analysis to carbon footprint result	A formal uncertainty analysis can be undertaken by employing a statistical approach such as Monte Carlo analysis to quantify these uncertainties	conducted within the software	formal uncertainty analysis may not be necessary for this PCF type	a formal analysis should be carried out
	Sensitivity analysis to carbon footprint result	It shows how key data and assumptions influence the results. It involves simply changing the value (activity data or emission factor) over which there is uncertainty, to see how this affects results.	conducted within the software	formal sensitivity analysis may not be necessary for this PCF type	a formal analysis should be carried out
Certify Footprint Result	Writing the carbon footprint report	Generating the footprint report	simple basic report	The report is served as internal reference	written by PCF team or external consultancy which complies with standards
	Communication of the carbon result to concerned stakeholders	These stakeholders include internal departments and external supply chain partners, and external stakeholders	This type of PCF serves the request from clients or customers	The result is revealed to internal departments	The result is revealed to internal departments and external consultancy
	Verify the footprint result with third-party assurance	There are three levels of assurance: self-verification, other third-party verification and independent third-party certification	No need to verify for this type of PCF	No need to verify for this type of PCF. But self-verification can be an option	The result should be verified by 3rd-party verification; The focal firm should gain independent 3rd party certification
	Determine Carbon Disclosure Types	The focal firm can accredit the result but does not disclose it	Usually only disclose to customers that ask for the result	The result may be disclosed in the focal firm's annual Corporate Social Report, and disclose in some professional conference	The footprint result is certified and disclosed to the public.
Reduction Plan	Setting Reduction Amount Target, reduction strategy, and reduction action plan	Based on the footprint mapping, further plans and analysis for carbon performance improvement can be conducted	Due to using secondary data, the detailed solution for improvement may not be applicable	Set up related reduction plans according to the PCF result	Set up related reduction plans according to the PCF result
	Use footprint result to drive reductions: efficiency, design, and work with supply chain partners.	Emission reduction action	To guide the improvement according to footprint result	The detailed information in PCF result can support the decisions of improvement practices	The detailed information in PCF result can support the decisions of improvement practices

An Extension to PAS2050 Guideline

This process framework reflects the basic steps as suggested in the PAS 2050 guidelines. But it details the practical options for each step of the guideline under different aims and strategic choice. Based on the cases above, firms change their implementation methods and tools according to their strategic choice—classified as 'Pilot-oriented, Process-oriented, and Market-oriented' strategies.

Although the PCF process framework emerges to have similar key stages to PAS2050, the activities in preparation and data collection stages are different from this standard. There are many factors that are affecting the activities in preparation and data gathering stages. These factors include the decision on the use of primary/secondary data, the firm's resources and capability, the sector in which firm is, the firm's position in the supply chain, and other factors. Our framework gives more flexibility to the PCF project because a complete and vigorous PCF process is hugely time-consuming, as well as human-resource-consuming and costly. So fundamentally the firm's goal of conducting PCF determines how the firm uses the framework--in different tailored ways. This point is also mentioned in the second version of PAS2050:

> "The **intended audience** for a study. This affects the degree of accuracy and resolution needed. A footprint analysis to be used to identify opportunities for reduction can be undertaken efficiently and at a high level initially, to be built on as needed. For external claims, gaining assurance is best practice, and a rigorous approach to data collection will need to be demonstrated."
>
> *(Source: The Guide to PAS 2050:2011, P3)*

Our framework not only provides a detailed procedure for the footprinting process, but also discusses the engagement of other business functions and external supply chain partners in order to collect footprinting data. This framework enriched the PAS2050 guideline in the following several aspects:

- The engagement activities with internal corporate business units and external supply chain partners. In the PAS2050 Guide, these details are mentioned in an aggregated way.
- The data collection process can be divided into two parts: data from internal functions and data from upstream suppliers.
- The tasks in the preparation and scoping stage are not clearly stated, especially for the firms which needs to build up measurement teams and does not have much experience.

In summary, the proposed framework expands the PAS2050 steps to make it more practical. This framework is a good supplement to PAS2050 guideline, and a workbook for managers/business owner who plan to implement PCF.

5.3.2 Analysis and Findings in Cases via Platts' Model

In this section the product carbon footprinting processes from case companies are framed by the 4P Platt's model for comparison and analysis in Table 5.12.

Table 5.12 PCF Process Assessment in Case Data

Cases		Point of Entry: Method of entry	Participation: Width	Participation: Depth	Participation: Outside	Procedure: Tools and Techniques	Procedure: Written Record	Procedure: Process Stages	Project & Process Management: Managing Group	Project & Process Management: Supporting Group	Project & Process Management: Operating Group	Project & Process Management: Timescale
Pilot-Oriented	ZTE	Treated as customer request	Product Quality, Manufacturing, Purchasing	Product Quality Team	BV software company	The EPD software EIME from France	Continuous Improvement	Streamlined LCA, Material, Design, Production, Transportation, User phrase and disposal.	Not Available	Not Available	The PCF specialist in product quality department	1-2 months
Pilot-Oriented	DELL US	Dell Environmental Affairs Department	Environmental Affair, Product R&D, Logistics, Supply Chain Management (OEM data, Dell have no plants)	Two staff in Environmental Affair in USA and Germany	N/A	Gabi Software from PE	Multiple Product Groups, but no repetitive	Stated in previous section	N/A	Multiple departments provided information	EA team	N/A
Process-Oriented	Lenovo	1.CEO of Lenovo signed up company internal policy on carbon issue; 2.Requirement from Deutsche Bank of their product carbon footprint report	Manufacturing, Logistics, Product Design, Public Relationship, R&D (Product Standards and Legislations) departments.	Under the R&D department, specialists in product environmental regulations and standards	1.The primitive measurement is totally internal; 2. The second measurement targeting China product group Lenovo cooperate with the Energy Research Institute of NRDC. As the pioneering Chinese company coping with product carbon footprint; 3.Lenovo cooperate with WRI, WBCSD, MIT PAIA program and the CESI in China, setting up the first guidelines of ICT product carbon footprinting in China	1. Gabi from PE 2. From 2012 using specific tailored internal LCA software from IKE company.	Tracking of carbon footprint of the same product	Follows the PAS2050 and general LCA methods	1.Setting up CEO (Chief Environmental Officer) from 2006;	Experienced environmental engineer was in charge of the steering team from 2009, titled as Head of low carbon technology and PCF	1.Lenovo has built up its internal LCA analysis process and PCF supporting capability. 2.Tutorial to over 200 suppliers	6 months
Process-Oriented	Tsingtao Brewery	1. The CEO declare the carbon issue management as one of the top priorities of the company--as 'Carbon Asset'. 2.Its products are exported to UK that are much concerned about the PCF	Manufacturing Management, Logistics, purchase	A team of 6 people under the Energy & Carbon Division of Manufacturing Department is assigned.	A Taiwan Consulting firm--ESTC assist the PCF	Template from ESTC company	Progress record template imported from ESTC consultancy	Follow PAS2050 guideline	1.CEO 2.The head of the manufacturing department 3.The GMs of Plants are directly responsible for the carbon performance of the plant, and it is one of the assessment factors, together with quality and cost	Steered by the manufacturing management department, which is the core one in Tsingtao	An operating group consists of two carbon specialist, one senior manager in Environmental Affair Department at headquarter.	6 months

Market-Oriented	**Acer**	At 2008 the sustainability office was set up directly under manage of CEO.	Manufacturing, Marketing, Logistics, Procumbent (Suppliers), R&D, Product Quality Certification	The steering team is under the risk management department	1.Work with WCBSD supplier workshop; 2.Industrial Development Bureau provided training; 3. Work with SGS consultant to conduct audit to suppliers in mainland China	Life Cycle Inventory Tool developed by TEEMA (Taiwan Electrical & Electronic Manufacturer's Association)	Product Category Rules	Stated in previous section	1.CEO 2.Sustainability Office under the Board	Product Quality Certification Department, ISO team in all branches	A specific team of 7 people for PCF	2-3 months
	BenQ	1. The CEO set up the pressure internally for changing the company to a low carbon mode. 2.a committee of CSR is organized by the General Manager	Marketing, Product Quality Department, Manufacturing--core departments, Logistics, Finance, R&D--non-core departments	A steering team in Product Quality Department. The team members have extensive experience in the product environmental declaration	The Taiwan Government Department of Economic Development set up a consultant project to tutor companies on product carbon footprinting in 2009. 8 consultants from the related Bureau of Industry are sent by the bureau as part of the project.	1. Using the eco-LCA software-SIMAPRO, and ECOEVENT for the source of emission factors. 2.The Taiwan EPA provided a template for data collection	Set up BenQ's own data pool for the continuous improvement	1. Supervised by IDB Taiwan, so the process is following the PAS2050 guidance. 2.The main bulk of the work comes from the data collection from suppliers	1. The General Manager will review the project progress. 2.CSR committee headed by the GM	Product Certification Team was with the Product quality control centre	There are project manager in each product lines who assisted the process.*Other business unit such as logistics provided data.	The first product lasts for 9 month, the second product for 6 month, and expected to be 2-3 months after gaining these experiences.
	AUO	1.Starting from the CEO requirement 2.Environmental Product Declaration has been conducted in 2007	Procurement department, internal production plant management, logistics department, product R&D	The steering team is operated under the Risk, Environment & Safety Department (RES)	AUO conducted the PCF by its own personnel	1.Developed a communication tool to collect data from suppliers--'Green Parts Aggregations & Reporting System' 2.Software SIMAPRO is applied	NA	1.Follow PAS2050 guideline Cradle to Grave analysis	1. Coordinated by senior managers from relevant departments. These managers monthly reported the progress of PCF project. And they reported the overall 'Green' progress to general manager every season and yearly.	Supported by representatives and managers from different business functions	The special PCF team is set up in the RES department. The team divided into 7 mini-groups to cover different aspects: R&D, procurement, manufacturing, logistics, recycling, low-carbon-experience sharing (to suppliers and downstream customers), and 'Green DNA' for low-carbon education to internal business functions	6 months
	Tungho Steel	1.Introduce the PCF program from Taiwan Bureau of Industry Development product carbon footprinting program directly to general manager	Production, product R&D, procurement department plays the key role which helps to communicate with suppliers to collect data	The PCF team is under the production plant department	Work with Taiwan technology university. The result is verified by Taiwan BV company	The footprint tool--'DoitPro' developed by Taiwan Bureau of Industry Development	Supported by Taiwan technology university	1.PAS2050 is applied to guide PCF process 2.The most difficult part of PCF was the data collection from suppliers (10 suppliers are involved in the project) due to their resistance to share information	1.The general manager was promoting the project 2.The head of production was supporting the project	Representatives in all related business functions, and especially the procurement department	The project was mainly operated by the PCF team under production department and external consultancy team from Taiwan technology university	7 months
	British Sugar	Corporate Culture for sustainability	Multiple Production Site, Logistics from farmers to plant	The managing staff in the PCF project is technical engineer of British Sugar CHP system.	North Energy Consulting services	No tool to support as the first a few companies to practice PAS2050	NA	Stated in previous section	N/A	Multiple departments attended	Experts in the plant's energy system	9 months

Point of Entry

In some 'Pilot-oriented' type cases, the focal firm conducted the PCF process purely on its software, so the support from the management level was not much needed. The motivation to conduct PCF usually comes from the request of customers. However, for the 'Process-oriented' and 'Market-oriented' type PCF, the acknowledgement and commitment from top-level management is critical because to complete needed to be involved nearly all business units. It is found in the cases that rather than being persuaded, that the senior management level has proactively triggered the PCF project. In some cases, the PCF team in a focal firm is formed under the green-related committee. This committee usually consists of executive level officers in different business units and the committee holds a regular meeting to steer green-issue-related developments. This type of organizational structure can ensure that the low-carbon issue will gain sufficient attention from the management level.

Participation

The participants of the PCF project include nearly all the business functions within the focal firm. This is because the PCF process aims to measure all of the whole life cycle of product, from raw material to end-of-use. All the departments that link to the product manufacturing, therefore, contribute to the PCF project by collecting the data which is required for the PCF calculation. These departments include procurement, production, product R&D, EHS (Environment, Health & Safety), and logistics. Marketing and customer-service-related departments are not directly related to the PCF process, but they sense the customer's requirement for information and request a carbon footprint disclosure, so they can feedback the result to customers afterwards. So a successful PCF project should ensure all the participation and engagement of the relevant departments. The PCF team should regularly communicate with these departments regularly and ensure that they understand the importance of the PCF data.

It is shown that the PCF team can be set up under different departments. According to Platts' model, the 'depth' dimension of participating requires that the best appropriated knowledge should be applied to the project. To comply with this rule, the PCF team should be led by the internal expert who knows PCF practices, otherwise the person who has the best knowledge on the hot-spot section of the product's life cycle emission should be consulted. In general, an expert in a product-related department—such as product certificate and product quality, can be a suitable option for this PCF task. For the products with heavy production conducted within the focal firm's own plant, production experts are also a reasonable choice. For the products with significant amount of emission from upstream suppliers, the PCF team can also be located under the environmental affair department or procurement because the PCF process is linked with other supply chain environmental improvement programs.

External experts are especially important in the PCF process because the PCF is new to most of the corporate, even for those large MNCs. The focal firm may rely on external consultants to teach carbon-footprint-related knowledge, standards, legislations, and offer their experience in conducting PCF projects. These external experts can be professional consultants, government bodies, and research institutions.

Procedure

Because most of the case company took PAS2050 as the guideline, then most of the procedure is already set. For the 'Pilot-oriented' type PCF, the streamlined LCA is used so only the key steps of a product life cycle is calculated. Popular LCA software such as Gabi and SIMAPRO are applied in most of the case companies to provide an electronic platform to handle primary & secondary data, and speed the footprint calculation action. External consultants bring in special tools to assist the PCF process, especially with industry-specific knowledge and data. One example is the Life Cycle Inventory Tool developed by Taiwan Electrical & Electronic Manufacturers' Association, which contains local transportation emission factors and electronic-manufacturer-specific production activities. An action plan set up at the very beginning of the PCF process can improve the efficiency and assure that project goals are achieved at the end.

Project & Process Management

The managing, supporting and operating resources are the key to PCF process. Support from a senior management group play a significant role in the project progress and communication between the PCF team and its relevant business units. With regular examination from top-managers in each of the departments, both the data collection process and data quality are assured.

The supporting group consists of representatives from different business units. Experienced engineers with practical LCA knowledge offer strong support to the project, but usually this role is filled by external consultants or experts, instead of an internal employee. Only a few companies have prepared their workforce with expertise in low-carbon issues. In this case, these employees usually act as the main officer who steers the holistic PCF project with his/her assistant team. The operating group are the people who do the real work: collecting and analysing the data, assessing the requirements, etc. These tasks are operated by the PCF team members under the supervision of external consultants or the internal 'facilitator' mentioned above.

Timescale for first-time PCF is usually 6-8 months due to inexperience. It can be greatly shortened by mounting the learning curve after several PCF projects. Also, establishing a regular data collection procedure can highly speed up the PCF process.

Figure 5.9 gives out a summary of PCF process.

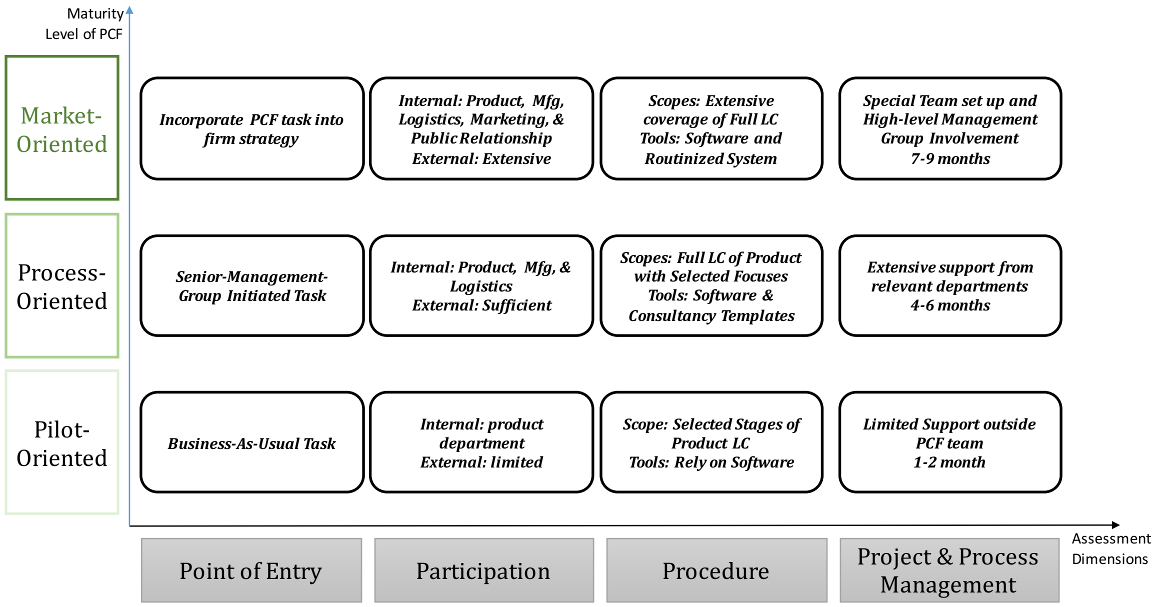


Figure 5.9. 4P model assessment to PCF process

5.3.3 PCF in Assembly-Oriented Industry and Process-Oriented Industry

From the cases above the differences can be found between the assembly-oriented industry and process-oriented industry which is mainly in the focus of the data collection part.

Assembly Type—Supply Chain Engagement

The examples of assembly industry are the Electronic Manufacturing and Automobile industries. Due to the large amount of components and their embedded carbon footprint, the PCF of the assembly industry is focused on getting the accurate footprint data from the suppliers. These data include the BOM of components that are imported to suppliers, and primary activity data of production and transportation in the suppliers' plants. As the case of Dell shows, the emission from the production of components is second or equal to the user phase, which are the Top 2 portions of the total life cycle emissions. Adding the fact that the number of components is a big figure, more time and effort may need to be spent on the upstream of the supply chain, in this assembly-type industry.

As the carbon footprinting is the new issue in supply chain management, and new to most of the suppliers as well, then awareness cultivation, engagement and carbon audit capability development become the key focus. And these are all related to the data quality provided by suppliers.

Cases of Acer, AUO, BenQ and Lenovo all show significant effort devoted to the supplier capability development. In the framework we proposed, a general meeting with suppliers, which is usually combined with the yearly supplier conference, should be organized to raise their awareness to the carbon issue. At the same time, the first training section provides suppliers with basic concepts and an auditing requirement. For the suppliers, the ISO14064 standard can gives sufficient preparation for the carbon footprinting. After sending out data collection templates to suppliers, a second training section should be conducted in order to counsel suppliers to fill in template forms. The Taiwan Industrial Development Bureau (IDB) program gives a good example of engaging suppliers for PCF—tutorial workshop with focal firm and its key suppliers attending side by side. So the instant interaction between a focal firm PCF team and suppliers enables there to be a high-quality-communication between them. After the second training, suppliers should be clear about the requirement for data collection templates, and return the data to the focal firm's PCF team. One to two site-visits should be implemented for two purposes: first, to advise the suppliers on how to collect data, in case suppliers return low-quality activity data; second, to give a review and verification on the suppliers' data collection practices to ensure that data is valid.

Process Type—Internal Production

Examples of a process-oriented industry are food & beverage manufacturing, steel, and chemical manufacturers. Compared to assembly type industry, process type manufacturers have a much smaller number of raw material suppliers, either by its types of raw material or by the numbers of suppliers for each material. For the steel industry, the key suppliers, who are ore suppliers , are usually only a handful. Also, instead of spending a huge amount of time engaging suppliers, there is a much more complicated internal production process for these process type manufacturers.

Training for internal department staff is especially necessary in order to obtain accurate primary activity data. Primary activity data from energy and material is easy to obtain for firms that have regular auditing practices. The time and effort consuming task comes from the allocation of activity data due to the complicated production processes. The common allocation bases include economic value, weight, unit, workforce (per head times hour), etc. The carbon footprint of semi-products, such as Beer in the Tsingtao case, can be allocated according to different bases along the production flow. This allocation principle is usually discussed between the PCF team and its external consultants.

Considering more special aspects in the footprint calculation is another issue that assembly-type manufacturers do not usually need to be concerned about. Issues such as land use change, internal renewable energy use, electricity exported to grid, are within the consideration of the PCF team in process-type manufacturers, because the focal firm's plant has implemented a CHP system, and in the food & beverage industry focal firms have agriculture-related activities directly in their product life cycles.

But the basic principles and PCF processes in PAS2050 are applicable to both of the two-types of manufacturers.

5.3.4 Capability, Supporting Resources and Routinization of PCF process

Capability

As discussed above, the ability to efficiently engage suppliers and develop supplier's capability on carbon emission measurement is key to successful high-quality data collection. PAS2050 does not mentioned the practical protocol of supplier engagement, the case data gives out an initial framework as it is presented earlier: Involved is an awareness raising meeting, first training workshop, second training work after initial data collection, and the 2-3 site visits to key suppliers.

The corporate-level carbon emission measurement can help both the focal firm and suppliers in the PCF, to prepare the primary activity data. But more importantly, the principles for carbon emission measurement at the corporate-level and product-level are similar. The capabilities developed in the previous green practices can contribute to the PCF.

In previous research, Gottschick has developed a material flow analysis (MFA) model for the visualization and communication of the aforementioned issues across the process chain. He concluded that this model could support ***organizational learning*** that is necessary for the required cooperation of the relevant actors involved. Similarly, PCF processes also support the organizational learning within focal firms and their suppliers.

Supporting System

It has been proven that the support and commitment from top-level management play a critical role in the above cases. With the senior management commitment, the PCF team can have the access to required data and supports with relative ease. Also the general culture in the focal firm helps to fullfil carbon-related commitments, with better support from its multiple departments.

For the external supports to focal firms, Jensen stated that without the external consultants, the LCA will probably be stopped due to the limited internal knowledge within the organization (Jensen, 2010).

On the other hand, the cooperation with a branch institute of an external business association could provide the firms opportunities to develop structures for LCA activities and monitor/compare their own activities against other organizations. The business association provides a platform for firms to compare with each other (Baumann, 2000). In the above cases a business association does play in an important role in sharing information, knowledge, and practices among members.

Routinization of PCF

In the previous research on institutionalization theory, it has been shown that the higher the cost of the investment, the higher is the possibility that the LCA practices will not be abandoned due to investment. Time and resources consuming the PCF also falls into this category. As Tolbert and Zucker (1996) have described a model for the institutionalization process stages: Innovation, Habitualisation, Objectification, and Sedimentation. After the first-time PCF is conducted, the routinization process of PCF starts.

In the sedimentation stage, the PCF activities have survived across the generalization of organizational members since the idea of PCF has been regarded as granted through the organization. And the organizational structures change emerges, from the informal PCF teams in the organization to an official PCF committees/groups and appointment of a specialist, with specific responsibility working towards integrating PCF into general environmental management and business processes. The experts/trained staff in the specific PCF team try to develop strategies to make PCF a part of the normal activities in the company. This is also the Normalization process of other green practices.

This routinization/standardization process is expected to end with more consistency in the use of simplified or IT-supported PCF. However, for the large companies, with diverse product groups, the PCF will continuously provide new insight.

5.3.5 Network-Level Carbon Emission Assessment

As corporates are expected to control their carbon emission in a more and more boarder scope, therefore, standards of carbon emission have been set up in multiple boundaries. Starting from the corporate-level carbon footprint, such as ISO14064, firms measure the carbon emission within their own operating scope. Product Carbon Footprinting (PCF) expands the scope to the supply chain. On the product level, some firms that conduct PCF only use the secondary activity data. Then some proactive firms measure their own primary activity data, but only within the scope of their plants. Furthermore, proactive firms consider the primary activity data in their suppliers and downstream supply chain partners. Under this scope, the emission of a firm's supply network is already captured. But it is expected in the coming future that in order to further reduce carbon emission, an even boarder scope of carbon emission in the supply network should be measured, including:

1. Regional Supply Network Emission Assessment—to measure the carbon emission in a local region of multiple firms, especially with industrial symbiosis practices;

2. Linked Industry Supply Network Emission Assessment—to measure the total emission of upstream and downstream supply chain partners and focal firm together, because optimization of one focal firm may not be the most optimized result for the network as a whole.

5.3.6 Implications

Implication to SCM

PCF has significant implication to the focal firm supply chain management. Obviously, as the importance of environmental performance in supply chains increases, it will affect the practice in supply chains. The PCF is the typical tool/activity to links the improvement of both the focal firm and its supply chain.

With the should high consistency in secondary data, the focal company would have to prioritize the use of primary data from suppliers to differentiate themselves from competitors. The challenge would be to make suppliers perform better than the secondary data sources and substitute these with more competitive primary data, thereby going beyond compliance with the requirements of the current standards. Then the overall green performance in the industry is improved gradually.

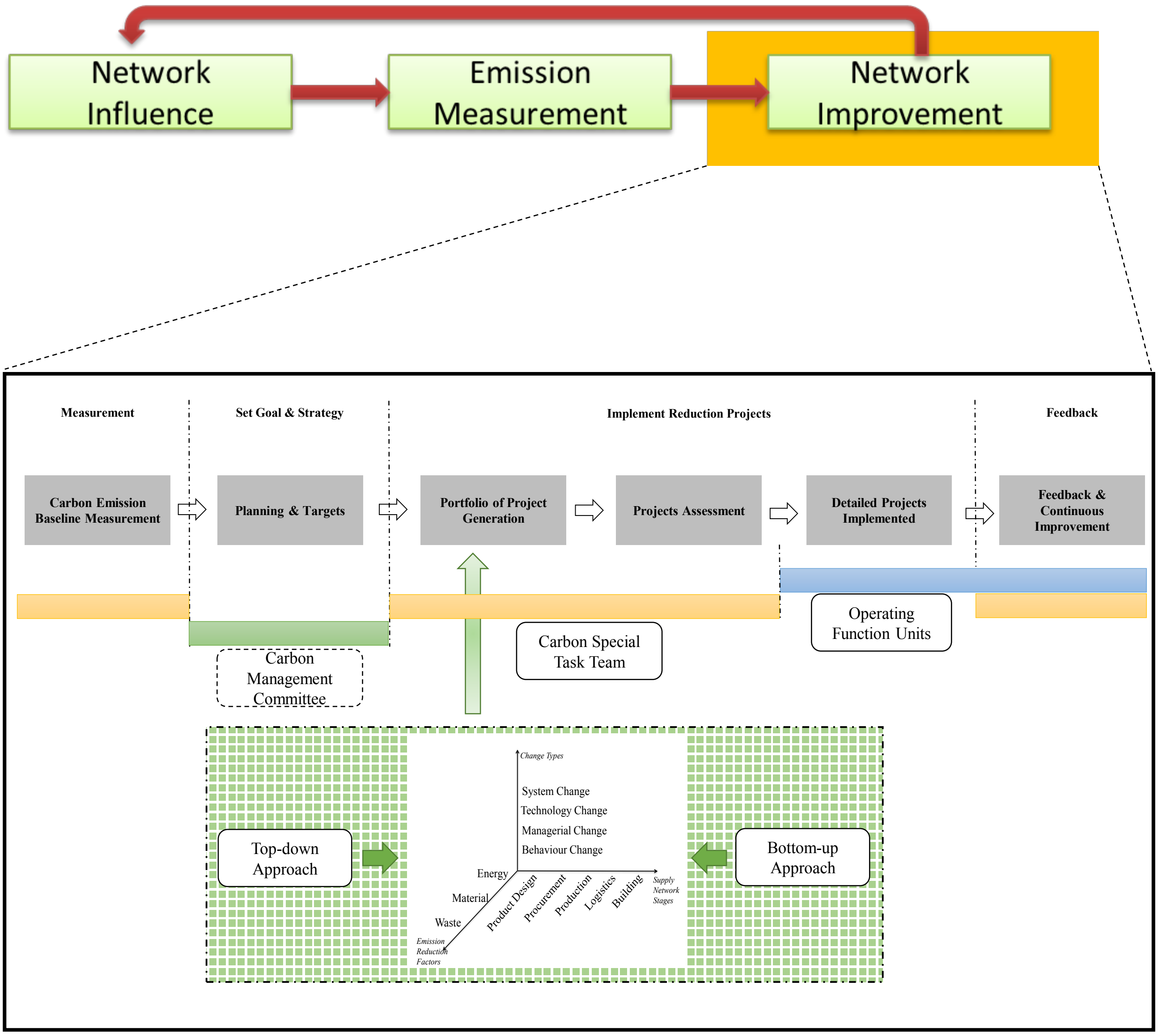
Implication to Life Cycle Assessment (LCA)

Some researcher argued that the current standards are similar and redundant since the LCA standard already fulfils the purpose of PCF (Weidema,2008 Schmidt,2009), some believes that different standards could co-exist due to the broader focus in LCA compared to PCF, and a more stringent method based on current progress should be encouraged (Jensen,2009; Weidema,2008). But still PCF brings LCA back to the focus arena of green supply chain management, due to the practical pressure in business and society.

5.4 Chapter Summary

In the IMI model, after the focal companies are influenced to take action in participating carbon issue, the next step is to measure the carbon footprint. Though the PAS2050 provides the protocol for product carbon footprint measurement, the practical working process for PCF still needs developing for businesses who are inexperienced studies carbon issues. In this chapter a new framework for a PCF process is proposed based on the case study. Three types of tailored PCF are summarized, according to the goals of conducting PCF. Process Measurement Model from Platts is applied to analyse PCF process in case companies. Based on the hotspots in the PCF result, focal companies can target carbon reduction focus areas. Further discussion of PCF framework implication to supply chain management and theories are deliberated in Chapter 7.

CHAPTER 6 NETWORK IMPROVEMENT TO REDUCE CARBON EMISSION



6.1 Introduction

After the carbon emission is measured, the next step logically is to look at carbon emission performance. Primary data in cases' improvement practices are presented first, including a summary of practices, idea generation processes and the supporting system to enable creating improvement recommendations. According to the cross-case analysis, an initial framework to classify improvement practices is generated. It is further tested with survey data from CDP Supply Chain Program, which is shown in the second section. Best practices in Automotive, Food & Beverage, Electronic, and Chemical industries are summarized and compared. A practices guideline list is then illustrated as a reference.

Based on analysis shown in the first two sets of data, a framework for the improvement process is then presented, which discusses the various approaches made to generate project ideas and also, which is just as important, the internal organizational supporting system to facilitate these projects.

6.2 Carbon Emission Performance Improvement Practices in Cases

In this section, the practices of case companies will be presented briefly in two parts: the systematic improvement method and the detailed aspects of the improvement. The detailed aspects part provides the analysis base for the improvement framework. This framework will then be summarized and compared with the results from the CDP database in the next section.

6.2.1 Brief of Cases

Lenovo

Lenovo started to tackle the carbon related issue from early 2008. Along with the yearly carbon footprint measurement, Lenovo began to gradually change its own operation and supply chain management practices to reduce emission.

<u>The object & target of carbon emission reduction</u>

Lenovo's milestone of reducing Scope 2 emissions by 13% relative to FY 2009/10 and offsetting or eliminating all Scope 1 emissions was achieved by March 31, 2013.

Lenovo is planning in the 10 year initiative to reduce Scope 2 emissions by 16% and 20%, respectively for FY 2015/16 and FY 2019/20, based on the result of FY 2009/10.

<u>The organizational structure to enable low carbon manufacturing and supply chain</u>

Lenovo's carbon strategy is supported directly at the most senior level the company's chief executive officer (CEO). In August of 2010 , Mr. Yang Yuanqin, who is the CEO of Lenovo, announced the firm's climate change policy. A platform across the whole group was set up to implement this policy, to carry out the carbon improvement practices.

Specially, a vice-president was assigned to be Chief Sustainability Officer, and in Lenovo, the environmental issue is a key part of the officer's duty. Mr. Jianhu Du has held this position since 2007. He is in charge of the overall environmental policy, low carbon policy, and the internal platform for the carbon emission management.

Because the low carbon issue is part of the environmental management, Lenovo built up the environmental-related organizational structure according to the ISO14000 standard. Directly under the management of the Chief Environmental Officer, the Global Environmental Affairs (EA) is the overall platform for the relative issue management. In each of the domestic office, there are coordinators to work with the global EA office. And there are also product design managers, plant managers and each support the department managers who are specialised in environmental issues and who also serves as a coordinator. The EA office acts as a committee and basically is joined virtually with every department and unit.

Idea generation & criteria for decision

The idea generation process of Lenovo can be described as a combination of a bottom-up and top-down approach. The overall target and policy are set by the Global EA office, while the detailed improvement methods are decided by the departments themselves. In the top-down approach, Global EA followed the definition of the GHG protocol and then used it as a reference to determine the aspects of its practice: Scopes of Carbon Emission. Resulting in Scope 1, 2, 3 and the participation in initiatives to engage with external organizations. So the detailed improvement request was passed to the corresponding departments: plant, supply chain, product design, marketing & public relationship, etc..

Overall Lenovo had set up a hierarchy of priority to accomplish these carbon emission reduction projects. This is a three-level hierarchy: the first aims at energy efficiency, the second the use of renewable energy, and finally the purchase of renewable energy credits or carbon offsets.

On the other hand, the improvement ideas are generated first by the managers in departments because they have first-hand experience on what should be put in practice. Over 60 energy efficiency and renewable energy projects were implemented during the years of 2009-2013. The purchase of renewable energy credits and carbon offsets was used to ensure that the reduction goals were met.

Implementation aspects and implementation process

Lenovo has taken advantage of the GHG protocol classification of emission sources—Scope 1, 2, 3 in order to implement its improvement practices. Lenovo targeted the following five aspects:

• Lenovo internal operations and the direct emissions from facilities--Scope 1 emissions

• Energy suppliers and their operational emissions which are attributable to Lenovo's operation activities--Scope 2 emissions

• Supply chain emissions associated with the production and delivery of goods and services to Lenovo--cradle to Lenovo's gate – Scope 3 emissions

• Emissions generated by customers, associated with customers' procurement, use and disposal of Lenovo products--Lenovo's gate to grave – Scope 3 emissions

• Cooperate with government, NGO, and society in the support actions of a transition to a low carbon economy---broad scope of low carbon manufacturing system.

The initial carbon reduction framework which is developed from literature shown in Chapter 2.3.4 is used to classify Lenovo's practices. For each category, the practices are further analysed and tagged with themes.

Table 6.1. Lenovo Carbon Emission Reduction Projects Summary

Aspects	Reduction Projects Details	Themes
Product Design	• Reuse of material in end-of-life products (Lenovo avoided in FY 2012/13 more than 27,050 MT CO2e thanks to recycling end-of-life electronic products. (This result is calculated according to the US EPA Waste Reduction Model) • Packaging -Lighter and smaller products -minimize the use of packaging material consumption per box -more compact and reusable packaging materials • Energy Efficient/Low Carbon Products -product design to generate less carbon emission of product in the customer user phrase	-Reuse waste -Packaging Material usage -Energy efficiency in user phrase
Procurement	• Supply Chain/Supplier Management -Lenovo engage Top Tier 1 suppliers into Carbon/Water Reporting Tools Coalition (Electronics Industry Citizenship Coalition carbon/water reporting tool, online platform from 2013) -Lenovo plans to add an evaluation of potential supplier climate change performance and strategy, as a differentiator in the procurement process. -Lenovo meets annually with its primary suppliers to share low carbon views and requirements. (Lenovo held a "Lenovo Environmental Affairs and Specifications Communication" conference for over 500 suppliers in Beijing, Shanghai and Shenzhen, China in October 2012, to engage suppliers and share Lenovo's requests on green product design, product carbon footprinting)	-Change of managerial requirement in its procurement
Production	• Manufacturing/Production -Area optimization-integrating and modifying assembly lines, -Reducing PC on-line testing time -Consolidation of operations -Use local manufacturing facilities in the Americas, Europe and Asia	-Optimize production process in new management way
Logistics	• Inward plant logistics -reduce transportation miles incurred and improve reuse of packaging and shipping materials. -In 2012 Pallet Pooling project: recycle and consumption reduction of wooden pallet recycle -bulk shipping alternatives -Use of low carbon shipping methods via trucks, rails, or sea-flights, instead of air-flight (During 2009, Lenovo shifted 7 percent of notebooks from air transport to ocean transport) -Working closely with its shipping partners to implement fuel efficient shipping standards. -In 2012 Lenovo begins collecting and calculating, or estimating product transportation emissions data via using DHL carbon data dashboard, and other 3 key carries data on shipment, these 4 key carriers represent majority of Lenovo's worldwide global logistics spend. -Regional distribution facilities allow for lighter loads, load consolidation and full-truck-load shipments.	-Material usage reduce -Reuse and recycle -new managerial tactics without using new technology -In pursue of saving fuel to reduce emission
Other	• Plant Environment -Installation of low energy lighting and related electrical equipment, -Energy efficiency improvements to HVAC system and chillers, -Eliminating or improving usage of transformers and air compressors • Behaviour Change in Plants -Building management adjustments that turn lights/HVAC on later in morning and off earlier in the afternoon -Signs/training for turning lights, laptops off • Behaviour Change in Office -Reduction in the number of company operated vehicles -Summer Hours program -LEED Commercial Interiors Gold Certification for a new office in Milan, Italy -ENERGY STAR® certification for Morrisville, NC buildings • Industry Specific (Data centres) -Improving data centres energy efficiency • Measurement to the Product Carbon Footprint	-Change equipment and lighting with new technology - Energy saving in plant building and office building -Individual employee behaviour change
Energy	• Renewable Energy---Scope 2 -Hot water solar system was implemented on some buildings in Chinese facilities -solar lamps were installed for parking lot lights in Beijing -Lenovo installed solar panel arrays at the manufacturing site in Shanghai in 2012. It could save around 10-15% of site's annual electricity consumption and reducing GHG emissions by more than 400 MT CO_2e yearly. • Purchase of renewable energy externally -Purchase of carbon credits, from Climate Action with a little over 5,450 carbon offsets from a renewable energy – biomass waste to energy	-Substitute energy source—renewable energy -Enabled by new technology -Applied to production site and buildings
External Network	• External Engagement for the low carbon economy transition -Lenovo participated in the Catalyzing Corporate Supply Chain Carbon Footprint Reporting in China's Export Industries project and has been engaged with the World Bank in their project named 'Spontaneous Promoting Green Travel' promoting more environmentally friendly employees' commuting practices. --Involved in the CDP Investor project and supply chain project	-Building a general network to work on emission reduction -Indirect emission reduction practice

From the summary of Lenovo's practices shown, several themes emerge for the supply chain stages: energy efficiency and new energy source, material usage reduction (by enhancing material usage efficiency) and the use of new material (substituted material), the reuse and recycling of products/components (waste management), changes in employee individual behaviours, changes in the managerial process of operations, changes in using new technology, etc. It can be observed that these themes continue in the reduction practices of other case companies.

It can be shown that the cooperation with external organizations on carbon footprint measurement and reporting does not directly improve a company's carbon performance, but its enables knowledge transfer and a potential system-level improvement practice for the future, such as low carbon industrial park.

Supporting capability and tools

All departments within the Lenovo groups are engaged to support the-above-mentioned projects, as well as all the coordinators.

External consultancy is rarely consulted due to confidential reasons. But there can be seen a lot of the co-operation with the NGO, Government Bureaus, International Organizations, and Academic institutions, providing rich resources on technology and knowledge on the carbon issue.

Progress towards accomplishing these objects and targets are tracked on a quarterly basis and reported to senior management every six months.

The procedure showing Lenovo's reduction process is shown in the Figure 6.1.

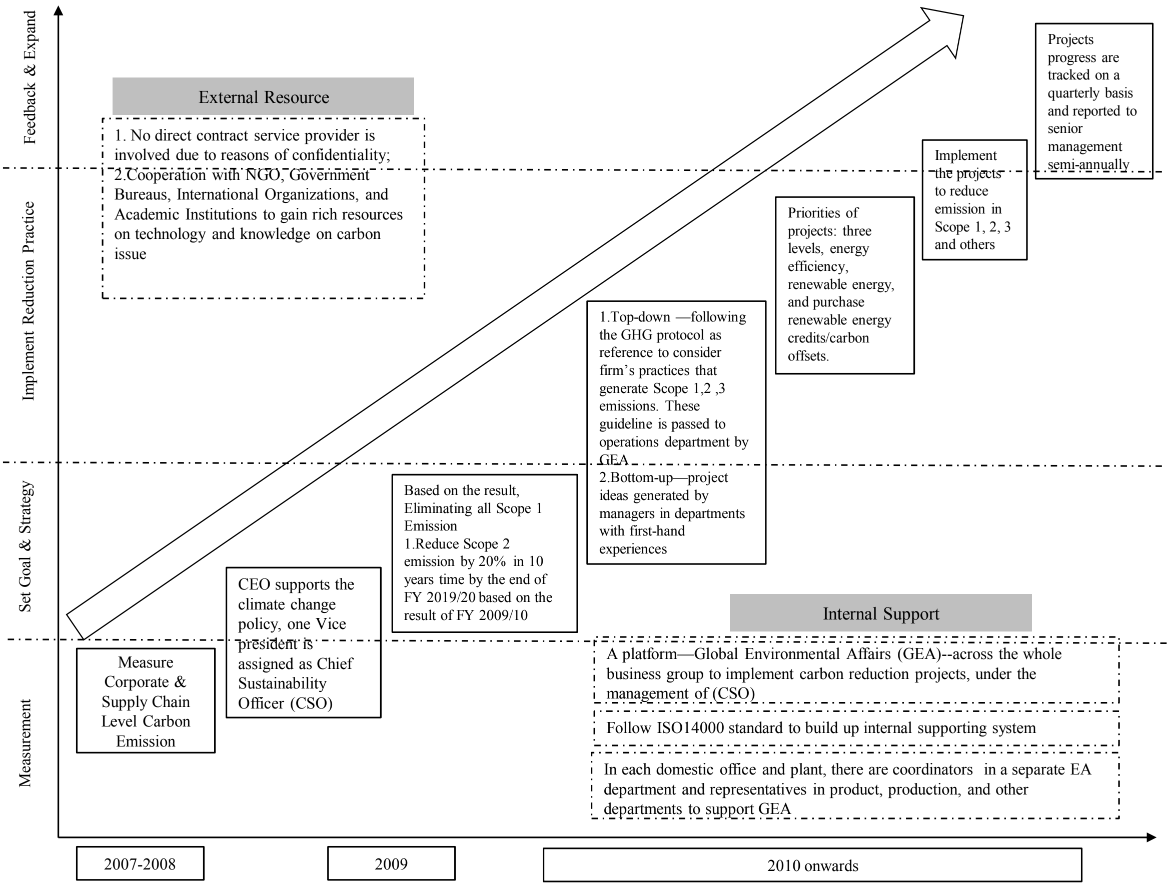


Figure 6.1. Lenovo Carbon Reduction Projects Implementation Process

Tsingtao Brewery

The object and target of carbon emission reduction

Tsingtao Brewery has set the utilization of waste as resources as the priority of the company's environmental management strategy.

For carbon footprint reduction, Tsingtao sets up the target in 2014 that its CO_2 emissions per unit product in the manufacturing process will drop by more than 15%。

The organizational structure to enable low carbon manufacturing and supply chain

The low carbon issue is managed in the Tsingtao brewery under the manufacturing department where a special team was set up named the "Tsingtao brewery carbon management team". This team is responsible for determining their carbon management strategy, targets, action plan, monitoring, and also evaluating the carbon management projects.

The standardized model is devised by the manufacturing department and popularized to all the brewery factories across the country. A Balanced Score Card (BSC) workshop training was applied to ensure the implementation of these projects, and especially carbon specialist roles were set up. There are 6 specialists in the manufacturing department headquarters, and in each brewery factory there is an extra specialist for the project coordination. The carbon specialist is regarded as a special technician, and a competitive evaluation system is also applied to this type of position, the same as for other highly specialized engineers/technicians.

The detailed management practices include:

-Improve the organizational structure of environmental management

-It is specified that the general manager was the first person responsible for the factories' environmental-protection management; every level of these environmental officers have to communicate with the general managers on a regular basis.

-Set up detailed evaluation system for environmental management,

-Apply the EMS system to the factories. By the end of 2011, 37 factories passed the environmental management system certification, and all the factories have to pass the EMS certificates in 5 years.

-Organizing environmental protection training. In 2011, 6 sessions of environmental-protection management training was held, and the trainees totalled 660.

-Green investment. A special fund of RMB 24.2 million is invested in upgrading, renovation and maintenance of environmental-protection facilities

Idea generation and criteria for decision

It should be mentioned that the awareness of carbon/energy management is spread from the senior level to all levels of staff. So the low carbon culture has been cultivated within Tsingtao, which greatly stimulates the low-carbon idea generation process, self-consciously. Most of Tsingtao's improvement practices ideas come from the plant-level workers, engineers and technicians. There is a special policy to encourage the generation and implementation of these innovative ideas: every half year, staff in all levels are encouraged to submit new methods on boosting energy & resources efficiency as a competition. These proposals are rewarded with economic benefits. And the criteria for evaluating these proposals include 5 aspects:

1. Innovativeness---whether the proposal is the first of its kind in different levels: brewery factory, company (Tsingtao), or sector level (beer brewery industry);

2. Feasibility & complexity--whether the proposal is feasible, and easy to implement

3. CO2 Reduction Potential--how much carbon emission/energy can be reduced

4. Economic Return--whether the proposal can bring in economic saving

5. Cost--the cost to implement the proposal.

A committee is set up for reviewing these proposals twice a year.

<u>Implementation aspects and implementation process</u>

Since Tsingtao Brewery has a lot of production processes to conduct within the scope of its plants, the carbon emission improvement projects are therefore focused on the production part. Until 2011 Tsingtao had implemented 51 projects in their factories for the saving of energy, boosting energy efficiency, waste gas control, material usage efficiency, etc. Re-utilization of its energy and materials waste is the main theme of Tsingtao's carbon reduction action.

Table 6.2. Tsingtao Brewery Carbon Emission Reduction Projects Summary

Aspects	Reduction Projects Details	Themes
Production	• Energy Efficiency --Heat-wave boiling technology for boiling wort liquid(14 factories) --Boiler operation control --Boiler stratified combustion transformation(35 factories) --Step-down operation of air compression system (45 factories) --Cascaded refrigeration • Energy Reuse --Stream heat recovery to energize cooling system --Heat recovery in mashing process (21 factories) --waste-heat recovery • Material Reuse --In 2011, the company's recycling rate of distiller's grains, waste yeast, malt culms, and waste wrap page reached 100% (shown in Figure 6.X.)	-Energy focus -New technology to enable saving energy -Managerial change in manufacturing process -Reuse of energy as a valuable waste -Innovative technology to reuse waste heat -Waste recycle
Innovative / Fundamental solution	Emissions Utilization --CO2 recovery and reuse in bottling process(51 factories), and 101 thousand Metric tons of CO_2 is retrieved annually, 11 out of these 55 factories do not need to purchase CO_2 from external sources. By means of improving the operation management and timing advance of CO_2 recovery, the CO_2 recovery per kl of cold wort liquid in 2011 increased by 6.70% compared with 2010. Plant Design --For the construction of new plants or the reconfiguration of the old plants, the location of energy facility and the plant infrastructure setting will be redesigned to save energy/stream.	-Innovative technology to reduce emission directly -Systematic change of infrastructure setting
Energy	Renewable Energy Usage --Solar Panel Street Lamp	-Renewable energy use

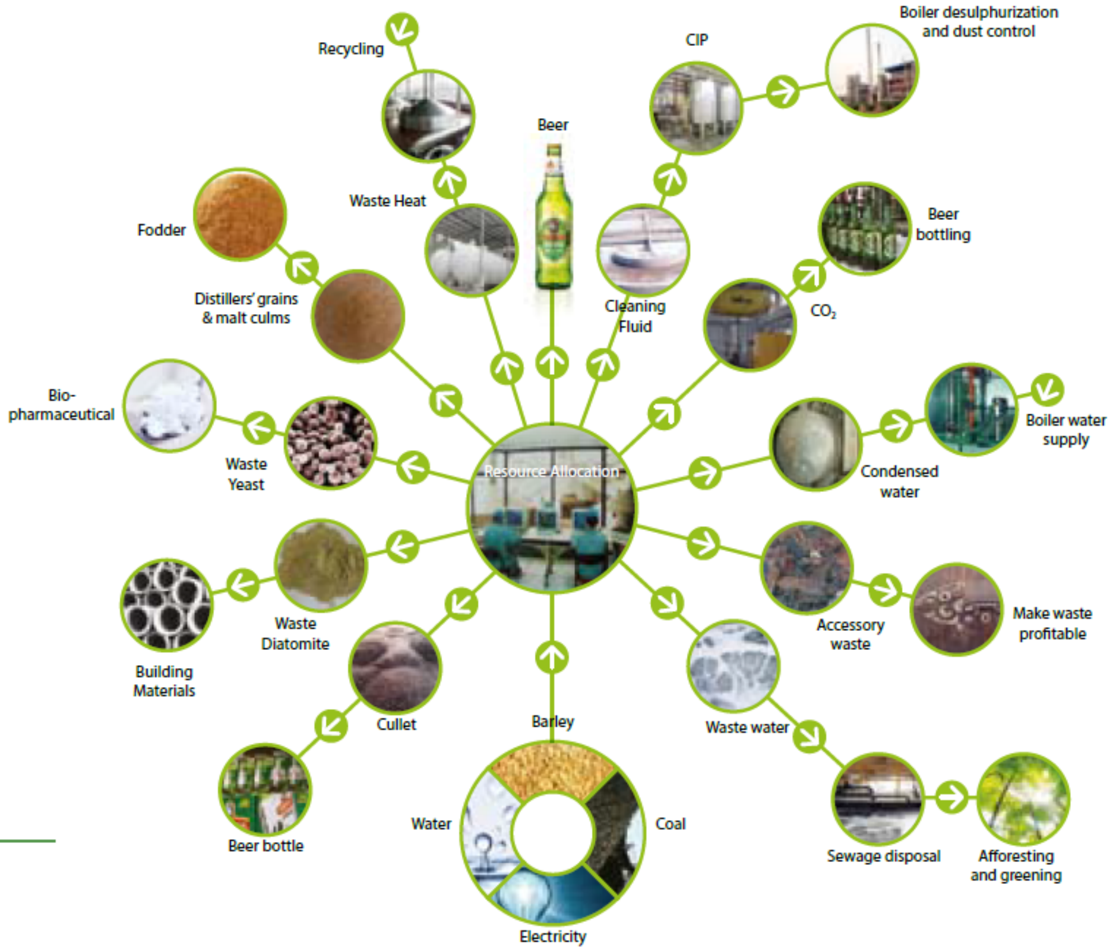


Figure 6.2. Tsingtao Brewery Recourse Reuse

Supporting capability and tools

The participation of senior management ensures that sufficient resources are allocated to carbon management projects. The execution of the carbon project is given priority funding, and given more human resources compared to other projects, with the exception of the core manufacturing task. And the carbon specialists are promised a faster-track promotion.

The process of the Tsingtao Brewery Reduction Implementation Process is illustrated in Figure 6.3.

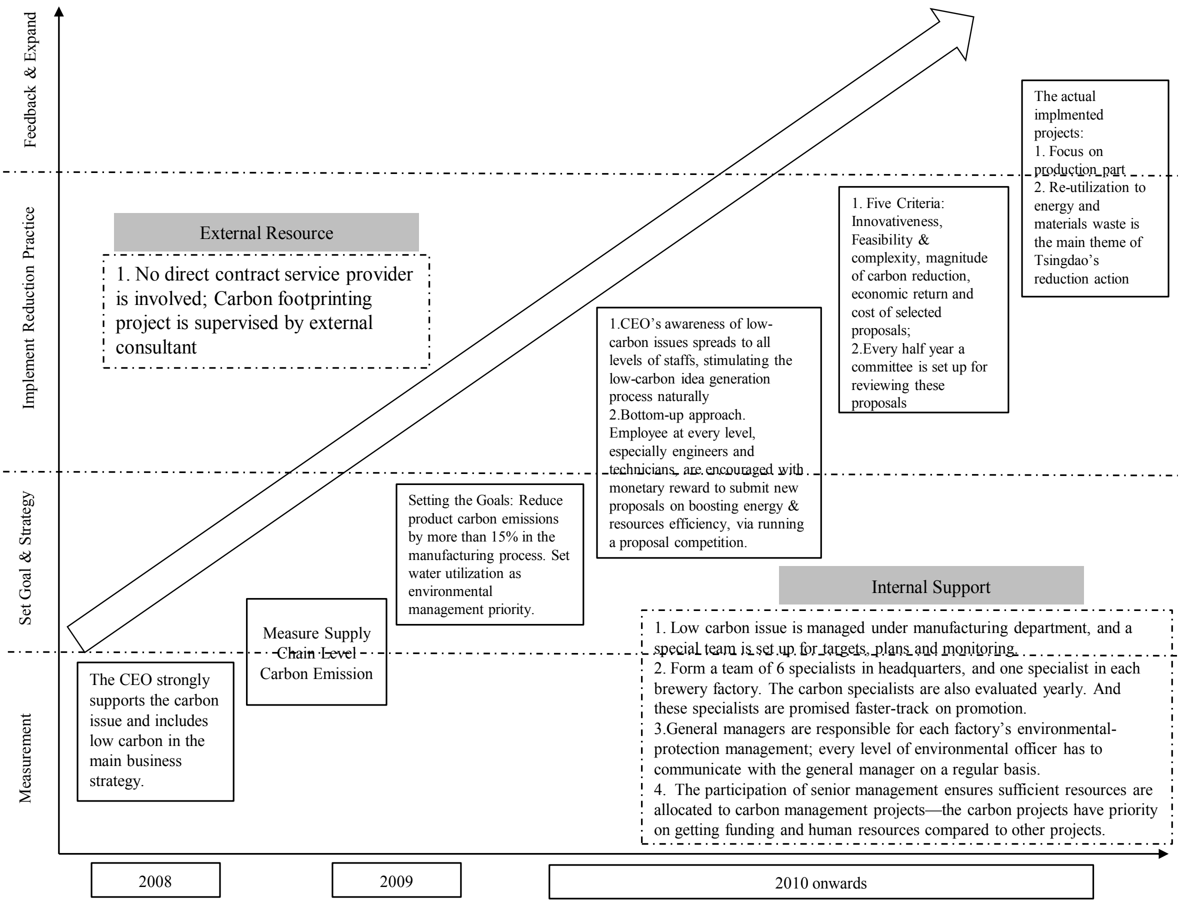


Figure 6.3 Tsingtao Brewery Carbon Reduction Projects Implementation Process

ZTE

The object and target of carbon emission reduction

ZTE does not set up specific targets for GHG emission reduction. Only the aims for reduction is pushed forward.

The organizational structure to enable low carbon manufacturing and supply chain

Starting from 2005, ZTE built up its EHS system following the requirements of ISO14001. From 2007, a special CSR Team was built up to implement the CSR architecture of ZTE. A Vice President was named specially as the representative of the ZTE CSR system. By working with the association Global e-Sustainability Initiative (GESI) and also with NGOs such as Green Touch, ZTE has been able to absorb more information and experience from the members in these associations. In 2012 ZTE conducted a GHG Inventory measurement of 2009-2011, and was accredited by ISO14064-1.

Especially for the carbon issue, ZTE has set up a virtual entity--committee for energy saving and carbon emission reduction. The work task is split into two streams: one for the corporate level improvement and the other for the product level. There are CSR managers in charge of implementing all the projects. Four specialists were allocated equally into the corporate-level team and product-level team.

Idea generation and criteria for decision

The idea generating process of ZTE comes from the principles of Cleaner Production. Cleaner Production is the continuous application of an integrated preventative environmental strategy to processes, products and services to enhance efficiency. The ZTE specialist team firstly went through the cleaner production assessment, which collects the operation data and calculates the material balance of input-and-output activities. According to the un-balance between the material input/output, specialists can think out potential cleaner production options from those unbalanced items (UNEP 2014). Eight potential aspects can be analysed： Resources, Energy, Technology, Equipment, Process Control, Products, Waste, Management and Personnel.

The improvement projects are implemented in various departments, including production technology, packaging, design, etc. Except for the cleaner production suggestions, other improvement ideas in these departments are generated from the line engineers and managers, and these ideas are uploaded and gathered together by the carbon management team. All the carbon reduction methods are categorized into different groups, such as packaging, production, office environment, etc.

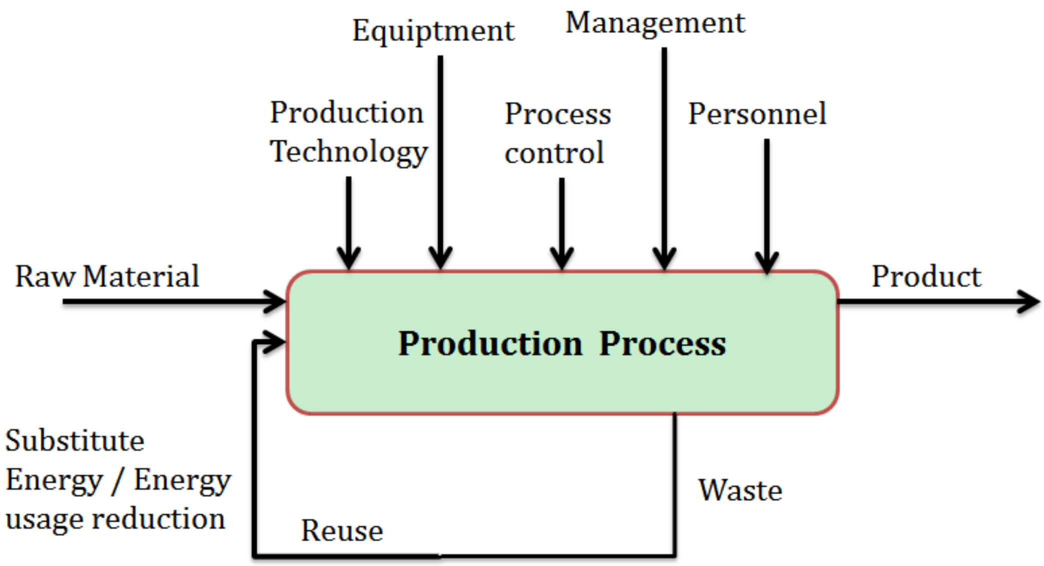


Figure 6.4. Cleaner Production Waste Analysis Aspects

<u>Implementation aspects and implementation process</u>

The energy-efficiency design of a product is the key part of ZTE's effort on carbon emission reduction.

ZTE reduction practices are listed as the Table 6.3.

Table 6.3. ZTE Improvement Practices

Category	Sub-Category	Detailed Practices	Themes
Production	*Facility Improvement*	In 2009, made the air compressors of building B1 and B2 in Xili industrial park to work in frequency conversion operation mode, and changed their networking, and thus saved more energy.	-managerial change under current technology -simple change of current operation -change via current technology -Energy efficiency and saving
		In 2009, optimized the power supply lines, and disabled 13 low-load transformers, totally 17080KVA. Reduced the transformers' self-loss and the power consumption.	
		In 2010, according to the changes of the manufacturing technique, adjusted the temperature of factories from 24 ℃ to 26 ℃, and thus saved energy while satisfying the manufacturing technique requirement.	
		In 2010, A frequency converters was installed for the frequency pumps of all the offices and factories, and saved 20% to 40% electricity.	
		In 2011, changed the ordinary high-temperature room to high temperature cabinet.	
	Equipment Improvement	In 2010, installed a timer for each coil machine in building 3 in Xili industrial park. The 1600 coil machines can shut down automatically when the employees get off work.	-change via automation technology
		In 2011, improved the SMT production line by changing single production line to double production lines.	
	Technology Innovation	In 2010, in the manufacturing process, used the energy feedback energy-saving electronic loads to replace the aged loads, and used the inverter grid to output and feedback the power lost by aged power supplies to the grid for reuse, and thus saved 85% of electricity.	-Reduction enabled by innovative/new technology -Electricity saving therefore energy saving
		In 2011, implemented the project of wave soldering plus nitrogen. Its core idea is using nitrogen to reduce oxidation of the solder, and then the solder joint can be formed more easily due to the inert characteristics of nitrogen. In this way, the solder joint can be formed in an environment of 5 ℃ lower, with the same quality.	
	Building Environment	Air compressor modification	-Plant environment
Office Building	*Facility management*	In 2010, A frequency converter was installed for the air compressor of office building B3 at the headquarters to change it from power frequency operation mode to frequency conversion operation mode, and thus saved more energy.	-Energy saving -Employee behaviour change
	Facility energy efficiency	In 2010, a timer was installed for each new drink machine. Every night from 20:00 pm to 8:00 am the next day (which is 12 hours), the new drink machines will automatically shut down.	
	Lighting improvement	In 2010, installed 50,000 timers for the lights of some office areas in Xili industrial park.	-Enabled by management process change
	Building Equipment	Light Bulbs Changing	-New technology
Renewable Energy	*Solar Power*	In 2011, installed solar photovoltaic power generation equipment on the top of the office and factory buildings at headquarters, and the photovoltaic field area became more than 16,000 square meters. Installed more than 4500 pieces of polycrystalline silicon cell components, thus the total capacity reached 1.27 MWp, and the annual electricity generating capacity reached 1.36 million KWh.	-Renewable energy use -In both office building and production building
		In 2012, installed solar photovoltaic power generation equipment on the top of the office and factory buildings in Xili industrial park, and the photovoltaic field area became more than 23,000 square meters. Installed more than 8880 pieces of polycrystalline silicon cell components, thus the total capacity reached 2.2 MWp, the expected annual electricity generating capacity was 2.4 million KWh, and the actual annual electricity generating capacity was 1.167 million KWh.	
Logistics	*Transportation*	The employee car-pool project	-Change to individual behaviours
Other	*Employee Behaviours*	Behaviours Change: --The Awareness of Staffs' attitude towards carbon issue --Long-distance meeting changed to IT conference meeting	-Change to individual behaviours

Except for operations improvement, ZTE also conducted multiple projects on boosting energy efficiency and recyclable material rates of products, reducing the hazardous materials in products. For recycle, ZTE worked with recycle-service provider in local markets to ensure life cycle tracking until the 'waste stage' of end products.

Supply chain management is a new area of carbon improvement for ZTE. A special team targeting supplier CSR performance was set up in 2012, offering training and workshops from external consultants. Suppliers are also required to build up their own CSR systems. For the selection of new suppliers, CSR system is counted as one portion of evaluation. 60% of new suppliers were conducted on-site CSR auditing in order to make sure the suppliers' green performance.

Supporting capability and tools

ZTE has obtained the LCA carbon analysis software "EMMi" to support product carbon footprinting. But for the improvement, due to business confidential issue, ZTE only relies on internal capacity for evaluating and implementing carbon emission reduction projects.

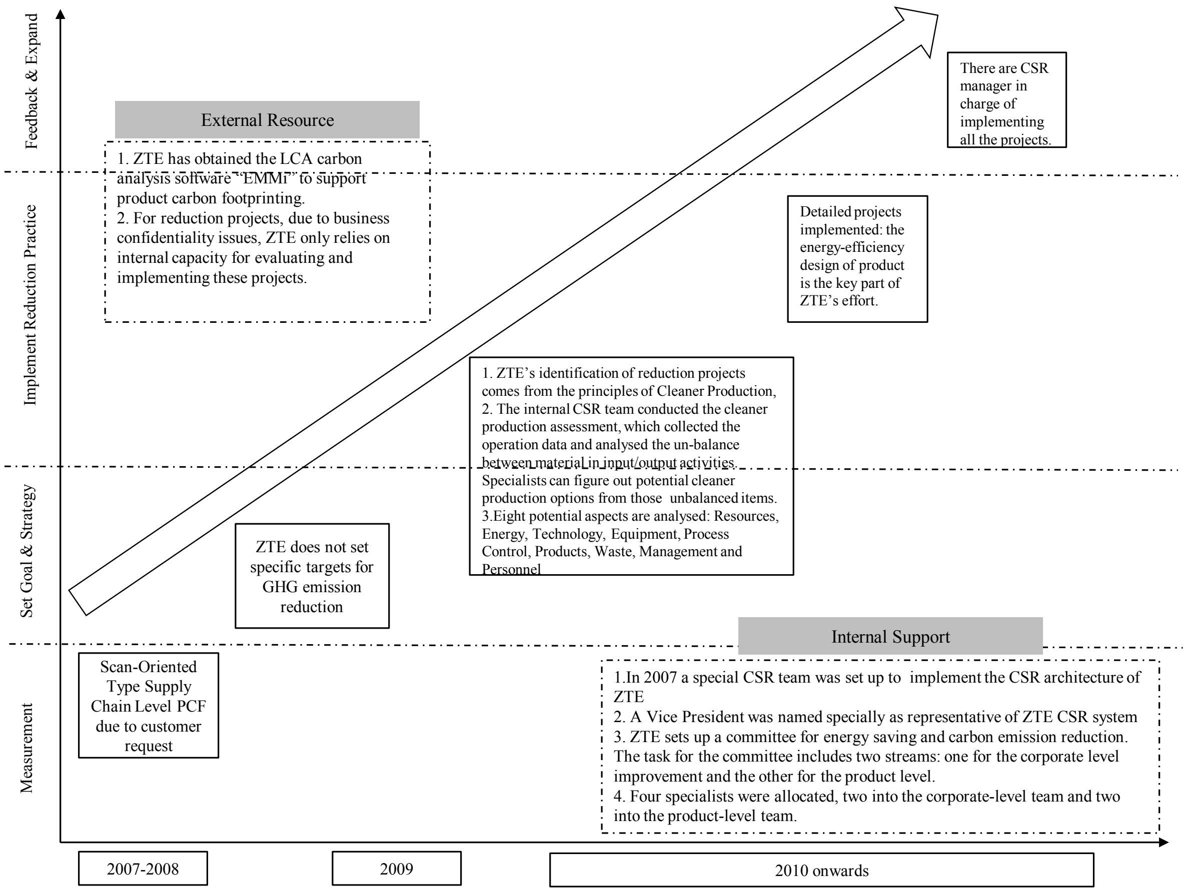


Figure 6.5. ZTE Carbon Reduction Projects Implementation Process

Acer

The object and target of carbon emission reduction

The target of Acer on carbon issue can be split into two parts: for Acer's own operation, carbon emission should be lowered 30% by 2015, as the baseline year is 2009; for the suppliers, yearly reduction is 3%.

The organizational structure to enable low carbon manufacturing and supply chain

Acer sets up environmental management committee to manage the environmental issue as a whole. Directly under this committee a group of 7 people formed the Acer sustainable office, which aimed to coordinate departments and special task groups for the environmental, health and social issues.

Idea generation and criteria for decision

Acer does not rely on the sustainable office to generate carbon emission reduction options. Instead, each department has their own responsibility to generate ideas , according to the overall carbon reduction targets. The environmental-related culture is embedded in the attitude of the staff in each department due to market competition and global consumer trends.

Implementation aspects and implementation process

The improvement of the semi-material supply chain plays a key part in reducing the carbon emission of Acer's operation, because Acer focuses on the product design and marketing, and all the production is outsourced to OEMs.

Targeting the suppliers, in order to help them to achieve carbon reduction goal, Acer requires suppliers to review their carbon performance every month. The review meeting requires suppliers to report not only carbon emission amount and shipment, but also the carbon reduction targets and the results so far. Since all the other suppliers are also present the poor-performers can suffer from peer pressure. And each year Acer has organized a supplier best practices road-show to share experiences.

A lot of Acer's effort has been focused on product design, including the green design of paper and packaging , product recycling, product green design, and disclosure of product environmental information. Taking the packaging as an example, Acer designed to reduce its packaging, resulting in less packaging material and more transportation space for higher transportation efficiency.

In the transportation and production part, a new manufacturing centre was set up in the south-western part of China. So the products for European distribution are now using the railways for logistic rather than the Air flights. Even though the cost of the train is not necessary reduced compared to flight cost, the carbon emission is surely lower.

Table 6.4. Acer Carbon Emission Reduction Projects Summary

Aspects	Reduction Projects Details	Themes
Product Design	• Packaging Reduce -Acer set up a special taskforce in 2003 to reduce the use of materials in packaging. -Maximize the use of eco-friendly paper products, including the use of recycled content, recyclable, and renewable materials -Minimize the consumption of paper products containing virgin wood fibre. • Reduce the paper consumption in user guide by cutting pages, changing to thinner paper and avoid using user manuals. • Use recycled materials to make packaging As to the recycled materials, all notebook packaging external cushions are made of recycled paper material. In 2009, all notebooks packed in reusable bags are made by non-woven fabric. • Recycle of product -Acer modularized its product to be easily upgraded in order to prolong usable lives and are easy to be disassembled to increase efficiency in recycling processes. -products use recycled materials to enable recycle. • Recycled plastics Acer used a 28% post-consumer recycled plastic material in monitor casings Innovation in Energy Efficient and Extension for Battery Life	-Reuse -Packaging -Design to enable better recycle of waste
Procurement	• Supplier Management Acer requires suppliers to review their carbon performance every month. The review meeting requires suppliers to report not only carbon emission amount and shipment, but also the carbon reduction targets & results so far. Since all the other suppliers are also present, so the poor-performers can suffer from peer pressure. And each year Acer organized supplier best practices road-show for experience sharing.	-Carbon reduction in supplier's operations.
Production	• Manufacturing/Production -Area optimization-integrating and modifying assembly lines, -Reducing PC on-line testing time -Consolidation of operations -Use local manufacturing facilities in the Americas, Europe and Asia	-Optimize through managerial change
Logistics	• a new manufacturing centre is set up in the south-western part of China. So the products for European area are now using the railways for logistic rather than the Air flights. •Though logistic devise re-design, each 40-foot container shipment holds 1,848 units, up by a factor of 1.5 from the former capacity of 728 units.	-relocation of operation centre -change in design via current technology
Other	• Plant Environment -Installation of low energy lighting and related electrical equipment, -Energy efficiency improvements to HVAC system and chillers, -Eliminating or improving usage of transformers and air compressors • Behaviour Change in Plants -Building management adjustments that turn lights/HVAC on later in morning and off earlier in the afternoon -Signs/training for turning lights, laptops off • Behaviour Change in Office -Reduction in the number of company operated vehicles -Summer Hours program -LEED Commercial Interiors Gold Certification for a new office in Milan, Italy -ENERGY STAR® certification for Morrisville, NC buildings • Industry Specific (Data centres) -Improving data centres energy efficiency • Measurement to the Product Carbon Footprint • Energy Conservation and Carbon Reduction Measures replaced office lighting equipment with energy-saving lamps as part of our action plan to save energy and reduce carbon emissions. Our statistics show that this alone can save 86,000 kilowatt hours of electricity and thus reduce emissions by 54 tonnes CO2e each year. •Implemented an auto shutdown system of office lights. • Waste Management -Acer Taiwan implements waste management in its office buildings by providing convenient recycling points for our employees so that they can recycle food left over from their meals and separate their refuse into containers for plastics, aseptic containers (Tetra Paks), glass, and metal cans. The 2011 recycling statistics for Xizhi headquarters are as follows: 464 kg of metal cans; 557 kg of PET bottles; 176 kg of aseptic containers; 74 kg of glass bottles; and 4,844 kg of waste food. • Employee Transportation and Commuting Program	-Plant Building improvement for energy efficiency -Behaviour change of employee -Behaviour change to reduce waste

New Energy	•Clean Energy -The first priority of clean energy is to have a green energy initiatives by using renewable energy (RE) in Acer's own facility if the RE condition is available. The second priority is to seek the green electricity in grids and to make advocacy to the governments if there is no green electricity available. The third priority is to seek the suitable regions to build RE facilities worldwide, especially those regions with larger carbon emission by Acer's facilities. The last priority is to procure Renewable Energy Certificates (RECs) or Carbon Credits when the other measures are not available. -Green Energy Initiatives by the Taiwan e-Enabling Data Centre (eDC) The e-Enabling Data Centre (eDC) in Taiwan is the first of Acer operations to install green energy facilities to reduce electricity consumption by 5% within three years. -In 2010 Acer installed a combined photovoltaic and wind power generation system. The wind power portion of this hybrid system had a total power output of 24 kWp (8 units x 3 kW each) in the first stage, which was increased by 30 kWp (6 units x 5 kW each) in the second stage for a total of 14 units, capable of curbing CO_2e emissions by 38,856 kg per year.	-Renewable energy use

Supporting capability and tools

Acer can gain support from external sources including research institute such as Industrial Research Institute of Taiwan, industry association such as Electronic Industry Citizenship Coalition (EICC), consultants, third-party auditors such as SGS consultants for the on-site auditing to suppliers plants, and government organizations such as Taiwan Industrial Developing Bureau special programs.

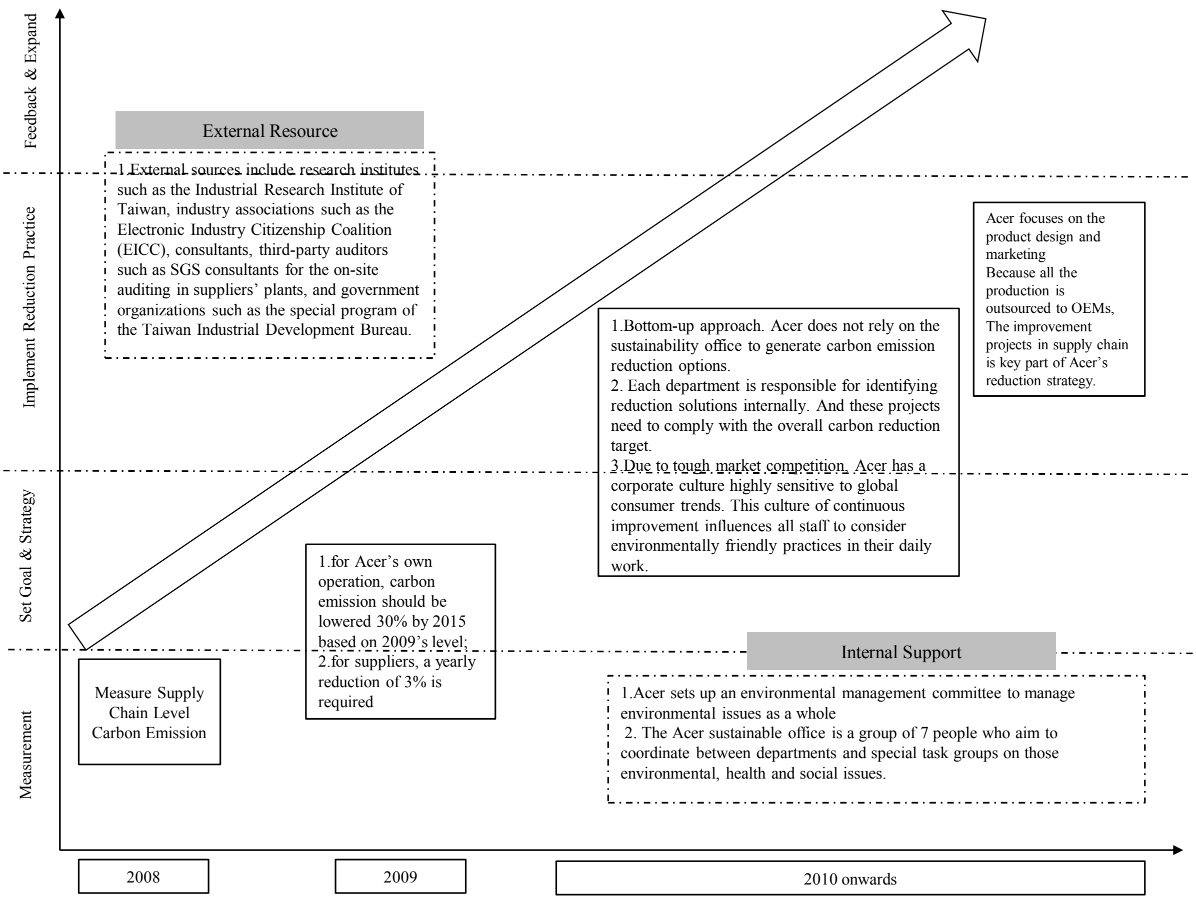


Figure 6.6 Acer Carbon Reduction Projects Implementation Process

TSMC (Appendix I-5)

The object and target of carbon emission reduction

TSMC has set up the following targets of Climate Change management:

- Greenhouse gas PFC reduction: Reduce by 2020 PFC emission intensity to 30% below the year 2010 level through adoption of best practices recognized by the World Semiconductor Council.
- Energy saving: Reduce by 2015 power usage intensity to 2% below the year 2010 level.
- Waste reduction: Achieve 95% waste recycling rate by 2015.

The organizational structure to enable low carbon manufacturing and supply chain

TSMC also forms a special committee to manage the environmental-related issues, and there are several units to implement detailed practices. TSMC's environmental management organization consists of: the central Environmental, Safety & Health Planning unit; the Industrial Safety and Environmental Protection Technical Board; and designated Industrial Safety and Environmental Protection departments in each manufacturing facility.

Idea generation and criteria for decision

All TSMC fabrication plants adopted the ISO 14001 Environmental Management System in early stages of their operation. The model of P-D-C-A (Plan, Do, Check, Action) is followed, together with annual audits and a "Green Award" in Total Quality Excellence (TQE) activities to promote continuous improvement for environmental protection.

First of all, the improvement ideas are managed in a 'Top-Down' method. After the committee determines the carbon emission reduction target, each business department gives out its own individual implementation plans according to the target. Before the plans are reviewed, the Industrial Safety and Environmental Protection Technical Board provide guidelines about the industry requirement in worldwide scope and government regulation. The central Environmental, Safety & Health Planning unit then decides and approves these plans.

Since the environmental issues have long been regarded as important in all TSMC business departments, they already form internal rules about energy efficiency improvement and polluted gas control practices. These experiences and actions can then be transferred under a new requirement—reducing carbon emission.

Each year, the Industrial Safety & Protection Technical Board conducts an internal audit to examine the results of these practices. Except for internal auditing to Environmental, Health & Safety system, external auditing service providers are also employed, and they give out improvement advice to TSMC. As well working with the World Semiconductor Council, industry-level best practices information are obtained to support improvement-options generation.

Except for the 'Top-down' type methods for continuous improvement, the bottom-up type activities are also promoted. Under the original Total Quality Excellence (TQE) program, a specific sub-group of "Environmental protection, safety & health" was set up to generate competition for ideas . These ideas originate from all the plants. In 2012, for example, 229 ideas for improvements were proposed and finally 7 of them are publicized across the whole TSMC group.

Implementation aspects and implementation process

For climate change management, TSMC determines a clear action map, shown as follow:

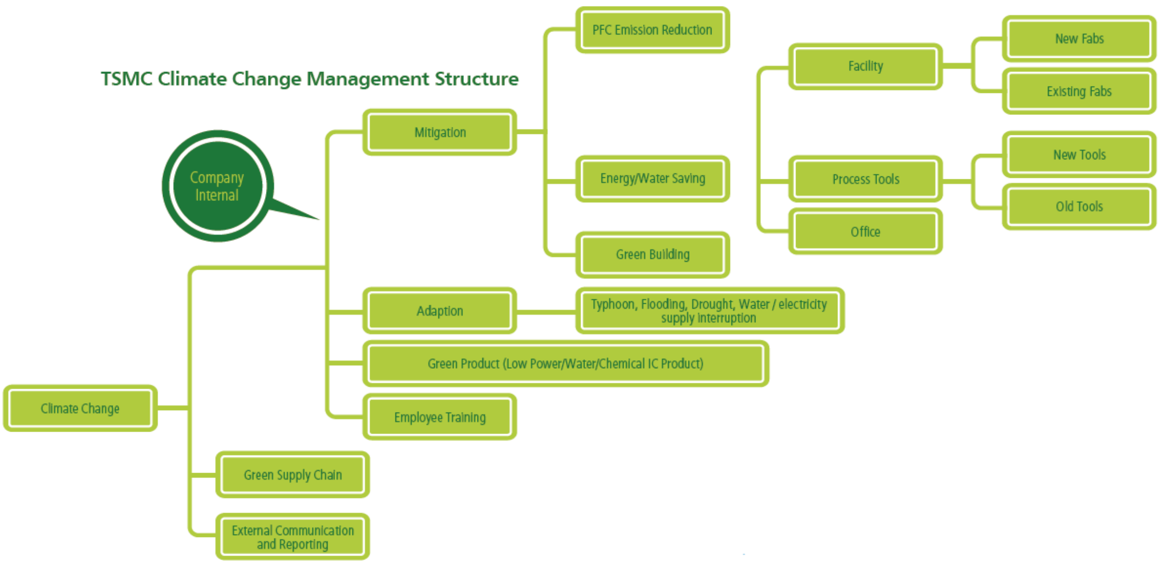


Figure 6.7. TSMC Climate Change Management Structure

(Adopted from TSMC CSR Report 2012)

At the end of 2010, TSMC set up a dedicated cross-department committee for energy conservation, which consists of the technical board, facility, equipment and environmental and safety personnel. The committee will define energy conservation indices and will propose five-year action plans to reduce energy consumption efficiently and achieve a better level of unit energy consumption. Technical boards will focus on improving energy efficiency of the facility and process tools in existing fabrication factories (fab), and transfer experience to adopt as standards for new fabs and new process tools; the new fab planning department will adopt the best-known energy-conserving designs for new fab construction.

Table 6.5 TSMC Carbon Emission Reduction Projects Summary

Aspects	Reduction Projects Details	Themes
Product Design	• Green Manufacturing with Lower Energy Consumption: -TSMC develops product with lower energy consumption and pollution in the product use stage. • Product Packing Materials Management and Reduction -TSMC uses recyclable plastic and paper as packing materials for shipping products.	-Energy efficient product design -Product packaging reuse and material efficiency
Procurement	• Supply Chain Climate Change Management TSMC not only engages in climate change management but also requests and assists suppliers to follow. measures are as follows: • Energy saving and carbon reduction management: -Suppliers are required to collect carbon inventory data in their manufacturing plants, develop a product-based carbon footprint and provide carbon reduction performance data. -TSMC requires and assist suppliers to conduct good hazardous substance management, pollution prevention, energy saving, waste reduction and other clean production measures, and even require suppliers to require their suppliers to do so, in order to establish a green supply chain. • Source Reduction - Raw Materials Usage Reduction -TSMC has a designated unit that periodically reviews raw materials reduction performance. -Continuously optimize our process recipe for raw material usage. -Require process tool suppliers to review and minimize the chemical usage step by step. Process tool suppliers are required to adopt the SEMI-S23 guideline to optimize the consumption of energy, resource and chemicals. The SEMI-S23 is set as a process tool procurement specification.	-Energy efficiency and material efficiency in suppliers -Material usage reduction -Requirement for technology change in equipment suppliers
Production	• Continuously reduce perfluorinated compounds (PFCs) --major greenhouse gas emissions • Energy efficient Equipment -TSMC will also try to purchase energy-efficient equipment by adjusting procurement specifications • Adopting ISO 50001 Certification in Wafer Fab -TSMC adopted the ISO 50001 Energy Management System in 2011 to extend its energy conservation efforts. The Fab 12 Phase 4 data centre completed ISO 50001 Energy Management System certification in 2011, becoming Taiwan's first company to earn this certification for a high-density computing data center. TSMC believes ISO 50001 supports energy saving and carbon reduction, and continues to apply the ISO 50001 Energy Management System to additional manufacturing facilities. In 2012, the Fab 12 Phase 4/5 and Fab 14 Phase 3/4 facilities and offices also adopted the ISO 50001 system and earned certifications.	-Energy efficiency and management in production
Logistics	• Packaging Material Reuse -TSMC reuses packing materials as much as possible to control usage. TSMC recycles packing materials from products shipped to customers, testing and assembly facilities for reuse after cleaning. Packing materials from raw wafers are also reused in product shipping. Wafer shipping boxes are completely made from reused sources. These measures have reduced both packing material consumption and waste generation.	-Material waste reuse
Other	• Waste Reduction and Resource Recycling -TSMC continued to develop new waste recycling technology with potential suppliers to raise its recycling rate and reduce waste disposed in landfills. TSMC's Taiwan sites carry out reduction and recycling programs in 2012, making waste recycling rate reached 93%, exceeding 90% for the fifth consecutive year, landfill rate was below 1% for the fifth consecutive year. • Selected less-hazardous chemicals to reduction, recycling and reuse.	

Supporting capability and tools

The external industry association and government-related research institution provide much technical knowledge and advice on carbon management.

TSMC has the culture of "Being edge of industry technology performance". It help TSMC to build up its capacity on continuous environmental-protection improvement. This capacity lays in all the business departments, from product design to logistics, from gradually improving old plants to building new plants with the latest green technology.

The general process of carbon reduction projects implemented in TSMC can be summarized in Figure 6.8.

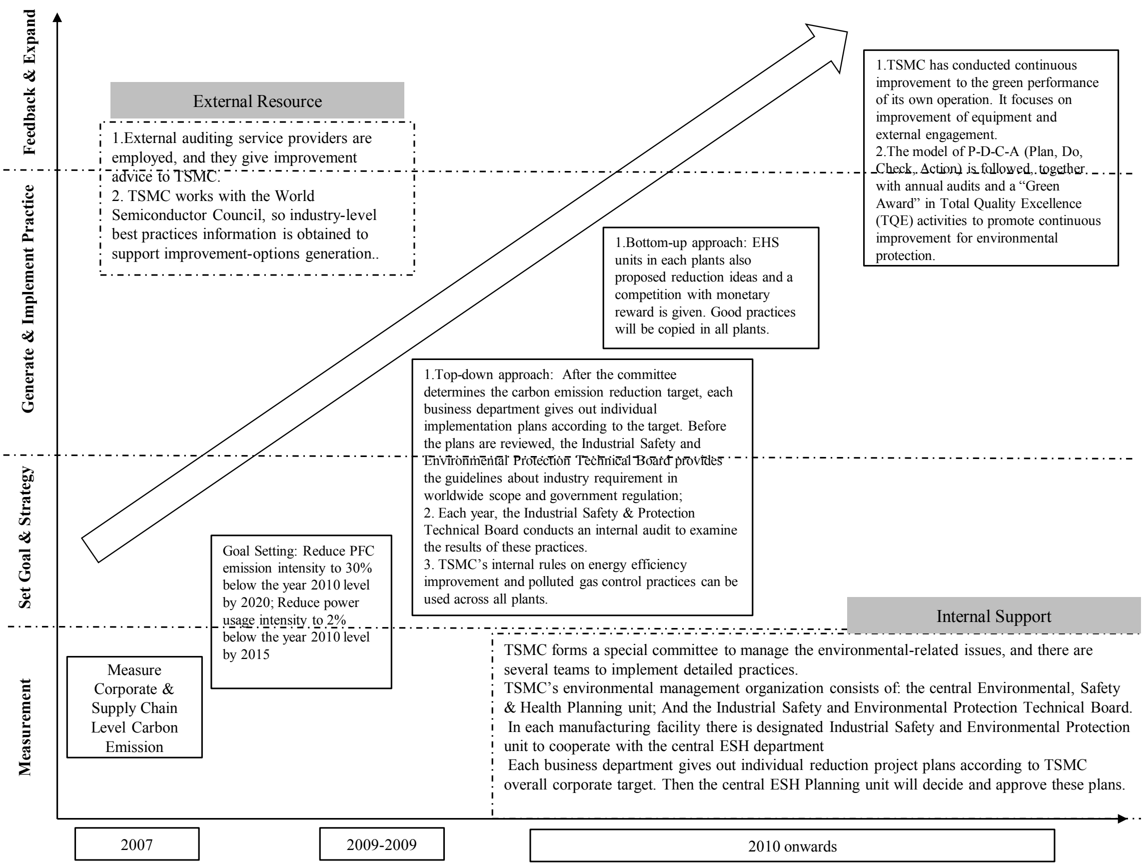


Figure 6.8 TSMC Carbon Reduction Projects Implementation Process

China Steel (Appendix I-6)

<u>The object and target of carbon emission reduction</u>

CSC aims to reduce carbon emission intensity of steel, reaching 1.97 tons of CO_2e/ ton steel by 2020.

Except for carbon emission, CSC targets to control air pollution up to a globally-advanced level and keeps zero disposal of waste/water during production.

<u>The organizational structure to enable low carbon manufacturing and supply chain</u>

CSC's visions in energy and environment are to promote “continuous energy saving, environmental protection and become a reliable green steel maker.” The concepts for energy and environmental management are：

(1)Improve KPIs (Key Performance Indexes) to achieve world-class level and be an international and environmentally-friendly enterprise.

(2)Make use of internal and external resources for maximum effectiveness.

(3)Speed up the application of BATs (Best Available Technologies) and renewable energy to meet low carbon, low pollution and high value goals.

(4)Develop energy-saving products and new green businesses in coordination with the development of the low-carbon green economy in Taiwan.

For the climate change management in senior-level, CSC set up the CSC Group Committee for Energy and Environmental Promotion in April of 2011, with the Chairman of CSC acting as the chairman of the Committee to assist the Company with the implementation of its related tasks with PDCA. This committee consists of several sub-committees to tackle environmental issues, as shown in Figure 6.9.

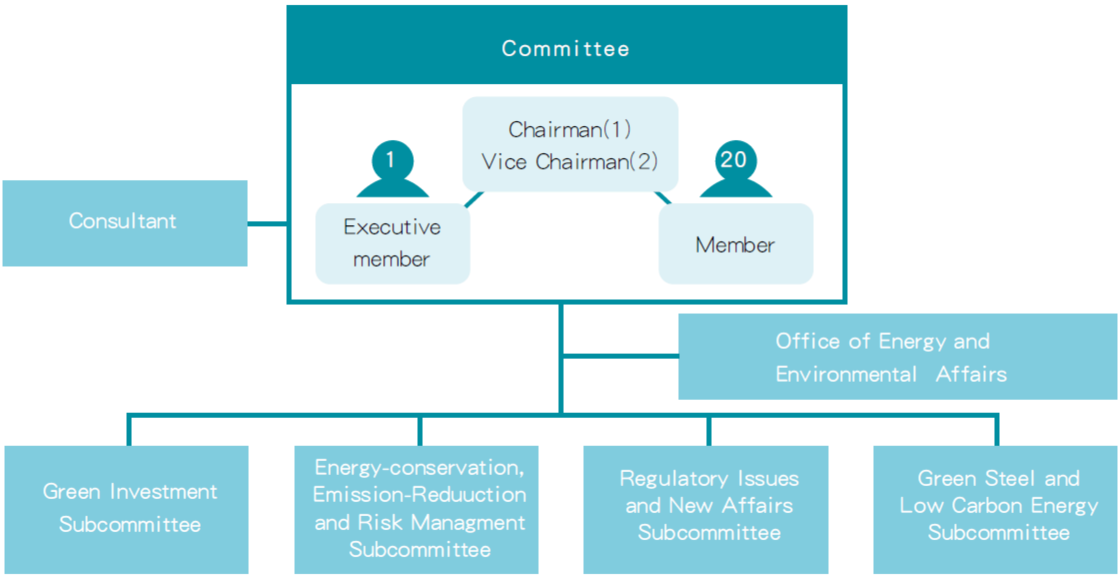


Figure 6.9. China Steel Corporation Energy & Environmental Promotion Committee Structure

In the detailed implementation within its production department, CSC set up the “Energy-Conservation Committee” with the Vice President of its Production Division acting as the chairman of the Committee. It has three task forces (which is a specific team) responsible for the implementation of energy conservation and carbon reducing affairs within all the plants.

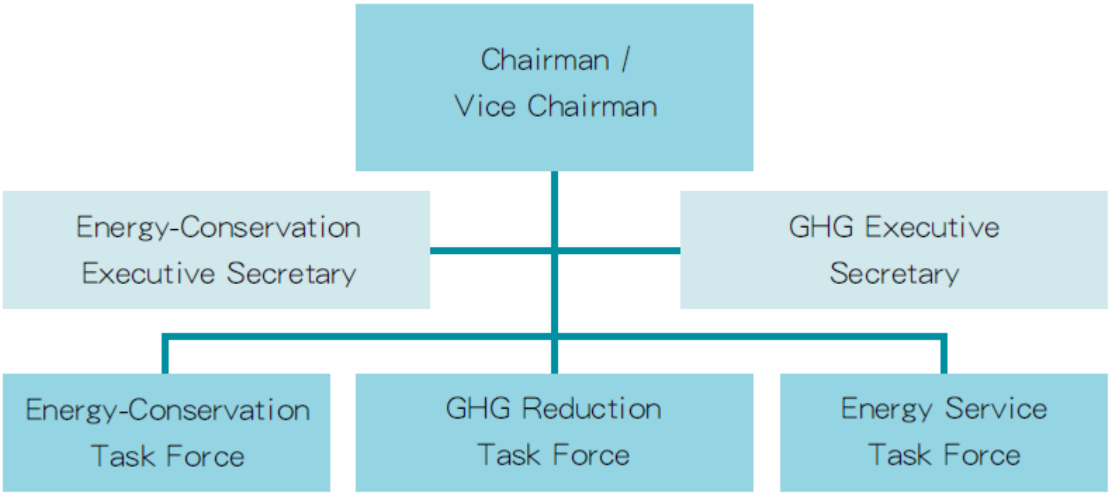


Figure 6.10. CSC Energy-Conservation Committee Structure

<u>Idea generation and criteria for decision</u>

The idea generation process in CSC is a bottom-up type. Groups that consists of lined engineers and senior engineers from different departments are formed to generate optimization ideas/options. This type of meeting with the line engineers are organized 4-5 times every year in order to collect timely ideas of operation optimization. After the meeting, these ideas/options are accessed by Office of Energy & Environmental Affairs, which is directly headed by CSC Group Chairman & Vice Chairman.

<u>Implementation aspects and implementation process</u>

Table 6.6. CSC Improvement Practices

Category	Sub-Aspects	Practices
Internal Carbon Reduction Projects		
Product	Product Design	Green Product Design
Sustainable Energy	Bio-Energy	1.Use bio-Coal instead of normal coal 2.Use bio-charcoal instead of normal charcoal 3. Build up 200MW bio-electricity 4. Use biogas
	Solar Energy	Solar Power
	Other	Fuel Cell
Plant/Production	Production	Apply BAT (Best Available Technology)-including Smart Grid Technology
	Energy Usage	Optimize the self-generating gas combustion
	CCS (Carbon Capture & Storage)	CCS technology
	New Production Technology	New Production Technology Development and Applied
External Carbon Reduction Projects		
Energy Source	Energy Integration	Regional energy integration--Industrial Symbiosis
Energy Management	ESCO (Energy Service Companies)	Domestic and Foreign
Other	CDM (Clean Development Mechanism)	CDM (Clean Development Mechanism)

The energy environmental affairs office is directly headed up by the CEO of the China Steel group, with general managers from different departments serving as committee members. And in the Energy Saving Committee beneath the manufacturing department, a group focused on energy saving and climate change are separately managed.

Supporting capability and tools

The PDCA methodology is applied to implement the carbon emission reduction practices. Software including Gabi and SIMAPRO were purchased to assist the carbon footprinting project. China Steel also works closely with Taiwan Industrial Technology Research Institute (ITRI) to gain carbon emission measurement knowledge. The most important information and knowledge comes from the involvement in World Steel Association, especially in its Climate Action programme. CSC regards the participation in International R&D programs to be a good way to enhance knowledge exchanges and prepare for new trends. At present, the World Steel Association promotes co-operative projects on energy saving and CO_2 reduction naming CO_2 Breakthrough Program. This program, sponsored by global steel companies, is devoted to reducing CO_2 emissions from iron making processes by 30～70%. Detailed projects in this CO_2 Breakthrough Program include Flue Gas Recirculation (FGR) experiment, CO_2 capture and Biological CO_2 fixation.

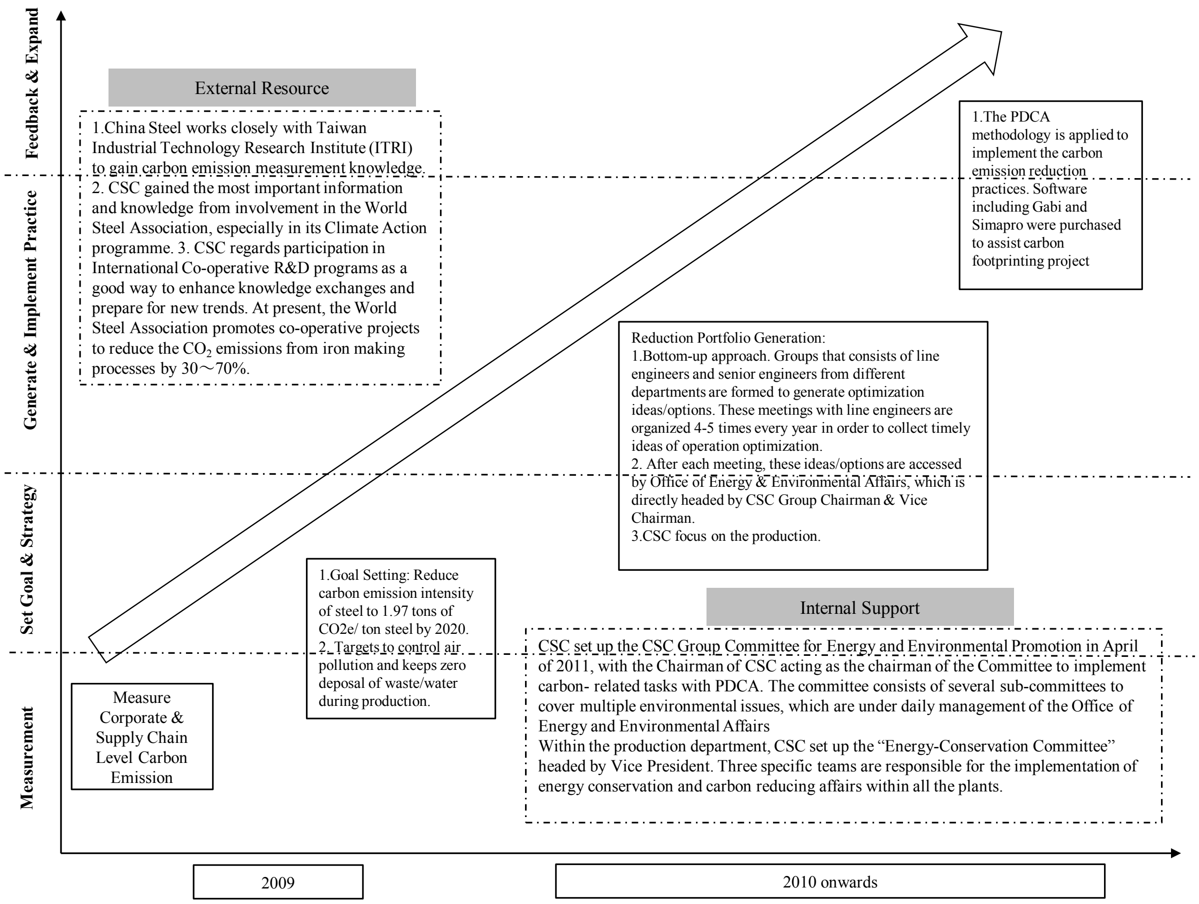


Figure 6.11 China Steel Corporation (CSC) Carbon Reduction Projects Implementation Process

AUO

The object and target of carbon emission reduction

AUO sets the target for 2015 to reduce carbon emissions in all fabrications by 25% based on 2012's emission level. The company has accomplished the 2012 goal of a 30% product carbon footprint reduction compared to 2009.

The organizational structure to enable low carbon manufacturing and supply chain

All the carbon management issues are managed under the Environmental, Health & Security department in AUO. The company does not specially set up a new committee to manage related practices.

Idea generation and criteria for decision

The senior management—Directors and Vice Presidents, who are the top manager for each region, organize seasonal meeting for idea exchanging between regions; The production managers for each production line, forms a Cross Function Team (CFT) to enable innovative green-practices experience sharing. There are different solutions generated in different plants, serving to resolve the same energy-saving problem. In order to choose the appropriate solution, AUO conducts comparative experiments on two plants based on these CFTs: two similar plants are picked, with one chosen to implement the innovative green-practices and the other not chosen to implement it. If the result turns out to be energy-efficient without affecting product quality, the innovative green-practices will be implement to all the plants in all regions. But this type of innovation mainly focuses on factory infrastructure improvements.

Implementation aspects and implementation process

AUO started the "AUO Green Solutions" program from 2008, its carbon performance improvement practices include green innovation on LCD products, glasses-free 3D display etc. AUO conducts low carbon practices from purchasing, production plant management, packaging and logistics, recycling.

Table 6.7. AUO Improvement Practices

Category	Sub-Aspects	Projects	Themes
Product	New Product Design	1. High Efficiency Solar Panel and special solution for residential buildings	-Energy Efficiency -Other change -Packaging material efficiency
	Product Carbon Footprint	PCF System	
	Packaging Redesign	Reduce raw material usage for packaging, carbon emission reduced by 23.8% compared to 2007	
	Packaging Recycle	semi-product packaging recycled for 92%	
Procurement	Management System	Build up Information System of GHG info of Suppliers, require suppliers to reveal data on system platform	-Managerial change
	Supplier Capability Building	1.15 suppliers verified with ISO 14064-1 2.Workshop for sharing experience of ISO50001(energy saving) among suppliers 3. Supplier Recycle packaging by 84%	-change in the supplier management -Reuse
	Reconfigure Value Chain	Use local suppliers, LCD business at the rate of 81%, and solar business at 52%	-managerial change in procurement
Plant /Production	Carbon Emission	carbon emission reduced to 72kg eCO2/m2	-Energy efficiency -Waste management
	Electricity Usage	electricity usage reduced to 92 GW/m2	
	Waste Reduction	waste reduced to 1.43kg/m2	
	Waste Recycle	Globally Recycle Rate 84%, Taiwanese Factory is 89%	
Logistics	Transportation Mode	Establish water transport, reduced CO_2 emission on transportation aggregately by 29.4% according to baseline on 2008	-Managerial process change
	Reconfigure Supply Chain	Integrate Packaging Supplier's upstream and downstream supply chain, reducing the transportation range by 1.39Mkm, and abating packaging material like paper and cupboards for 23,491 tons	-Reduce material usage
Recycle	Product Recycle	1.Reduce product decomposition time by 5.5% 2.Reduce product weight by 8.7%	-End of life recycle
	Adopt recycled new Raw Material	Develop PC+PET+GF recycled plastic, reducing carbon emission from 5.05 kgeCO2/kg plastic (PC+GF) to 4.19 kgeCO2	-Reuse/Recycle

Supporting capability and tools

AUO purchased the SIMAPRO software to assist in its carbon footprinting process. Externally, it cooperates with the Industrial Technology Research Institute of Taiwan (ITRI) for carbon management knowledge and information. In 2011 AUO participated in an environmental assessment of the ICT Industry at the MIT. The “Product Attribute to Impact Algorithm” Project helped AUO stay up-to-date on developments in international carbon footprint calculation science. The projects were aimed at developing the LCD product footprint algorithm and tools, establishing the lifecycle assessment standard, and the item and methodology of the LCD modules. Also the tools developed for PAIA can be used to significantly shorten the time required for calculating the carbon footprint of flat panel products.

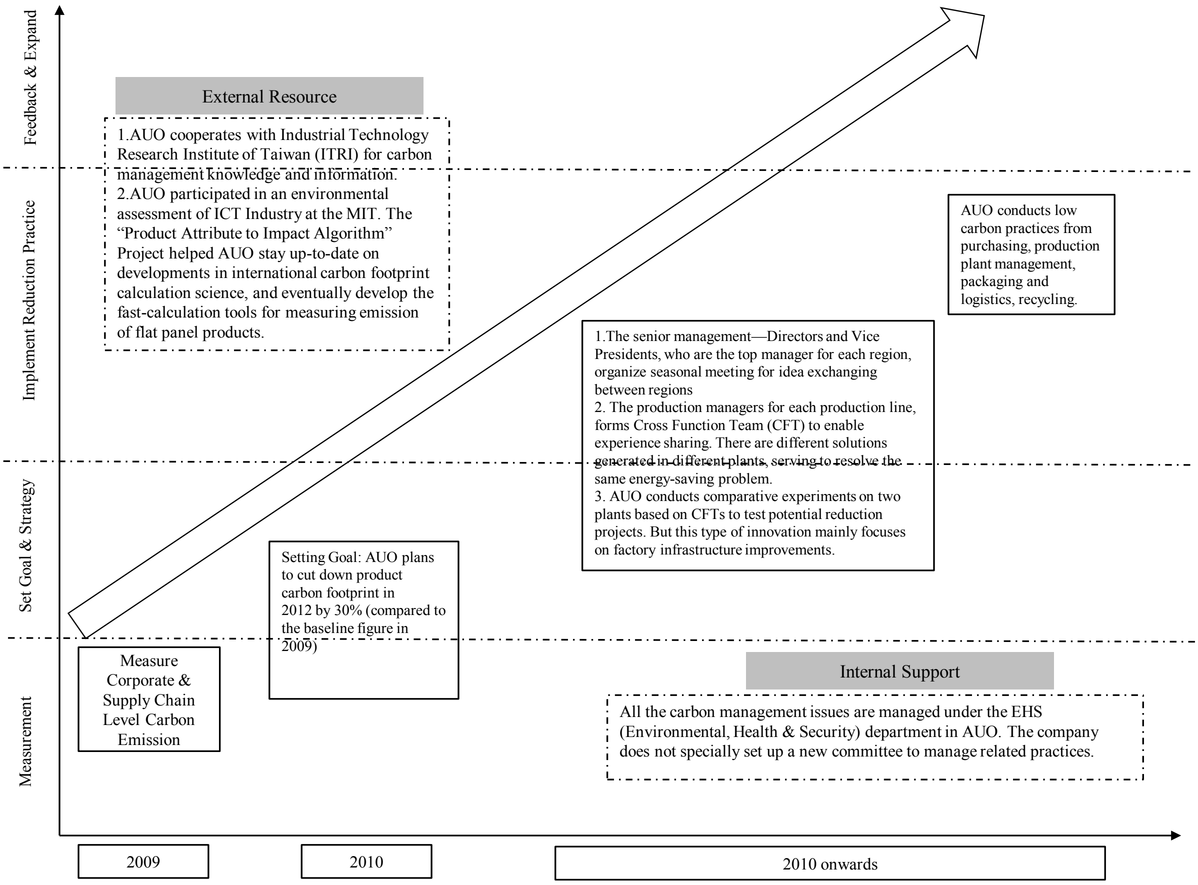


Figure 6.12 AUO Carbon Reduction Projects Implementation Process

BenQ

<u>The object and target of carbon emission reduction</u>

For its products BenQ plans to reduce the energy consumption by 30% in each product generation. Because BenQ also focuses on marketing rather than production, it only retains product design and marketing management. The production is completed by the OEM. So improvement in BenQ focuses on product specification and supplier management.

<u>The organizational structure to enable low carbon manufacturing and supply chain</u>

Carbon issues are managed in their Product Technology Centre, under which are their procurement centre, supply chain centre, quality management centre, etc.

<u>Idea generation and criteria for decision</u>

The carbon management target is set up by the CSR team and then approved by the General Manager. The requirement for reaching targets is then allocated to each product line. Under each product line, each department considers the detailed implementation options. These potential options are simulated by the LCA software, estimating new carbon emission targets if options are implemented. Then the improvement practices are carried out.

In the monthly review, this carbon emission target is set as KPI of evaluation. Product line leaders and department leaders are responsible for achieving this target.

Implementation aspects and implementation process

1) Supply Chain Management

BenQ set up a procedure to recruit new suppliers. Basically BenQ would firstly require the supplier to provide basic certificates, including ISO9000, ISO14000, SA8000. And then BenQ would set up a requirement for the carbon footprint audit experience, and the relevant management needed. A survey table is then sent to suppliers to fill out, in which they have to satisfy the conditions. Only those meet the criteria could stay in the pool. For the companies in the pool, if they do not continue to meet the requirements, they will be cancelled from the qualified list, and BenQ will source a new supplier, or reduce the order from them.

2) Green Product and Packaging Design

BenQ has developed requirements for green product design, by looking at 1. product recycle, 2. reducing packaging types, 3. Increase the packaging volume and reusability, achieving 80% of reuse ratio.

A lot of countries have set up the energy saving standard including China, India etc. Europe is the earliest with an ErP requirement. BenQ tried its best to get the lowest energy usage of its product, so that the CF would reduce as well. ErP started on the its certification on energy in 2006, then it gradually moved on to the carbon issue. BenQ also tried to follow this path, starting the carbon footprint measurement from 2009.

BenQ has done some EPD (environmental product declaration) itself, Ecofact, whose purpose is to identify the 'greenness' of the product. On the Ecofact label, it shows what the percentages of the material is that has included reused material, which is provided as information for the customer. BenQ provided the first Carbon footprint for TV in the world and this was certificated in 2010. From 2009 BenQ has had five products that have a carbon footprint certificate, greater than all of the other Taiwanese companies. There were three in 2009 and two in 2010, which totals 5 products. BenQ has also gained a lot certificates for hazardous materials reduction (See the CSR report).

In their reuse management policy, BenQ have used a lot of reused plastic, achieving a plastic reuse percentage from 37%-65%.

In packaging, BenQ have used sustainable paints and fewer different kinds of wrapping packages, to increase its inner capacity for packaging, so that it could carry more products. These improvements successfully brought in 36.8 tons of CO2 reduction in 2010 saving1472 trees.

This has shown that product design is also very important in reducing carbon as well, such as the example of projector. The usage of education projects is better designed to save energy in its daily usage.

Table 6.8 BenQ Carbon Emission Reduction Projects Summary

Aspects	Reduction Projects Details	Themes
Product Design	• Green Product & Packaging Design BenQ has developed requirements on green product design, looking at 1. product recycle, 2. reducing packaging types, 3. Increase the packaging volume and reusability, achieving 80% of reuse ratio. A lot of countries have set up the energy saving standard, China, India etc. BenQ has done some EPD (environmental product declaration) itself, Ecofact, which has identified the 'greenness' of the product. • Material Reuse BenQ use a lot of reused plastic, with a plastic reuse percentage from 37%-65%. In packaging, BenQ uses sustainable paints and fewer kinds of wrapping packages, and increased the inner capacity of packaging, so that it could carry more products---these improvement brings in 36.8 tons of CO2 reduction at 2010—1472 trees.	-Energy efficient product design -Reduce material usage in production and product
Procurement	• Online system to collect suppliers' energy consumption information	-Efficient supplier management
Logistics	• Vendor Selection -Qualified vendor should have ISO14001 certification • Transportation -Change from air freight to sea freight and inland river freight.	-Change in managerial method in order to reduce energy usage in logistics
Other	• Building Facility Optimization -Air conditioners system upgrade -Setting solar energy system • Lighting -Change to LED lights -Optimization to electricity control system schedule.	-Design of manage system

Supporting capability & tools

The LCA software SIMAPRO is used for assisting estimation of production carbon footprint under new potential design.

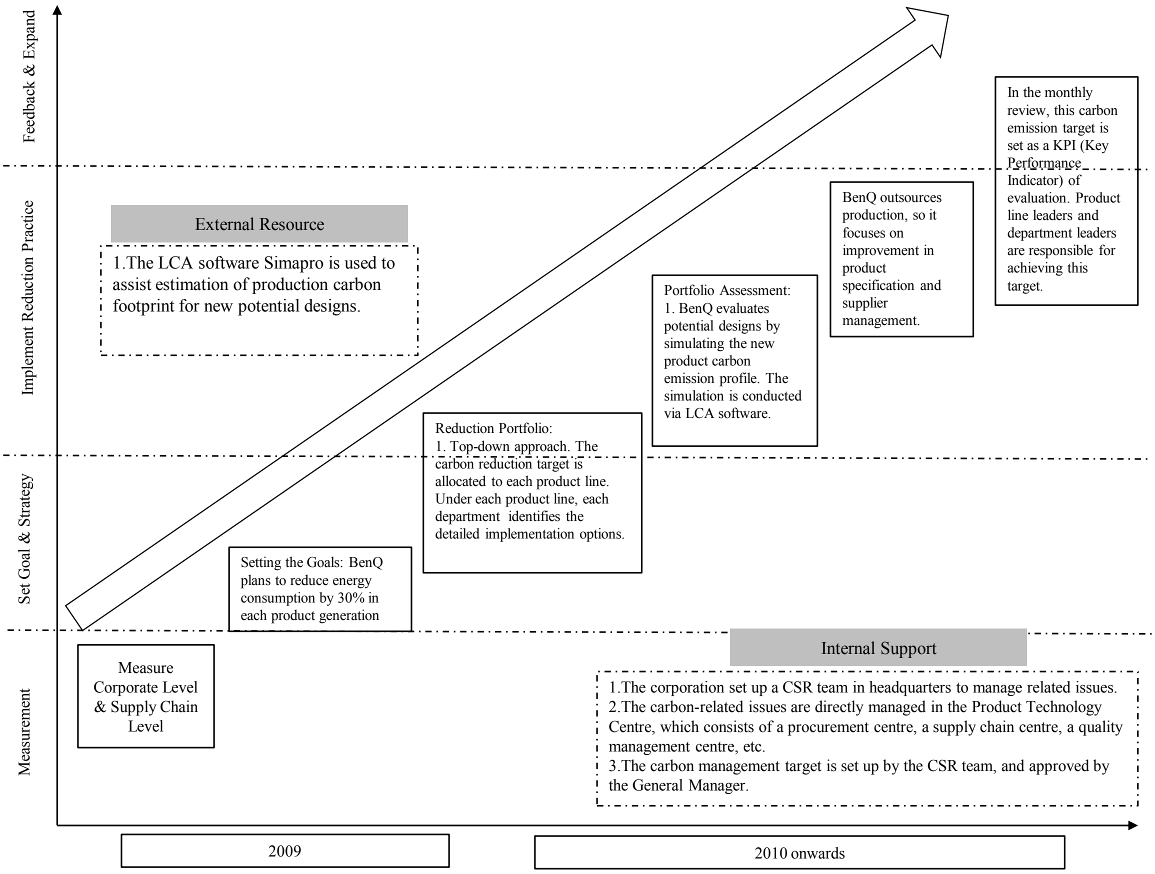


Figure 6.13 BenQ Carbon Reduction Projects Implementation Process

TungHo Steel

<u>The object and target of carbon emission reduction</u>

TungHo Steel Corporation is determined to increase their energy efficiency by 2% yearly from 2005 in order to reduce their energy intensity by 20% in total by 2015.. And the target they want to reach by 2025 is to reduce the intensity by over 50%, achieved via technology innovation and infrastructure improvement. Especially for their carbon emission target, TungHo aims to cut down their emissions back to the same level of 2005 by 2020, and back to 2000's level by 2025.

<u>The organizational structure to enable low carbon manufacturing and supply chain</u>

The "committee of GHG emissions inventory" was established, with the president becoming the head of the committee and the director of R&D technology department becoming the vice head. This senior management involvement ensures that are all types of resources are available that are supporting the carbon-related improvement practices. So the technology department in the factory is the key division to be in charge of the process.

Idea generation and criteria for decision

The green innovation practices in TungHo Steel Corporation have come from the production line staff. A system called "Staff Green Improvement Proposal System" has been set up. Every year 2-3 proposals in the system are put into practice, giving a share of the economic benefit to the proposer.

Implementation aspects and implementation process

The projects conducted by Tungho steel is illustrated in Table 6.9.

Table 6.9 TungHo Steel Improvement Practices

Category	Sub-Aspects	Practices	Themes
Plant/Production	Electricity Usage	Help to improve the emission coefficient of the locally-produced electricity	-Energy Efficiency -Managerial change -Reduce energy usage
	Production Operation	1. Increase the billet temperature before it goes into the furnace 2.Optimize the dust catcher in the furnace by a control system 3. Furnace parameter optimization to save natural gas by $0.2NM^3$/Ton billet 4. Increase the cleanness of scrap steel as a raw material so as to enhance the recovery rate of scrap steel, saving electricity and resources at the end	
Procurement	Green Purchasing of materials	1.Purchase from the suppliers with green certificates from government according to the principle "less polluted, resources saving and recyclable" 2. Priority to purchase low carbon material for large amount purchase.	-supplier management -Managerial change to procurement
	Green Equipment Purchase	Priority to energy-saving machines purchase.	
Others	Human Resources	Employee Improvement Initiative System, to reward employees submitting new ideas about Carbon Emission reduction & continuous improvement in production/daily operation with cash	-Change in Managerial way of implementing projects
	Organizational Structure	"GHG Measurement promotion committee" is established and headed by the chief officer of R&D department	

Supporting capability and tools

In the PCF project, external consultants are involved to help Tung Ho conduct the process, including knowledge support from the IDB. The Steel Association in Taiwan has gathered together steel manufacturers to share their GHG emission reduction experience. There are also a number of cleaner production knowledge sharing between Tung Ho and other business associations, such as the Taiwan Green Productivity Foundation.

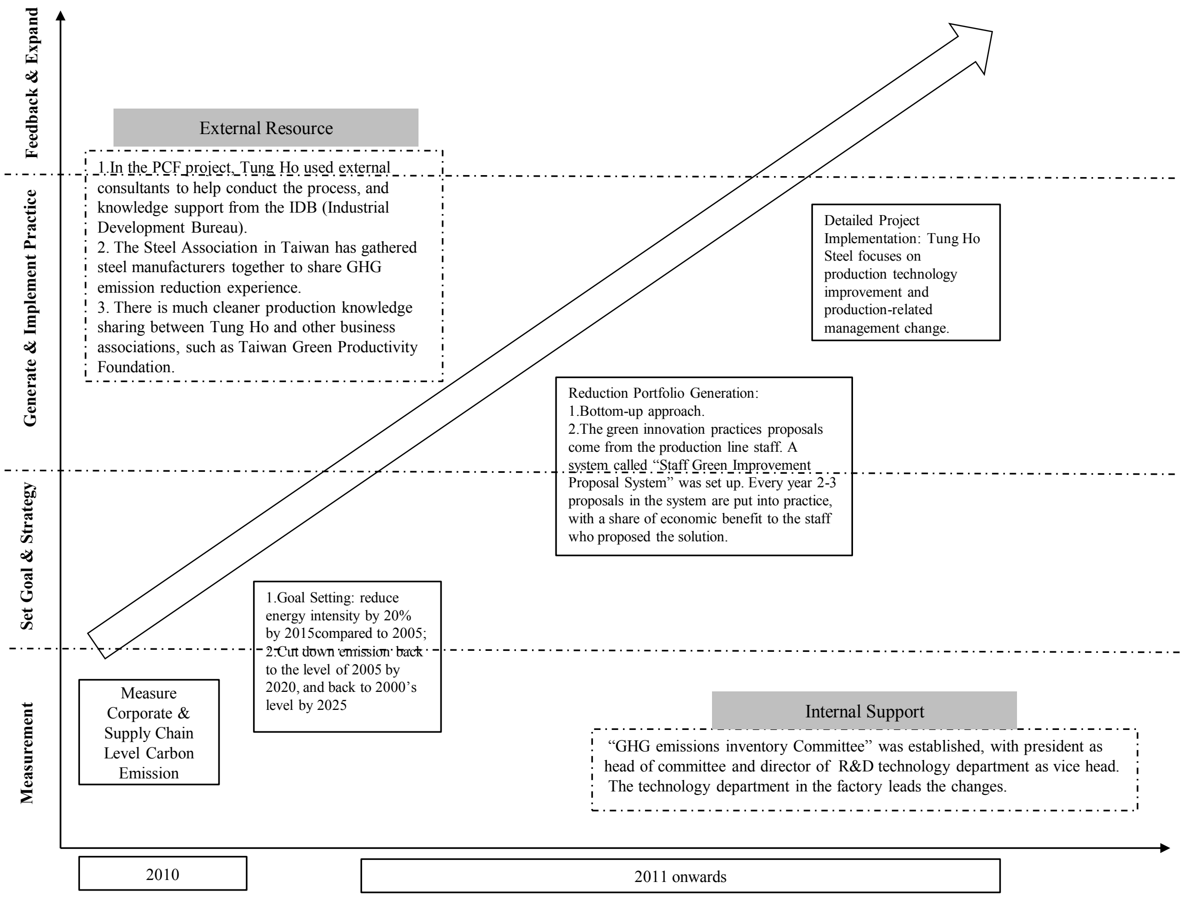


Figure 6.14 TungHo Steel Carbon Reduction Projects Implementation Process

British Sugar

The object and target of carbon emission reduction

Between 2006 and 2009 British Sugar worked to reduce its use of energy by 19%, and in the future it aims to achieve a 30% reduction in the amount of energy produced per tonne of sugar by 2020 (as measured against the same 1990 baseline).

The organizational structure to enable low carbon manufacturing and supply chain

Within British Sugar the managers in the Energy Management Team are responsible for the overall carbon management issue.

The Energy Management Team have ensured that multi-million pound investments in new and improved techniques go hand-in-hand with daily energy conservation initiatives. From power-saving drives to lighting management schemes, from compressed air savings to reducing dilution; from the Combined Heat & Power (CHP) system optimization to the innovative idea of nurturing tomato with CO_2, the energy management team engineers keep improving the material usage rate of British Sugar continuously year by year.

Idea generation and criteria for decision

There is a strong culture of 'No waste' in British Sugar. The engineers in British Sugar aim to transform every of their raw materials to becoming sustainable products. British Sugar has generated highly innovative ways to fully utilize all their raw materials: building up the largest tomato glasshouse in Britain; building up the UK's first bioethanol plant; using the residuals of products to make animal feeds; and finally the topsoil and liming products are aggregated and sold.

British Sugar holds to a continuous improvement business theory, and has invested an average of 1.8 million per year into R&D projects to achieve this goal. The research project has a target to increase the productivity of beet sugar production, and to promote sustainable and environmentally responsible practices across the whole supply chain—from farmers, beet transportation, to packaging.

British Sugar also manages an innovation pipeline where any individual can put forward energy reduction ideas for consideration by the senior Leadership Team.

Implementation aspects and implementation process

British Sugar is investing over £20m in energy reduction projects from 2008. These projects vary from small ones such as more efficient lighting, to larger ones such as the investment in heat recovery, energy recapture and the use of biogas as an alternative fuel.

British Sugar's factories contain state-of-the-art Combined Heat & Power (CHP) plants which are reaching 80% efficiency and even generated a further 700,000 MW hours of electricity exported to the local electricity grid.

In other aspects, British Sugar have also implemented the project of capturing biogas from the effluent treatment plant and then using it as a supplementary renewable fuel; and a project re-circulating Flue gas from the dryers to the dryer combustion chamber, achieving a saving of 1,200 tonnes of CO_2 each year.

Table 6.10. British Sugar Carbon Emission Reduction Projects Summary

Aspects	Reduction Projects Details	Themes
Product Design	•Reducing the density of packaging paper together with suppliers	-Material usage reduction
Procurement	•Education to suppliers on tractor diesel, fertilisers and soil management to reduce emission	-Supplier Management
Production	•Advanced gas turbines is installed enabling an extraction around 80% of the energy contained within fossil fuel which is double the efficiency of a conventional power station. •Capturing waste heat from animal feed dryers and reusing it. Flue gas from the dryers is re-circulated to the dryer combustion chamber, achieving a saving of 1,200 tonnes of CO2each year.	-New technology change -Waste Energy management
Logistics	• Delivery Managers monitor daily performance and make improvements through optimising payloads, the fleet, routes, driver-training and backhauling pallets.	-Managerial change to reduce emission
Energy	• To minimise energy consumption and maximise efficiency, a number of methods are employed including; plant design, additional co-product lines. •In one CHP plant the remaining steam and associated heat is recovered to use for evaporation and again to heat sugar juice at various process stages. •A system to capture biogas from the effluent treatment plant and use it as a supplementary renewable fuel.	-Design under current technology -Waste reuse and recycle

Supporting capability and tools

British Sugar works with the consultants in North Energy Ltd and participated in pilot project of Carbon Trust.

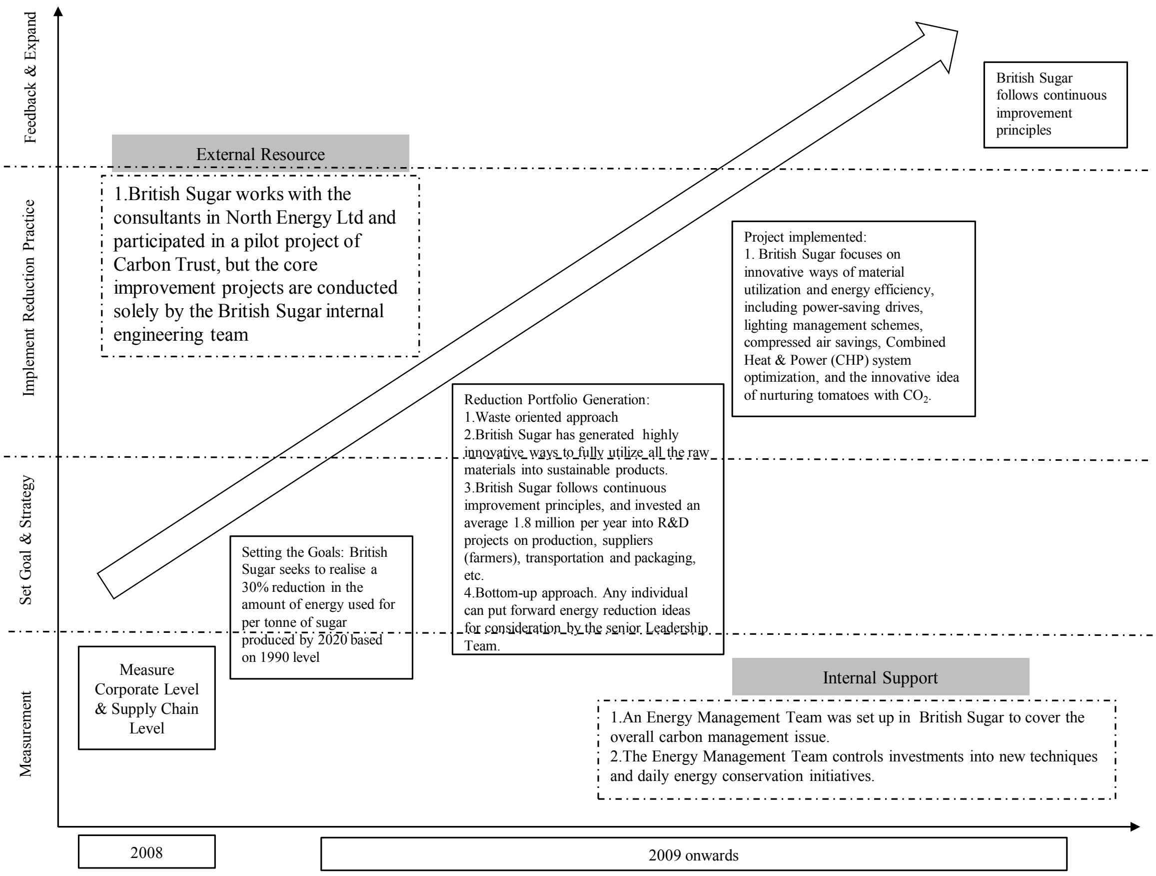


Figure 6.15 British Sugar Carbon Reduction Projects Implementation Process

WWF

The object and target of carbon emission reduction

The LCMP was firstly piloted in 3 manufacturers located in the Pearl River Delta (PRD) area. In these pilots, it is shown that even during the first year 12-24% of their total energy consumption/carbon emission was reduced. WWF expected that if all the 55000 HK-company-owned factories in PRD area were to participate, that 74 million Mt CO2 can be exempted. WWF planned to recruit 300 manufacturers not only in PRD but also within the YRD area, and inland China.

The organizational structure to enable low carbon manufacturing and supply chain

Because WWF is not a business organization, it does not apply an organizational structure. Instead WWF relies on an external technical expert for detailed engineering knowledge. It aims to play the roles of motivator, coordinator, and monitor. The SMEs involved in the program have different organizational structures on carbon emission reduction issues.

Idea generation and criteria for decision

The pilot companies tried multiple methods to generate ideas. Some of them hire external technical consultants to get the latest green solution proposals; Some even formed an alliance to share experience: To identify the "right" kind of green practices to be applied in the garment industry, one garment manufacturer took the initiative to form an alliance with other garment manufacturers for sharing and promoting green practices. With a government agent serving as the secretary, an alliance comprising 37 garment manufacturers was formed and it has become an important source for sharing and promoting green practices.

All these manufacturers gained support from WWF's best practices action list, which is generated by WWF LCMP external partners: the Hong Kong Productivity Council and Azure consultant Ltd. The productivity council has gained lots of carbon-related best practices methods. The Ecofys Azure consultants are specialised expert on clean production, renewable energy, so they could provide technical knowledge for the LCMP project. Before the spinning out of LCMP, WWF teamed up with these special consultants for 1 year to design the GHG management system and best practices action plan which are illustrated in the next section. So the idea generation of WWF's LCMP project is not the same as within firms, but it is the result of a specialised expert's experience, and as well follows the guidelines of the ISO14000 standard.

Some of the pilot companies learn from the supply chain. One of the garment manufacturers jointly developed innovative ideas with suppliers, designed machinery that can separate the water from the dye, which was based on the engineering concept of separating lubricants. Getting the technical "know how" is very important for manufacturers. Based on the interview with a major NGO, many corporations are reluctant to start their green operations because they have no technical competence to measure or predict the performance of their green operations initiatives.

Implementation aspects and implementation process

For the pilot companies, WWF sent out consulting teams to assist firms on GHG management and reduction. These practices include 2 parts: Application of carbon accounting software; Application of Best Practice Action Plan.

The Best Practices Action Plan gives guidelines on improving a firm's carbon emission performance. It consisted of 3 parts:

GHG management practice

A checklist compatible with ISO 14001 which, if followed closely, will ensure that the best GHG gas management practices are implemented. But these management practices are also extended to identify additional risks and the rewards of GHG emissions management, and to be extended beyond the traditional energy efficiencies to encompass the entire organization's performance in relation to climate change.

Factory General Utilities Practices

A list of Improvement measures to maximize efficiency in the design and maintenance of a factory's general utilities including HVAC (Heating, Ventilation and air-conditioning), Electrical, Lighting, Compressed Air and Steam Systems.

Manufacturing Process Practices

Advice on how to streamline industry-specific production processes facilities including all kinds of production machines, monitoring and control facilities directly related to production processes to conserve energy consumption.

The following Table 6.11 shows the detailed measures that WWF has applied.

Table 6.11. WWF Carbon Emission Reduction Practices

Category	Sub-Category	Detailed Measures	Themes
Production	Diesel System	•Conduct proper maintenance	-Energy efficiency -Optimization via new technology or management schedule change -Individual employee behaviour change
	Compressed Air System	•Implement a leakage reporting and repair program •Use of high-efficiency motors instead of normal motors •Install variable speed drive (VSD) control •Optimize the control of multiple compressors •Install heat recovery measures where appropriate	
	Production Machines	•Reduce idle and standby time •Install VSD control on motors •Replace standard motors with energy efficient motors	
	Behaviours Change	•Raise awareness of all users on the proper use of compressed air	
Building / Infrastructure	Lighting System	•Use natural light to reduce the need for lighting •Redesign the lighting system •Use high-efficiency lighting equipment	-Improve building energy usage
	HVAC System	•Increase temperature setting point of HVAC system by 1-2 °C •Ensure refrigerant pipes are properly insulated •Clean filters •Use scale control for condensing water •Use solar shading devices •Retrofit chiller plant	
	Behaviours Change	•Implement good management policy of lighting system	
Renewable Energy	Solar System	•Conduct proper maintenance	-Change in technology

<u>Supporting capability and tools</u>

WWF have received funds from the Green Dragon Foundation to support the operation of LCMP. It has also obtained lots of connection resources from the Hong Kong Productivity Council. The Ecofys is the technical partners to WWF, serving as external consultants as well in implementation.

6.2.2 An Initial Framework to Classify Reduction Projects

Cross-case analysis is conducted in the reduction projects, which are summarized in the summary tables for each case. This analysis focuses on the practices 'Category' and 'Themes' in each table. Three constructs of reduction practices emerge which is shown in the Figure 6.16.

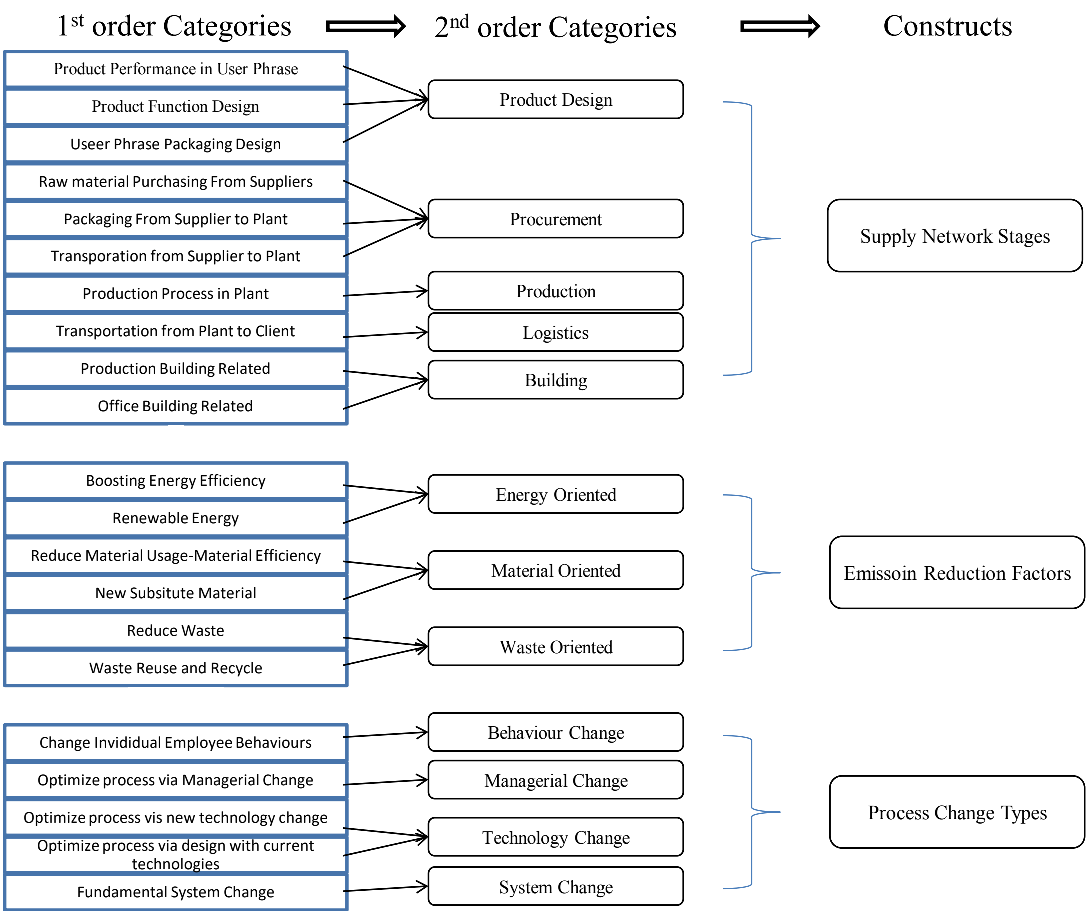


Figure 6.16. Three Constructs from Data of Improvement Practices

The themes concluded from the detailed practices of each case are listed in under the '1st order Categories'. These themes are further classified into 2nd order categories according their characteristics. Sub categories are eventually grouped into three constructs: supply network stages, the factors that links to carbon emission, and the type of change.

Supply Network Stages

These network stages include product design, procurement, logistics, and building. The 'Product Design' refers to all the reduction solutions that targets on the design of the product. Design has direct impact to product performance in the user phrase. A significant example is that CSC put effort to light-weight steel which can help motors achieve better energy efficiency. The product design also affects the production process: AUO modified its product model to enable fewer electricity consumption in manufacturing the LED panel. The packaging of products is within the consideration of product design.

The 'Procurement' refers to all the related issues of raw material or semi-components from suppliers, such as engaging suppliers to reduce emission, purchasing low-carbon semi-components, etc. Another sub-issue is the transportation from supplier's plants to focal firm's production plants. Packages used in this transportation stage has to be considered as well.

'Production' covers all the manufacturing processes. The re-design, re-engineering, and optimization to production procedures of products fall into this category. Operation consolidation and production lines re-design in Lenovo is an example of this kind.

The 'Logistics' part focuses on the transportation process between the focal firm and clients. Transportation route, pallet design, and other similar issues need to be considered in this category, such as those case companies that have changed from air freight delivery to sea freight or road freight. The Packaging issue also has an impact in this category.

The above-mentioned four categories are largely discussed in the literature, which can be shown in the Chapter 2 Literature Review. However, there is a new issue—'Building' category that emerges from the case data. The projects in the 'Building' part includes plant buildings and commercial office buildings. These projects refer to the lighting, HVAC (heating, ventilation, and air conditioning), power supply, and other general infrastructures operations. Most of the case companies have conducted this type of reduction projects due to its easy feasibility and utility. Although it is rarely discussed in the literature, the 'building' part supports most of the supply network stages and it is usually the firm's first attempt at carbon emission reduction activities. In the following section, the CDP questionnaire data shows strong evidence for this point.

Carbon Emission Performance Improvement Choice

From the guideline of PAS2050 as well as the themes emerged from the case practices, it can be identified that emission factors mainly come from three types of sources: energy consumption, materials used, and waste generated. The input from their production system are energy and material, and the outputs are product/service, GHG emissions, and waste. The waste eventually contributes to carbon emission as well. The relationship of carbon emission of three sources can be simply expressed as follow:

$$Emission = Energy * Emission\ Factor_{(energy)} + Material * Emission\ Factor_{(material)} + Waste * Emission\ Factor_{(waste)}$$

Through the analysis to case reduction practices, these three sources are targeted to be improved by two methods: boosting efficiency and using substitutes. These two methods are widely found in the cases:

Efficiency Approach:

- Energy efficiency--improve energy efficiency in CHP (Combined Heat & Power) & building, etc. Examples include TSMC's continuous improvement on equipment energy usage efficiency ;
- Reduce material use--improve the resources usage efficiency, including raw materials, production-process materials, such as Acer's better design for packaging which requires few papers;
- Reduce waste—process control which can minimize waste generation. AUO put large amount of effort to reduce generation of PFC (Perfluorinated compounds) emissions.

Substitute Approach:

- Substitute energy—using renewable energy, including solar, biological, wind power. Most of the cases companies are found to consider solar power supply to buildings;
- Substitute material—apply decomposable, low-carbon-emission material, such as Lenovo changed the wrapping packaging in replacement to the original plastics ones;
- Substitute waste—Waste recycle, reuse, reengineering. A large amount of practices fall into this category, including waste heat recovery, Tsingtao's reuse of CO_2 from wort fermentation process, Lenovo's recycle plastics in new product model, etc.

These general approaches can be powerful tools to guide operation managers to generate ideas to reduce carbon emission.

Types of Changes

There are many changes to the focal firms during the emission reduction projects. These changes require different levels of organization involvement. Based on the analysis to case data, these changes can be categorized into the following types:

Behaviours Change

This type of change refers to the individual level of change. An employee in the focal firm is tutored to change their daily operations and habits, such as turning off lights, reusing papers, car-pooling, etc. This kind of change is most easy to implement but usually has a limited effect to reduce emission.

Managerial Change

Managerial change refers to importing new management methods or new managerial schedules to change the current operation mode. This type of change involves more than individual changes, in some occasions multiple levels of organizational structure may need to be modified as well, such as importing an e-system to the supplier information management. In the Tsingtao Brewery case, new positions were set up to coordinate their headquarters and local plants in executing carbon projects. Simple examples of managerial change include air compressor optimization, intelligent machining optimization, etc.

Technology Change

This change includes optimization to the process via product/process design and new technology. The product/process design refers to the significant change to manufacturing procedure or techniques to the products or processes, such as Lenovo's new product design using recycled plastics. On the other hand, the new technology means different-from-original techniques, including equipment. Examples include many case companies' that implemented solar panels, and British Sugar installed advanced gas turbines to extract double the amount of energy from fossil fuels.

System Change

This type of change refers to the radical, system-level changes. These system changes contain a radical change to procedures, processes, and products, as the manufacturing system can be reconfigured as a whole in order to achieve reduction targets. This type of change is not found directly in the case data, except for two examples which are in the initial stages of the system change. The CSC company enabled a waste heat and gas exchange system with over 15 firms in local area. And Tsingtao Brewery plans to re-configure its energy supply setting in its new plant.

The behaviour and managerial changes normally come together with the technology changes and system changes. The daily operations routine and schedules in some occasions should be modified in order to comply with the new technology or equipment. However, it can be concluded from the case data that the technology change shows a higher maturity level to behaviour change and managerial change.

So an initial framework to classified reduction practices can be generated according the above-mentioned three constructs: supply network stages, emission reduction factors, and types of changes. These three constructs are independent to each other. To further validate the applicability of three constructs (shown in Figure 6.17), the data in CDP Supply Chain Program is applied to the analysis and illustrated in the next section.

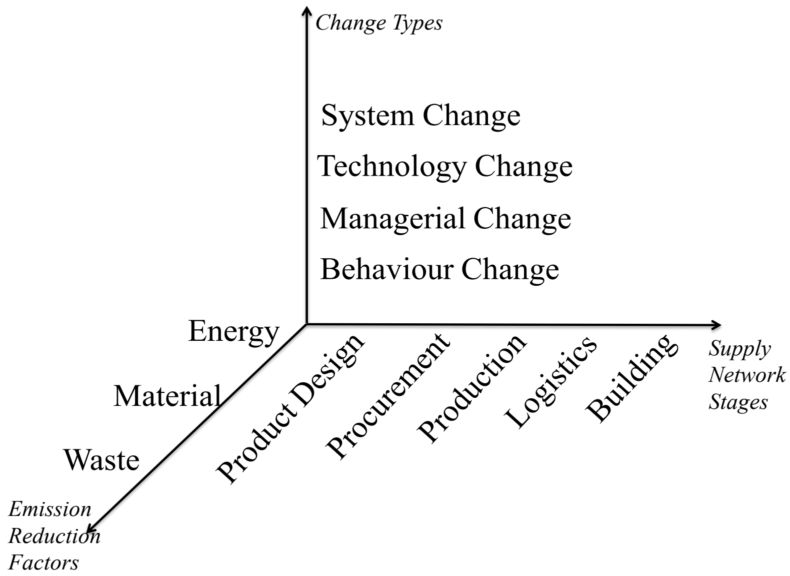


Figure 6.17. Classification for Reduction Projects

6.3 Best Practices Summary from CDP Database

CDP Supply Chain Program requires the suppliers of large MNCs to complete its questionnaire to report their carbon management practices. The information for this Supply Chain Program has been introduced in Chapter 4. This section 6.3 is based on researcher's co-author paper with Mr. Yuan Zhang*. An enriched analysis is conducted and a framework is modified, which is different from the content presented in Mr. Zhang's MPhil thesis.

One question in its questionnaire, question 3.3, specifically targets companies' emission reduction initiatives. The question 3.3 and its sub question 3.3b are as follows:

Question 3.3 Did you have emissions reduction initiatives that were active within the reporting year (this can include those in the planning and/or implementation phases)

Question 3.3b For those initiatives implemented in the reporting year, please provide details

Based on the CDP 2012 database, answers from global manufacturing companies to this question are analyzed in this research. Four industries are selected: Automotive, Food & Beverage, Electronics, and Chemical industry, because the supply chain emission have a large impact in the products' total

* "Best Practices in Low Carbon Emission Supply Chain Networks: Lessons and Implications from the CDP Survey Data from Four Industry Sectors", Y. Zhang, J. Hu, Y. Shi, Proceeding of Asian Conference Management Science and Applications (ACMSA), Kunming, China, Dec 21-23, 2013

life cycle emission in these industries— Automotive, electronics, food & beverage industries have a high-energy-consumption user phrase for their product, chemical industry has high-emission raw material input, and automotive and ICT industries also have a complex sub-components list and therefore a large amount of suppliers. A summary of firms in these industries is presented in Table 6.12.

Table 6.12. Overview of CDP 2012 supply chain program survey

Industrial Sector	Number of participating companies	Number of companies which answered Q3.3b	Response rate
Automotive	114	67	59%
Food & Beverage	212	103	46%
Electronics	220	122	55%
Chemicals	122	85	69%

In next section, the initial framework for reduction projects shown in Figure 6.17 is applied to the CDP data, then a brief summary of each industry will be illustrated followed.

6.3.1 A Brief Summary of Best Practices in Four Industries: Automotive, Food & Beverage, Electronics and Chemicals

In the Table 6.13- 6.16, the symbols represents different 'Emission Factor': E-Energy, M-Material, W-Waste, O-Other; and different 'Change Type': B-Behavior, M-Managerial, T-Technology, S-System.

Automotive Industry

Overall, 59% of the participating companies indicated that they have implemented some actions to reduce their carbon emissions. Through the analysis of 2012 CDP supply chain data and designed research framework, Table 6.13 is structured. From Table 6.13., it can be found that most automotive companies (near to 30%) concentrate on their internal carbon efficiency improvement such as implementing some activities of low carbon production or building energy efficiency. Only some leading automotive companies indicated that they have implemented some actions to product design and logistics. However, implementation of carbon reduction activities in their waste recycle issues seems to be the least popular option for companies to start with, and this may be due to the fact that this method is not widely adopted by companies. Despite the fact that automotive companies have started implementing some carbon reduction actions, it still focuses on the company's internal level not at the supply network level. This point can be demonstrated from the firms' limited practices in the 'procurement' category. In the emission factor column, a new type of factor named 'Other' emerges, which represents the fact that the specific action either contributes directly to carbon emission reduction, or indirectly contributes to the other three factors—energy, material, and waste. In Table 6.13, the PCF project falls into this category. It can also found in Figure 6.18 that energy-related and managerial-type practices are a firms' priority.

Table 6.13 Summary of automotive companies' emission reduction initiatives in 2012

Category	Sub-Category	Companies' Initiatives	Emission Factor	Change Type	No.	%
Product Design	Improving Product fuel usage efficiency	Optimized engine and transmission technologies	E	T	4	6%
		Improving the overall fuel efficiency of vehicles by optimizing vehicle architecture (aerodynamics and mass) and equipment (tyres, etc.)	E	T		
		Deploying hybrid technologies with different size engines and battery capacity	E	T		
	Product LCA Design	Reducing carbon footprint based on LCA process and its result	O	M	1	1%
	Product Green material redesign	Robust EMC shielding, up-integrated mechanical assembly features, and significant weight savings	M	T	5	7%
		High strength steels and aluminum alloys: safety, weight reduction, thickness reduction	M	T		
	Package material redesign	Change corrugated pad to chip pad	M	T	1	1%
	Recycling	Windscreen glass recycling	W	M	2	3%
Procurement	Material procurement	High strength steels and aluminum alloys	M	T	6	9%
		Using Chip pad	M	T		
Production	Performance measurement system	Metering and monitoring system to collect electricity and gas consumption data	E	M	12	18%
	Renewable Energy	Use natural gas co-generation system instead of heavy oil co-generation system	E	T	14	21%
		Green energy procurement/purchase	E	T		
		Renewable energy: solar energy, biomass energy, wind energy, gas-steam energy	E	T		
	Energy efficient strategy	Raised free cooling temperature	E	M	8	12%
		Slow conveyor speed and reduce cure oven temperature	E	M		
		Automated control systems on plant powerhouses and wastewater treatment equipment	E	M		
		Increasing chiller water set points	E	M		
	Increasing awareness of employees	Shutting down unused equipment and lights	E	B	14	21%
		Training program and champion program	W	B		
		Disconnect special equipment during night/weekend (especially compressor)	E	B		
		Disconnecting air conditioners and air compressors during long periods of idle	E	B		
	Improving equipment efficiency	Equipment such as: boiler, chiller, cooling tower, other pumps used to supply chilled water, oven, heat washer (ambient temperature washer), chip drying drum, heaters, dryers, motors, fans and etc.	E	M	24	36%
		Optimizing compressed air systems, monitoring and repairing compressed air leaks: more efficient cooling for production molding machines	E	M		
	Recycling	Reusable steel pallet	W	M	2	3%
Logistics	Fuel use efficiency	Intermodal transportation	E	M	6	9%
		Alternative fuel and more efficient & sustainable vehicle	E	T		
		Monitoring fuel consumption	E	M		
		Reduce maximum speed	E	M		
	Training drivers	Eco-driving strategy	E	B	3	4%
	Transportation planning	Transport mix: increase the use of more environmentally-friendly transport - river, rail and sea - in transport plans	E	M	4	6%
	Optimization of utilization of transportation volumes	Full load shipment: reduce number of trips	E	M	4	6%
		Reduce empty truck return	E	M		
		Sharing transportation	E	M		
	Location selection	improved sourcing to select in-region suppliers to reduce upstream logistics; and locating sites closer to our customers reducing downstream logistics	E	M	1	1%
Building	Lighting	Replacement of inefficient light (new lighting system)	E	T	25	37%
	Building insulation	Localizing energy leakage - door fit closer/building envelope: prevent heat loss, reduce energy consumed on heating	E	M	18	27%
		Waste heat recovery: Pass the heat generated from air compressor and oven to other place	W	M	18	27%
		Sensor door installation	E	T		
	Nature resource use	New (White) roof - better use natural light & reduce steam demand	E	T	6	9%
		Natural ventilation system (reduce the use of air conditioning and heat system)	E	M		

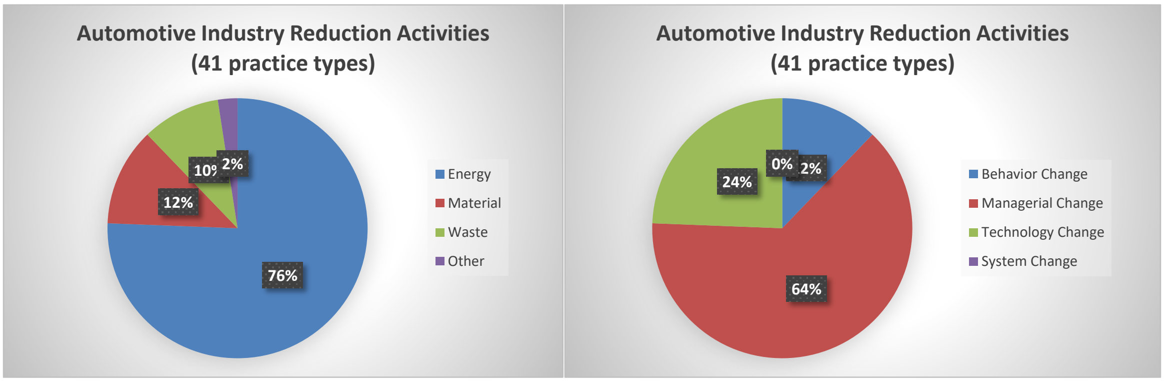


Figure 6.18. Automotive Industry Reduction Portfolio Summary by goal and by change types

Food and Beverage Industry

46% of the participating food and beverage companies have reported practices that are summarized in Table 6.14. Activities under sub-categories of "low carbon energy", "High efficient equipment upgrading" and "lighting" are relatively easy to implement and the returns are immediately visible. As a result, these initiatives are reported by the highest number of companies. In contrast to the automotive industry, the product design activities in the food industry concentrate more on the product package aspect. Nearly 10% of the participating food and beverage companies indicated that they have redesigned their product packaging from the aspects of packaging material and package shape. Despite the various manufacturing emission reduction actions such as "energy consumption", "heat control" and "temperature control", none of them was adopted by the majority of the participating companies. However, using renewable energy are a popular practice. Within the area of logistics, only a few leading companies started optimizing their vehicle fuel efficiency and load capacity. Similarly to the automotive industry, the companies in the food and beverage industry still need to continue improving their manufacturing actions across the supply network in order to minimize their GHG emissions. Compared to the automotive industry, firms pay significant effort to their technology-type reduction projects.

Table 6.14 Summary of food and beverage companies' emission reduction initiatives in 2012

Category	Sub-Category	Companies' Initiatives	Emission Source	Change Type	No.	%
Product Design	Light weight recyclable packaging material	• Convert packaging material from HDPE to 100% light weighting recyclable PET to increase recyclability	M	T	10	10%
	Package shape re-design	• Light weight: Save material and make shipping more efficient	M	T	9	10%
		• Reduce packaging material thickness	M	T		
Procurement	Packaging material	• PET material purchase	M	T	10	10%
Production	Energy consumption monitoring system	• Real-time energy monitoring for energy management system	E	M	4	4%
		• Energy consumption self-assessments and tools	E	B		
		• Energy usage management audit	E	M		
	Low carbon energy	• Use natural gas/bio gas instead of fuel oil	E	T	39	38%
		• Installation of solar panels	E	T		
		• Use of Bio-mass source: Installation of bio-mass boiler to support steam	E	T		
		• Purchasing renewable energy such as solar panels/wind turbines generated electricity from certified renewable sources, to offsetting emissions	E	T		
	Production line	• Reduce downtime and "changeover" times	E	M	12	12%
		• Increase production capacity	E	M		
		• Realigned process operational schedules	E	M		
		• Re-engineering of process lines that has led to the stop of several engines and machines	E	M		
		• Reduce production scrap	M	M		
		• Adjust paint shop burners for optimal performance	E	M		
		• Packing line motors are connected to soft start controller: use of Energy efficient motors with speed controls	E	T		
	Heat control	• Installation of heat recovery loop -> Hot water loop for heat recovery->Heat recovery to increase boiler efficiency	E	M	5	5%
		• Use of waste heat to heat wash water	W	M		
	Temperature control	• Coolers/storage rooms use outside air when it falls within allowable temperatures	E	M	6	6%
		• Raise plant temperature in the summer and lower temperature in winter	E	M		
		• Process optimization of oven lines, which allows oven to be run at lower temperatures	E	M		
	Increasing employee's awareness	• Power down lines when not in use	E	B	21	20%
		• Sustainability action plan guidance documents	E	B		
	High efficient equipment upgrading	• Boiler, refrigeration, baking oven equipment upgrade	E	T	33	32%
Logistics	Vehicle efficiency optimization	• New efficient engine: Euro V EEV engine	E	T	15	15%
		• Introduction of hybrid trucks, electric fleet vehicles	E	T		
	Optimization of vehicle usage	• Increase the load per vehicle	E	M	12	12%
		• logistic partner, Shared logistics with another company, raising truck fill	E	M		
	Transport rout optimization	• Location optimization	E	M	4	4%
		• Reduce travel distance	E	M		
		• Support local farm	E	M		
	Employee's awareness	• Driving techniques training: eco-drive	E	B	2	2%
		• Turn off when not use/stop the vehicles	E	B		
Building	Lighting	• lighting system (T8 Technology & LED with motion sensor)	E	T	39	38%
		• installing auto light switch sensors and controls	E	T		
	Building insulation	• wall, roof, windows, pipe (avoid heat leakage)	E	T	28	27%
		• Repair programs	E	T		

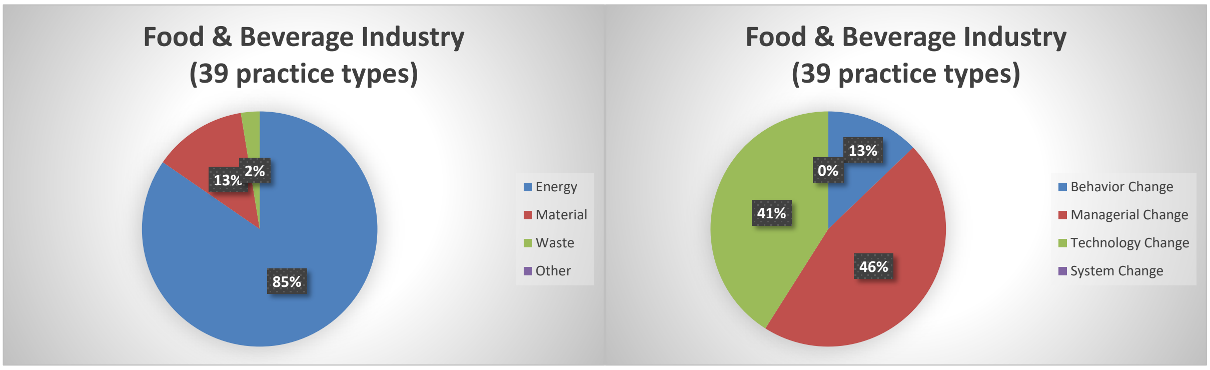


Figure 6.19. Food & Beverage Industry Reduction Portfolio Summary by goal and by change types

Electronic Industry

Table 6.15 Summary of electronic companies' emission reduction initiatives in 2012

Category	Sub-Category	Companies' Initiatives	Emission Source	Change Type	No.	%
Product Design	Increasing energy efficiency	• Increasing resource efficiency	M	T	8	7%
		• Minimize energy usage	E	T		
		• Reducing the carbon footprint for products in operation	O	T		
	Material management	• Select low carbon, low energy components	M	T	2	2%
	Life-cycle perspective	• Launch new product: reduction in carbon emissions over whole life cycle	O	M	4	3%
	Product shape design	• Reducing product size	O	T	2	2%
	Packaging material	• Reduce packaging weight	M	T	3	2%
		• Reduce package size	M	T		
Procurement	Components procurement	• Purchase low carbon, low energy components	E	M	2	2%
Production	Green energy purchasing	• Purchase renewable energy sources such as wind, hydroelectric, geothermic, photovoltaic and thermal solar	E	T	12	10 %
	Green energy generation	• Installation of Solar photovoltaic panel, wind turbine, solid oxide fuel cells and etc.	E	T	22	18 %
		• Nuclear power generation	E	T		
		• Natural gas usage	E	T		
	Employee's awareness	• Turn off light and facility power	E	B	34	28 %
		• Timer control, set higher temp: air conditioner	E	B		
		• Business travel improvement and reduction	E	B		
		• Increase recycling (Office)	W	B		
		• Reduction in waste generation	W	B		
		• Reduce the use of air conditioner, heater, electronic fans, and so on.	E	B		
		• Training and Campaigns programs	E	B		
	Equipment upgrading and optimization	• Maintenance: reduce energy leakage	E	T	23	19 %
		• Upgrading/Replacement: more efficient equipment	E	T		
		• Chiller system, gas boiler, heat/cooling pump, water heater, air compressor, and vacuum pump	E	T		
	Energy saving practices	• compressed air system: Installation of VFD (Variable-frequency drive) and piping improvement	E	T	19	16 %
		• Injection system: Installation of VFD, thermal efficiency improvement	E	T		
		• Energy Recycle from Burn-in System: Installation of Energy Restoration System, improvement of recycles efficiency	E	T		
	Process improvement	• Improvements of heating efficiency	E	T	5	4%
		• Production re-schedules	E	M		
	Automatic energy monitoring system	• Smart meter installation	E	M	10	8%
		• Time controller	E	M		
		• Establish Smart Grid / Smart Meter programs	E	M		
	Waste heat recovery program	• Use heat from manufacturing process to heat air / water	W	M	16	13 %
		• Reuse the heat from compressor, chiller and so on	W	M		
		• Hot/cool air exchange system	W	T		

Logistics	Low emission vehicles	• Changing to more fuel efficient vehicles such as electrical vehicle or hybrid vehicle	E	T	9	7%
	Shared transportation	• Share logistics with other companies	E	M	6	5%
		• Increase delivery volume per vehicle	E	M		
	Employee awareness	• Smart drive skills	E	B	2	2%
	Transport mileage reduction	• Route optimization	E	M	4	3%
		• Select vendor nearby factory to reduce transportation	E	M		
	Reduce air transportation	• Shift to surface shipment such as land or sea shipment	E	M	5	4%
	Business travel reduction	• Use Skype video conference	E	B	6	5%
Building	Lighting upgrading	• Efficient LED lamp	E	T	30	25 %
		• Installation of motion sensor	E	T		
	Improving building thermal insulation	• Installation of thermal barrier roof and Building shell	E	T	5	4%
		• Reduce heat leakage	E	M		
	Air-conditioner system optimization	• Central air conditioning control system	E	M	8	7%
	Ventilation	• Variable frequency drives improvement HVAC	E	M	5	4%
	Natural source usage	• Free air cooling system	E	M	2	2%
		• White Roof: nature light, sun heat	E	T		

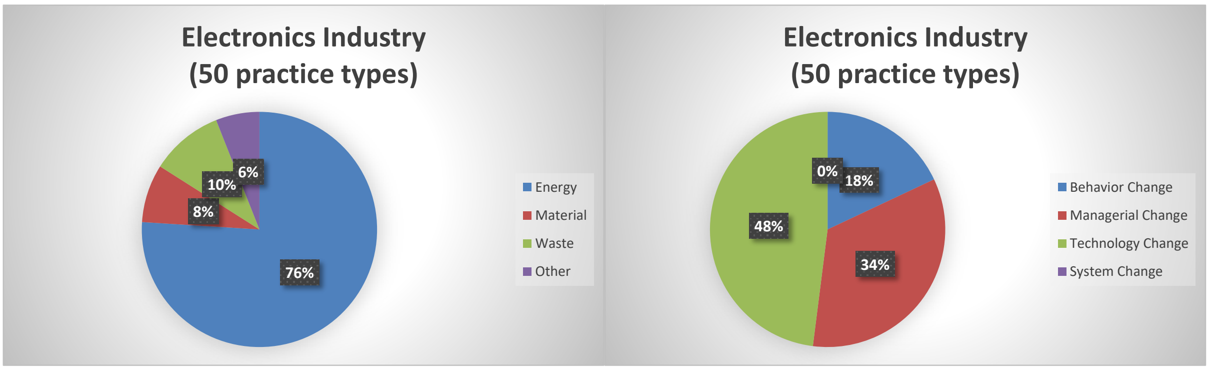


Figure 6.20 Electronics Industry Reduction Portfolio Summary by goal and by change types

In 2012, around 220 electronic companies worldwide took part into CDP supply chain program with 55% response rate indicated the emission reduction initiatives (See Table 6.15).

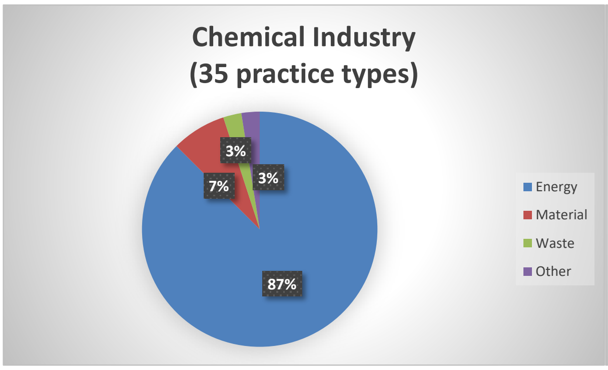
Compared to the previous two industries, there were more varieties of initiatives sub-categories indicated by electronic companies due to the large number of industrial export demand. Some leading electronic companies seemed to have implemented green manufacturing into their operational and strategic perspectives. To reduce the potential risk and cost, some interviewed companies such as Lenovo and Dell said that they have implemented some collaborating works of green manufacturing research with other electronic companies. Despite the various categories of carbon reduction initiatives, the overall electronic industry still showed an initial level in the implementation of low carbon supply chain management. Internal staff training and lighting system improvement are the main focus areas of the electronic industry. Technology-type change is found to be the most popular methods to improve firm's carbon performance.

Chemical Industry

In 2012, 69% of 122 global participating chemical companies reported their carbon emission reduction initiatives to CDP (Table 6.16.).

Table 6.16 Summary of chemical companies' emission reduction initiatives in 2012

Category	Sub-Category	Companies' Initiatives	Emission Source	Change Type	No.	%
Product Design	Material selection	• Use less carbon intense raw material	M	T	3	4%
		• Performing lightweight: less raw material use	M	T		
	LCA analysis	• Doing LCA on products	O	M	1	1%
Procurement	Raw material	• Less carbon intense raw material procurement	M	M	1	1%
	Recycling material	• Recycling cardboard from raw material packaging	W	M	1	1%
Production	Employee's awareness	• Raise employee's awareness of energy saving	E	B	6	7%
		• Turn off equipment when not use	E	B		
		• Reduce heat temperature and increase cooling temperature	E	B		
	Low carbon energy generation	• Installation of solar panels	E	T	7	8%
		• Biomass energy usage	E	T		
		• Hydroelectric power usage	E	T		
	Green energy purchasing	• Purchasing green energy from local resource	E	M	4	5%
	Waste heat recovery system	• Thermal insulation of steam systems	E	T	15	18 %
		• Locate heat and reduce leakage	E	M		
		• Reuse the heat generated from boiler	E	M		
	Enhancing energy efficiency	• Maintenance/upgrade/Replace old inefficient equipment such as Air handler system, magnetic ballast, pump, gas burner, air compressor, and boiler	E	T	23	27 %
		• Installing variable frequency drivers (VFD) on equipment	E	T		
		• Enhancing the efficiency of high energy consumption equipment such as Air separation units, hydrogen units, liquefied gas deliveries, steam generation system	E	M		
		• Energy efficient design	E	M		
	Improving manufacturing process	• Reduce energy waste and improve energy usage efficiency	E	M	17	20 %
		• Optimization of process chain: eliminate bottleneck & Improving yield	E	M		
		• Eliminate waste heat generated	E	M		
		• Additional decomposer use	E	M		
		• Automatic production line with high efficiency	E	T		
	Changing the setting of equipment	• Optimizing operation temperature set point	E	M	5	6%
		• Optimizing operation voltage	E	M		
	Energy monitoring system	• Implementation of auto energy usage measurement/control system	E	M	6	7%
Logistics	Transport millage reduction	• Logistic route optimization	E	M	3	4%
	Low emission/high efficient vehicle	• Diesel truck, hybrid truck, tractor	E	T	7	8%
	Increasing the use of land shipment	• Reducing air shipment	E	M	4	5%
		• Switch from the road to rail	E	M		
Building	Lighting system	• low energy consumption and high efficient LED lamps	E	T	16	19 %
		• Installation of motion sensor	E	M		
	Ventilation	• Natural cooling system: eliminate air conditioning units	E	M	2	2%
	Insulation	• Improving the insulation of roof, wall and piping system	E	M	4	5%



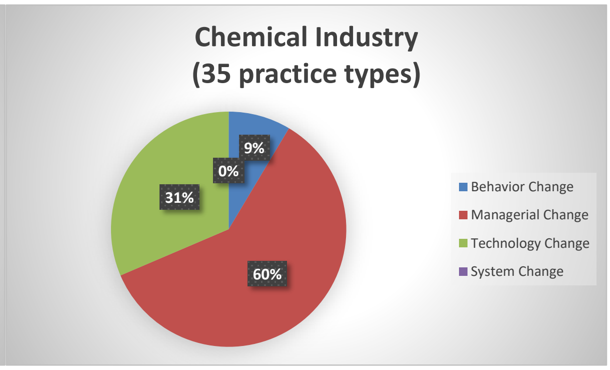


Figure 6.21 Chemical Industry Reduction Portfolio Summary by goal and by change types

Despite the highest response rate of the chemical companies among all four industries in 2012, most chemical companies only held one or two initiatives. Since the chemical industry is a relatively high polluter, its emissions information is usually sensitive and nontransparent to the public. After different pressures came from governments, society and markets, the chemical companies had no choice but to disclose some of their carbon information. However, companies usually wrote some fuzzy information into their cooperation social reports (CSR). Amongst these reported carbon reduction initiatives, chemical companies mainly focused on improving process efficiency and energy usage. As the chemistry industry has high energy consumption, it is reasonable to find firms' higher focus on energy issues than other industries.

6.3.2 Cross Industry Comparison and An Initial Practices List

Table 6.17 Comparison among four industries

	Automotive (67)		Food &Beverage (103)		Electronic (122)		Chemical (85)	
	No. of firms took action	%	No. of firms took action	%	No. of firms took action	%	No. of firms took action	%
Product Design	8	12%	16	16%	13	11%	5	6%
Procurement	5	7%	10	10%	2	2%	1	1%
Production	40	60%	83	81%	79	65%	65	76%
Logistics	8	12%	36	35%	8	7%	12	14%
Building	28	42%	36	35%	28	23%	23	27%

Table 6.17 compares the focusing area of different industry. A similar pattern with the highest percentage at manufacturing aspect can be found in all industries. The 'production' area is the main focus of all four industries to conduct improvement practices. After the emission reduction initiatives in the production aspect, activities in the building area held the second highest percentage for all of the industries. Except in the automotive industry, the remaining three industries chose logistics as the third main focusing area. The Table 6.17 also showed that procurement as well as design aspects seem to not have been a high priority in all industries' radars. If the analysis drills deeper, it can be found that waste control and reuse, such as product recycle, seem to be still less attractive practices for firms.

The Table 6.13-6.16 also confirm that the initial three-construct framework can cover the majority of reduction practices in a systematic way.

An Initial Practices List

Based on the investigation of four industries' carbon emission reduction initiatives, an initial practices list for enterprises to reduce carbon emission across supply network can be grouped as Table 6.18. It can be referenced by practitioners to generate a detailed proposal for a reduction project portfolio.

Table 6.18. An Initial Practices List to Reduce Carbon Emission across Supply Network

Product Design	
R&D	• Product shape redesign: reduce the size of product in order to save more space and decrease the total weight of product. • Applying life cycle assessment on the product and calculating product carbon footprint. • Alternative material selections: Using environmental friendly recyclable material.
Package design	• Package shape redesign: save storage and transportation space. Lightweight recyclable packaging material selections.
*Energy consumption improvement	• Applying new technology or redesigning the internal circuit in order to reduce the energy consumption during the product use phase. (not applicable for all industries)
Waste Management	• Creating recycling network
Procurement	
Environmental friendly material procurement	• Purchasing green recyclable material for product and package. (must be associated with low carbon design phase)
Closer supplier partnership	• Selection of local or closer suppliers so that the transportation mileage can be reduced.
Production	
Employee's awareness	• Improving employee's environmental or energy saving awareness such as turning off lights, machines, equipments etc after use. • Setting training program and energy saving championship.
Low carbon energy	• Self-generation of low carbon energy such as solar, wind, biomass energies. • Purchasing low carbon energy from local resource.
Optimization of equipment	• Repair program: frequent equipment maintenance, repairing equipment leakage, optimizing equipment setting points (temperature, speed, heat) and etc. • Equipment changing program: replacing old equipments by higher efficient ones.
Production line optimization	• Reducing the wastes in production lines and eliminating the production bottlenecks. • Applying continues improvements strategy on the process efficiency so that the energy consumption can be reduced.
Energy recovery	• Reusing the waste energy (heat, cooling air, water) to the other place. • Improving/optimizing the energy transmission systems.
Energy monitoring system	• Implementing an energy auditing system to record the energy consumption at each point.
Waste Management	• Cooperating with local environmental services provider
Logistics	
Vehicle energy efficiency	• Introduction of efficient engine • Introduction of hybrid or electric vehicles
Vehicle space usage	• Increasing the load volume per vehicle and avoiding empty transportation. • Sharing transportation: sharing logistics with other companies to raise truck load.
Transportation route	• Warehouse location optimization: close to customers. • Redesign the transportation route: reducing the transit points and travel mileage. • Reducing air shipment: increasing the rate of road shipment.

Employee's awareness	•Eco-driving: setting speed limitation and turning off the vehicle when not use
Recycling	•Develop recycling logistic network
Building	
Lighting system	•Installation of high efficient lamps such as LED •Installation of motion sensor control system
Building insulation	•Installation of thermal barrier roof and building shell •Repairing doors, pipes and windows to reduce heat leakage
Nature resource usage	•Ventilation: natural cooling down system and reduce the use of air conditioning system. •Natural light: installation of white roof

6.4 A Framework of Carbon Emission Improvement Process

The three-construct framework for reduction projects can be used by practitioners to generate a solution idea. However this systematic way to devise a solution is a 'Top-down' approach, and the bottom-up approach to generate reduction projects also emerges from the case data. Table 6.19 summarizes the portfolio generation methods, and internal/external supporting system in each cases.

6.4.1 Portfolio Generation

From the case data, it can be found that there are generally two types of sources to generate the emission reduction projects: Top-down approach and Bottom-up approach.

Top-down approach refers to that the improvement knowledge comes from external resources. Therefore the solution project portfolio will be generated by the environmental-affair team and deploy top-down to each departments—R&D, production, logistics, etc. The sources of these external carbon reduction knowledge include mainly three types:

- International Standards and guidelines: GHG protocol, ISO 14064/14067, etc. Lenovo uses GHG protocol to guide its reduction projects ideas;
- Industry specific reduction knowledge: WSA (World Steel Association)'s carbon reduction guideline for steel manufacturers. China Steel Corporation gained many support from WSA.
- Practitioner tools and guidelines: cleaner production principles, PDCA continuous improvement.

These resources can be obtained from multiple external entities, including NGO, Business associations, consultants, industrial standard organization, Government bureaus, academic institutions, technology service provider, supply network partners, etc.

Table 6.19. Summary of Improvement Process in Cases

	Project Portfolio Generation	Internal Supporting System	External Support
Lenovo	1. Top-down way—following the GHG protocol as reference to consider firm's practices that generate Scope 1, 2, 3 emissions. These guideline is passed to operations department by GEA (General Environmental Affairs Department) 2.Bottom-up way—project ideas generated by managers in departments with first-hand experiences 3. Priorities of projects: three levels, energy efficiency, renewable energy, and purchase renewable energy credits/carbon offsets.	1.CEO supports the climate change policy, one Vice president is assigned as Chief Sustainability Officer (CSO) 2.A platform—Global Environmental Affairs--across the whole business group to implement carbon reduction projects, under the management of (CSO) 3.In each domestic offices and plants, coordinators in separate EA department and representatives in product, production, and other departments to support GEA 4.Follow ISO14000 standard to build up internal supporting system	"Cooperation with NGO, Government Bureaus, International Organizations, and Academic Institutions to gain rich resources on technology and knowledge on carbon issue"
Tsingtao Brewery	CEO's low carbon awareness spreads to all levels of staff, stimulating the low-carbon idea generation process naturally and self-consciously Bottom-up approach. Employee at every level, especially engineers and technicians, are encouraged with monetary reward to submit new proposals on boosting energy & resources efficiency, via running a proposal competition.	1. The CEO strongly supports the carbon issue and considers low carbon into main business strategy. 2. Low carbon issue is managed under manufacturing department, and a special team is set up for targets, plans and monitor. 3.6 specialist formed the team in the headquarters, and one specialist in each brewery factory. The carbon specialists are also evaluated yearly. And these specialists are promised with faster-track on promotion. 4. General manager was the first person responsible for the factory's environmental-protection management; every levels of environmental officers have to communicate with the general manager on a regular basis. 5. The participation of senior management ensures sufficient resources allocated to carbon management projects—the carbon projects have priority on getting funding, human resources compared to other projects.	Carbon footprinting project is supervised by external consultant
ZTE	1. ZTE reduction projects identification comes from the principles of Cleaner Production, 2.The internal CSR team conducted the cleaner production assessment, which collects the operation data and analyse the un-balance between materials in input/output activities. Specialists can figure out potential cleaner production options from those unbalanced items. 3.Eight potential aspects are analysed: Resources, Energy, Technology, Equipment, Process Control, Products, Waste, Management and Personnel	1.In 2007 a special CSR team is built up to implement the CSR architecture of ZTE 2.A Vice President was named specially as representative of ZTE CSR system Specially for carbon issue, ZTE sets up a committee for energy saving and carbon emission reduction. The task for the committee includes two streams: one for the corporate level improvement and the other for the product level. 3. Four specialists were allocated equally into the corporate-level team and product-level team.	1. ZTE has obtained the LCA carbon analysis software "EMMi" to support product carbon footprinting. 2. For reduction projects, due to business confidential issue, ZTE only relies on internal capacity for evaluating and implementing these projects.
Acer	1. Bottom-up approach. Acer does not rely on the sustainable office to generate carbon emission reduction options. 2. Each department is responsible to identify the reduction solutions by their internal capability. And these projects need to comply with the overall carbon reduction target. 3. Due to tough market competition, Acer has a corporate culture with highly sensitive to the trend of global consumer's attitude. This culture influence every staff to consider environmental friendly practices in their daily work, which is part of continuous improvement conduct.	1. Acer sets up an environmental management committee to manage environmental issue as a whole 2.A group of 7 people consist the Acer sustainable office, aiming for coordination between departments and special task groups on those environmental, health and social issues.	1. External sources include research institute such as Industrial Research Institute of Taiwan, industry association such as Electronic Industry Citizenship Coalition (EICC), consultants, third-party auditors such as SGS consultants for the on-site auditing in suppliers' plants, and government organizations such as the special program of Taiwan Industrial Developing Bureau.
TSMC	1. Top-down approach: After the committee determines the carbon emission reduction target, each business department gives out individual implementation plans according to the target. Before the plans are reviewed, the Industrial Safety and Environmental Protection Technical Board provides the guidelines about industry requirement in worldwide scope and government regulation; 2. Each year, the Industrial Safety & Protection Technical Board conducts internal audit to examine the results of these practices. 3. TSMC's internal rules on energy efficiency improvement and polluted gas control practices can be transferred. 4. Bottom-up approach: EHS units in each plants also proposed reduction ideas and a competition with monetary reward is given. Good practices will be copied in all plants. 5.PDCA principle is applied	1. TSMC forms a special committee to manage the environmental-related issues, and there are several teams to implement detailed practices. 2.TSMC's environmental management organization consists of: the central Environmental, Safety & Health Planning unit; 3.The Industrial Safety and Environmental Protection Technical Board; 4.In each manufacturing facility there is designated Industrial Safety and Environmental Protection unit to cooperate with the central ESH department 4. Each business department gives out individual reduction project plans according to TSMC overall corporate target. Then the central ESH Planning unit will decide and approve these plans.	1. External auditing service providers are employed, and they give out improvement advice to TSMC. 2. TSMC works with World Semiconductor Council, so industry-level best practices information are obtained to support improvement-options generation.

China Steel	1. Bottom-up approach. Groups that consists of lined engineers and senior engineers from different departments are formed to generate optimization ideas/options. This type of meeting with line engineers are organized 4-5 times every year in order to collect timely ideas of operation optimization. 2. After the meeting, these ideas/options are accessed by Office of Energy & Environmental Affairs, which is directly headed by CSC Group Chairman & Vice Chairman.	1. CSC set up the CSC Group Committee for Energy and Environmental Promotion in April of 2011, with the Chairman of CSC acting as the chairman of the Committee to implement carbon- related tasks with PDCA. The committee consists of several sub-committees to cover multiple environmental issues, which are under daily manage of Office of Energy and Environmental Affairs 2.Within production department, CSC set up the "Energy-Conservation Committee" headed by Vice President. Three specific teams are responsible for the implementation of energy conservation and carbon reducing affairs within all the plants.	1. China Steel works closely with Taiwan Industrial Technology Research Institute (ITRI) to gain carbon emission measurement knowledge. 2. CSC gained the most important information and knowledge from the involvement in World Steel Association, especially in its Climate Action programme. 3. CSC regards participation in International Co-operative R&D programs is a good way to enhance knowledge exchanges and prepare for new trends. At present, the World Steel Association promotes co-operative projects to reduce the CO2 emissions from iron making processes by 30~70%.
AUO	1.The senior management—Directors and Vice Presidents, who are the top managers for each region, organize seasonal meetings for idea exchanging between regions 2.The production managers for each production line, forms Cross Function Team (CFT) to enable experience sharing. There are different solutions generated in different plants, serving to resolve the same energy-saving problem. 3. AUO conducts comparative experiments on two plants based on CFTs to test potential reduction projects. But this type of innovation mainly focuses on factory infrastructure improvements.	All the carbon management issues are managed under the EHS (Environmental, Health & Security) department in AUO. The company does not specially set up a new committee to manage related practices.	1. AUO cooperates with Industrial Technology Research Institute of Taiwan (ITRI) for carbon management knowledge and information. 2. AUO participated in an environmental assessment of ICT Industry at the MIT. The "Product Attribute to Impact Algorithm" Project helped AUO stay up-to-date on developments in international carbon footprint calculation science, and eventually develop the fast-calculation tools for measuring emission of flat panel products.
BenQ	Top-down approach. The requirement of carbon reduction target is allocated to each product lines. Under each product line, each department identify the detailed implementation options.	1. The corporate sets up CSR team in headquarter to manage related issues. 2. The carbon-related issues are directly managed in Product Technology Centre. This product technology centre consists of procurement centre, supply chain centre, quality management centre, etc. 3.The carbon management target is set up by CSR team, and approved by General Manager.	The LCA software SIMPRO is used for assisting estimation of production carbon footprint under new potential design.
Tungho Steel	1. Bottom-up approach: The green innovation practices proposals come from the production line staff. A system called "Staff Green Improvement Proposal System" is set up. Every year 2-3 proposals in the system are put in practices, with a share of economic benefit to the staff proposed the solution.	1. "GHG emissions inventory Committee" was established, with president as head of committee and director of R&D technology department as vice head. 2. The technology department in factory is the key division to be charge.	1. In the PCF project, external consultants are involved to help Tung Ho to conduct the process, including the knowledge support from the IDB (Industrial Development Bureau). 2. Steel Association in Taiwan has gathered steel manufacturers to share GHG emission reduction experience. 3. There are also numbers of cleaner production knowledge sharing between Tungho and other business associations, such as Taiwan Green Productivity Foundation.
British Sugar	1. Waste oriented approach 2.British Sugar has generated highly innovative ways to fully utilize all the raw materials into sustainable products. 3. British Sugar holds the continuous improvement principle, and invested an average of 1.8 million per year into R&D projects onto production, suppliers (farmers), transportation and packaging, etc. 4.Bottom-up approach: Any individual can put forward energy reduction ideas for consideration by the senior Leadership Team.	1. An Energy Management Team is set up in British Sugar to cover the overall carbon management issue. 2. The Energy Management Team controls the investments into new techniques and daily energy conservation initiatives.	1. British Sugar works with the consultants in North Energy Ltd and participated in pilot project of Carbon Trust. But the core improvement projects are conducted solely by British Sugar internal engineering team
WWF LCMP	1. WWF's external partners were teamed up for 1 year to generate the best practices action list. These partners are capable on industry-related technical knowledge on carbon emission management. The best practice plan follows the principle of ISO14000. SMEs involved in the projects are guided with the plan and these specialist hired by WWF LCMP program. 2. SMEs gain experience from supply chain. Getting the technical "know how" is very important for manufacturers to improve their technical competence.	WWF relies on external technical expert for detailed engineering knowledge. It aims to play the roles of motivator, coordinator, and monitor.	WWF get the fund from Green Dragon Foundation to support the operation of LCMP. It has obtained lots of connection resources from Hong Kong Productivity Council. The Ecofys is the technical partners to WWF, serving as external consultants as well in implementation.

Bottom-up approach is when the improvement knowledge comes from internal resources—field engineering, staff at direct business line. So the solution project portfolio will be proposed by these front-line employees and then approved by the senior management group, who will then deploy the solution. Emerging from the case studies there are two types of methods gaining this kind of knowledge:

- Encouraging front-line engineers and staffs to propose new practices based on their operation experience. In most cases, monetary reward are used, e.g. Tungho Steel set up 'Staff Green Improvement Proposal System'.
- Investing R&D project for Energy efficiency, such as British Sugar invested average 1.8 million GBP per year on energy & material efficiency projects on production, suppliers, transportation & packaging.

In most of the case companies, these two approaches are in fact applied simultaneously to generate the potential reduction of the project portfolio. The top-down approach can give focal firms a systematic view of the carbon reduction requirement and a possible solution, but the solutions are in general not feasible for the focal firm; On the other hand, the bottom-up approach provides practical, specific and an applicable solution. The bottom-up approach can be very innovative, such as Tsingtao Brewery who collects the CO2 generated in wort fermentation to substitute the gas which is used to seal beer bottles. However, the bottom-up approach can be so limiting to a firm's current operation that other aspects of reduction projects are neglected. Thus, a special environmental –affair team is needed to perform as a hub, absorbing external knowledge and internal proposals, and then they make the decisions afterwards.

As well for most of the companies, these two approaches can be more effective than the other one under different situations depending on the decarbonisation projects. In the supply network stages, the production and building stages are found to be more applicable in using the bottom-up approach, while the product design, procurement and logistics stages can more easily use the top-down approach. This is due to the fact that the previous two stages are within the scope of the focal firm, thus the potential opportunities for decarbonisation are easier to identify. In terms of a change in types, the bottom-up approach is more to be found in the behaviour and managerial changes when the technology and systematic type changes are usually introduced in the top-down approach. New technology and fundamental innovation methods are usually generated from a research institution or external industries; therefore, these types of knowledge need to be imported externally rather than generated internally. In the third scale of the framework—emission reduction factors, and energy related projects are generated more by the bottom-up approach, and the other two types, which are material and waste related projects, are often introduced by the top-down approach. This is because material related projects are at many times initiated along with a technology breakthrough, and waste related projects require cooperation with external partners; therefore, the top-down mode helps to facilitate these projects.

6.4.2 Internal Management Structure

The above-mentioned special team plays a key role to enable the projects to be implemented, however, there are other components in the system to support, as shown in the case data. From the 'internal supporting system' column in Table 6.19, a pattern in organizational structure emerges, as shown in Figure 6.22.

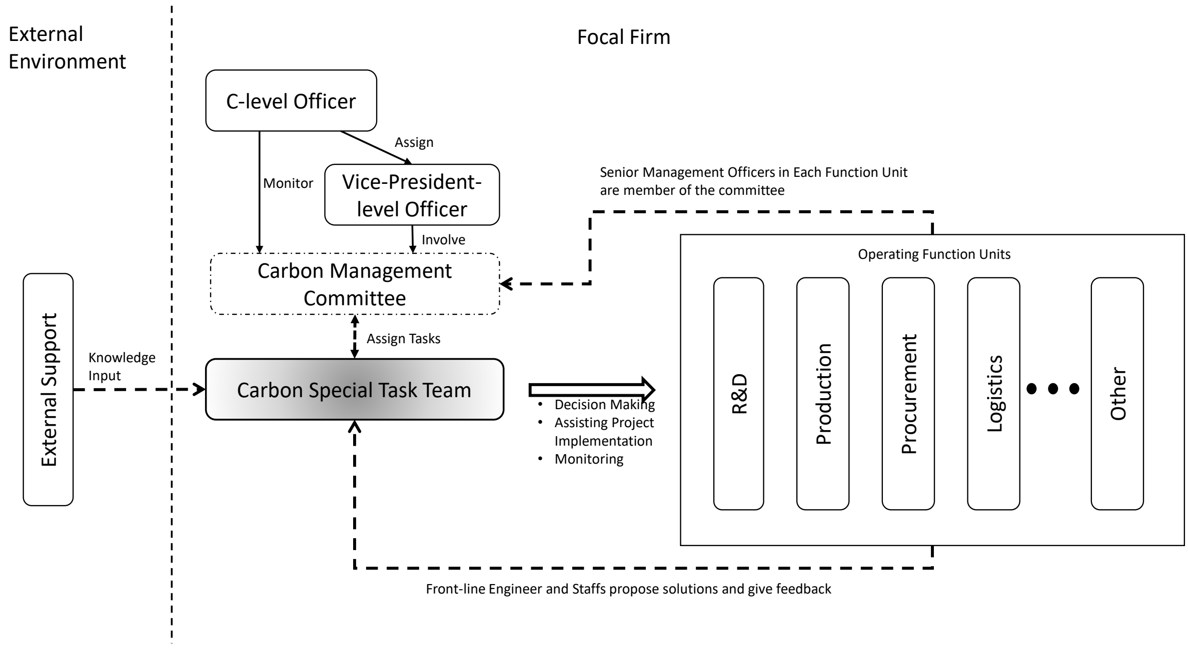


Figure 6.22. A General Model of Carbon Management Organization Structure

The support from the top-level management group is important for implementing the improvement project, which ensures sufficient resources can be allocated to these projects. A vice-president-level officer is normally assigned to manage the carbon management issue as whole. Many case companies have set up virtual carbon management committees, which consist of the CEO, vice president for the carbon issue, and senior managers in each of the functional units—R&D, production, procurement, etc. These senior managers report the overall progress of carbon projects, and they are assigned with tasks to cooperate with the carbon special task team. This carbon management committee have regular meetings, but are not actually involved in the project implementation. The operating team is the 'Carbon Special Task Team' which facilitates reduction projects from beginning to the end.

The ratio of external and internal supporting resources varies for the different types of carbon reduction projects and for the different types of firms. Firms taking the top-down approach require more external knowledge and technology for implementing projects; therefore, the ratio of external over internal resources is as high as 80%, and the rest of the resources come from internal support. While for those firms that are taking the bottom-up approach internal resources are more critical, especially the front-line engineer and the factory workers' innovative projects. Thus the ratio can be as low as 20%. In general the 'proactive' and assembly-oriented firms tend to have a higher ratio of external/internal resources, and the 'passive' and process-oriented firms use a lower ratio. The average ratio is 40% because in most situations firms rely more on internal resources.

Carbon Special Task Team

The team normally has a few members to cover the different projects or different plants (if the focal companies have these, such as Tsingtao Brewery). The team acts as the carbon expert in the focal firm who best know carbon management and the related standards. The carbon targets should be proposed by the team to the carbon committee. Absorbing knowledge from external sources and reviewing the solutions proposed by front-line staff in each functional units, the team has to make decisions to select reduction projects, and then choose tutors who support and monitor the project implementation in the function units or multiple plants. This team normally belongs to the EHS (Environmental, Health & Safety) department, which is separated from other departments. However, it can also belongs to production departments or product QA (Quality Assurance) departments, depending on the focus of firm. E.g., Tsingtao Brewery sets its team under production due to Tsingtao's focus on boosting energy efficiency in the production stage.

6.4.3 Improvement Process

As emerged from the cases' implementation process from Figure 6.1-6.14, a process model to implement improvement practices can be summarized (shown in Figure 6.23.).

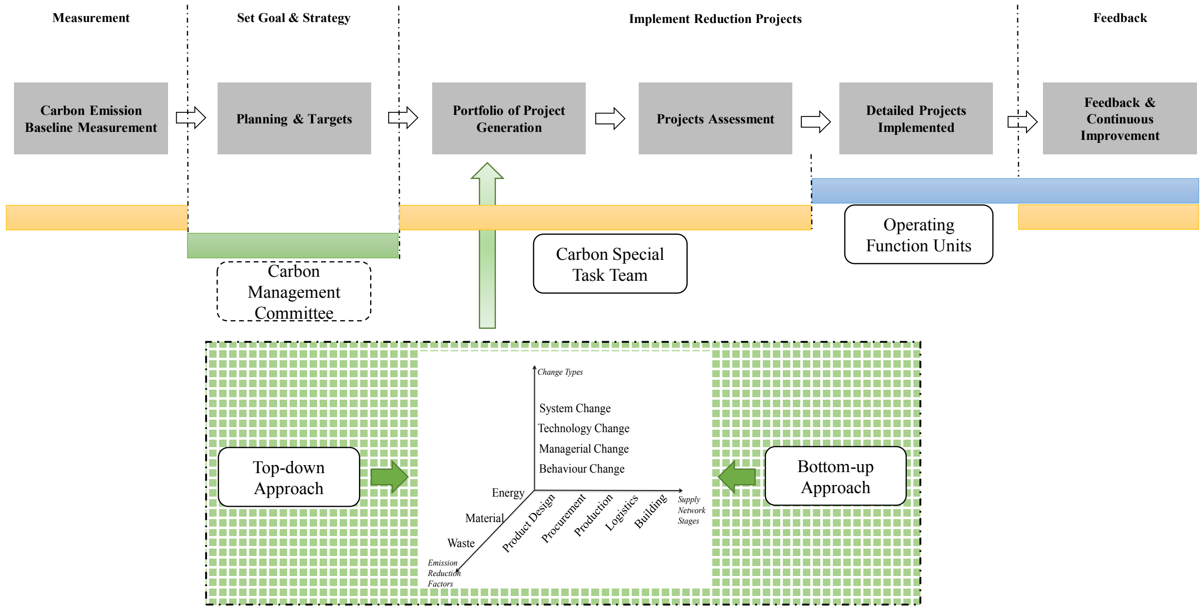


Figure 6.23. A Process Framework of Implementing Improvement Practices

The measurement to corporate a supply chain level emission is the first step and it sets the baseline which is needed to create carbon reduction targets and plans. The plans and targets are normally proposed by the 'carbon special team' and determined by carbon management committee.

There are three steps to implement the reduction projects:

- Generate portfolio of projects

The carbon special task team collects and generates the project portfolio, using both the 'Top-down' approach and 'Bottom-up' approach. The classification model of reduction practices shown in Figure 6.23 can be applied by the team to group and design potential actions.

- Assess projects

The project portfolio needs to be assessed and some of these projects are selected to implement it. The firm sets selection criteria according to its own context and targets. Feasibility, cost & benefit, payback period, and risks are four common aspects to consider. In the Tsingtao Brewery case, five criterion are used: the innovativeness of the project, feasibility & complexity, carbon reduction potential, economic return and cost.

- Execute projects

The selected projects are executed by different departments and supervised by the carbon special task team. In the AUO case, a tactic is applied--comparative experiment of reduction project was conducted in two plants to test its utility.

After implementing the projects, feedback and continuous improvement are in need. Case companies devise monthly, quarterly, or half-annual reviews and report to the senior management group in order to gain timely feedback. Both the functional departments and carbon special team are responsible for the project's success, and achieving the reduction target as well. Continuous improvement tools—e.g. P-D-C-A (Plan, Do, Check, Action) is applied, together with annual audits and "Green Award" to cultivate the environmental protection culture of the firm.

6.5 Chapter Summary

After the carbon emission is measured, carbon emission performance is logically the next step. Based on the case study, this chapter discussed the improvement practices in case companies, idea generation processes and the supporting system to enable creating improvement recommendations. From the survey data from CDP Supply Chain Program, best practices in Electronics, Automotive, Food & Beverage, Chemical industries are summarized and compared. An initial list of practices is illustrated as a reference. Based on analysis to the case data, an initial framework to classify improvement projects is presented, which aims to grid most of practices. Based on this framework, the process model to implement reduction projects is proposed, and also, which is just as important, the internal organizational supporting system to facilitate these projects.

CHAPTER 7 FINDINGS, DISCUSSIONS, AND CONLCUSIONS

7.1 Introduction

The changing environment under the pressure of climate change urges practitioners and researchers to update the theory of their green operations management and especially set up a theory for mitigating global warming. This research contributes to the study of a low carbon supply network management. It structures and integrates existing knowledge and generates a comprehensive and in-depth view of the emerging new network redesign for the purpose of reducing carbon emission. This study into the carbon-related change of the supply network can help researchers and practitioners understand and manage the transition of supply network from a current mode to a low carbon emission mode. At the same time, taking the carbon management issue as an example, this study will shed light on the following: research of organization networks, the institutionalization process of organization, the life cycle assessment of the network and also network change management.

This chapter summarises and highlights the key findings of this research, and will give further discussion to the issues mentioned in the separate chapters, by linking these issues together. This chapter starts with an integrating framework which presents the findings part of the conceptual framework. According to the three main components in the conceptual framework, the findings in these parts are discussed separately. Firstly this research has identified the crucial resources of the firms, based on which resource mode for the firm is suggested The research then suggests an influence model to be applied to the firm, and the content and steps of influence process. Secondly, the research develops a goal-oriented process model for a carbon footprint measurement at the network level, and patterns of measurement according to these purposes. Thirdly, a carbon reduction project implementing process model is advocated, based on an initial framework to classify improvement projects. It is then followed by suggesting the theoretical and practical implications, and also the limitations of this study. In the end, the research opportunities are discussed and the future studies are planned.

7.2 Major Research Findings

7.2.1 Overall Influence-Measurement-Improvement Framework

This section discusses the findings of the IMI framework as a whole, and its application to supply network improvement for the purpose of reducing carbon emission.

In previous chapters, an overall framework showing the transition to a low carbon emission supply network was built via analysis from the cases, as shown in Figure 7.1. The Framework consists of three parts: network influence, emission measurement and network improvement. These three parts are linked in order to depict the change process of the firms in the network under the carbon-related pressure. The three steps, namely influencing firms, measuring performance, improving performance, provide a holistic view to re-configure the supply network.

The model serves as a new type of supply network reconfiguration process. Being different to traditional supply chain redesign methods, this model aims to provide new research which will improve the supply network in a continuous improving way. Also, the framework works in a loop, starting from its influence, and as improvements are implemented it encourages the participation of more firms in the same industry. This loop links back to influence more companies. The overall framework also complies with the institutional process of low carbon institutional practices.

Except for the loop back from improvement to influence, there are also underlying links among the three components. Though these linkages are not empirically tested, some hypothesis can be raised: 1) The way the firm is being influenced has impact on the firm’s choice of measurement; 2) The hot-spot analysis of the firm’s carbon emission performance which is gained from the measurement action also leads to the choice of reduction practices.

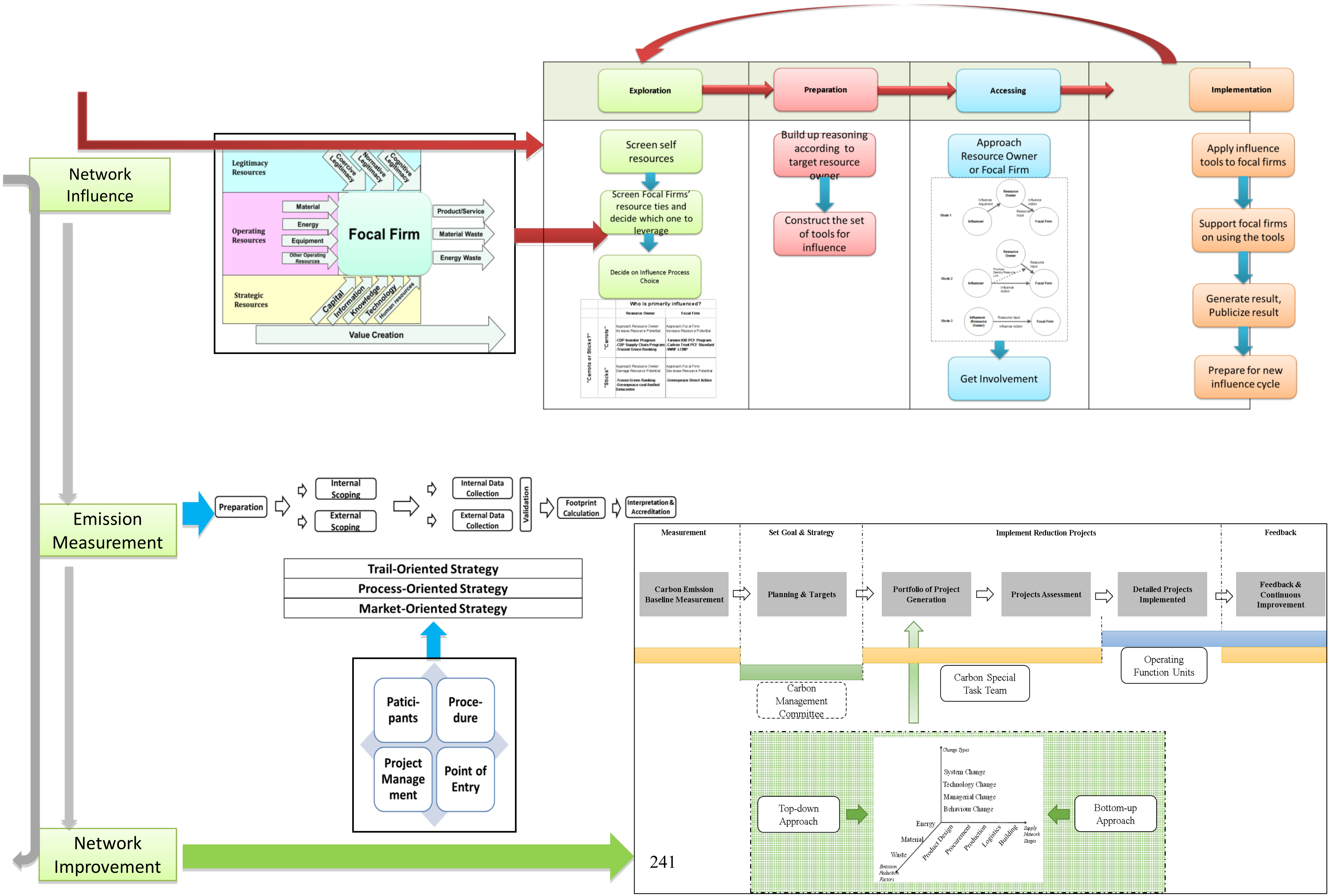


Figure 7.1. IMI Model

7.2.2 Influence Process

This section summarizes the findings in the building block of network influence process.

Resource Model

The analysis of the influence process starts from the categorization of the firm's resources. This research takes the view of resource dependence theory (RDT): organizations, which hold critical resources that firm need to acquire externally, have power over the firm, then sequentially can influence the firm's behaviours (Salancik and Pfeffer 1978). Resources that are needed by firm are categorized into three types:

Table 7.1. Explanation of Focal Firm Resources

	Resources	Description
Operational Resources	Material	The input manufacturing-related material and semi-products
	Energy	Includes electricity, CHP, fuel and gas, renewable energy, etc.
	Equipment	Manufacturing related equipment
	Other Operating Resources	Including infrastructure, land, etc.
Strategic Resources	Capital	The finance input to support firms' operation, including public listed, funds, and loans
	Information	Including industry information, market information, supply & demand information
	Knowledge	Organizational skills, management knowledge
	Technology	Including the manufaturing, equipment, process and industry technology,
	Human Resources	Including the people in plant, management and senior level
Legitimacy Resources	Normative Legitimacy	Recognition at the industry level (compared to its competitors) from customer, including the brand name, recognition as a trustful product/service provider
	Cognitive Legitimacy	Recognition from the end consumer, local community
	Coercive Legitimacy	Recognition according to the legislation
Output	Product / Service	The result of manufacturing, the products/services provided by focal firm that generates income
	Material Waste	Including physical waste e.g. waste water, gas, scrap
	Energy Waste	Including extra stream, heat and other fuel & gas

Operational Resources: The resources that are needed in a firm's production operation, including input materials, energy, equipment for production, infrastructure, land, etc. These resources are critical for firms to produce its product or service. And these resources are flowing in a short time frame cycle.

Strategic Resources: The resources that help firm sustain long-term growth, including Capital, Information, Knowledge, Technology for R&D, and Human Resources, etc. These resources usually take effect in a longer time frame compared to operational resources. And these resources are critical for firms to gain competitive advantage.

Legitimacy Resources: The resources that enable firm's legitimacy as a corporate citizen in industry, country, and society. These resources, or called legitimacy, include coercive legitimacy, normative legitimacy, and cognitive legitimacy. The coercive legitimacy are usually legislations and regulations.

Normative legitimacy consists of social, customer, and industry normative legitimacy. Cognitive legitimacy originates from the both the local community and society as whole. The legitimacy resources do not directly contribute to the firm's operation, but hold a mediating effect on the allocation of operational and strategic resources mentioned above.

The dependence of the firm towards one specific resource has a moderating effect on the firm's response to the requirements from the resource owner. The higher the dependence is, the greater the likelihood of the firm's proactivity to the requirement. This complies to the institutional process suggested by Oliver, an institutional theory researcher(1991).

Typology of Influence Process Choice

Based on the resource model and the case analysis, this research advocated a typology of influence process choice, from two dimensions, namely initial influence organization, and influence options. The initial influence organization refers to the first entity which receives influence pressure, and this entity may not be the focal firm itself but can be the holder of the focal firm's critical resources, such as an investor as shown in the CDP Investor case. Influence options refers to the way the focal firm is being influenced, either by a "Stick" or a "Carrot". This typology sets up a grid and a potential mapping useful for any organization that decides that they want to influence certain targeted firms in a supply network.

Influence Process Model

Based on the resource model and typology of influence choice, a four-step influence process is suggested in the research, as follows:

Exploration: the organization that exerts influence needs to examine its strategic position and the resources it holds to determine what type of influence choices are available;

Preparation: the organization constructs the relevant arguments according to influence choice. And the relative tools are prepared in this stage;

Accessing: The organization then approaches the influence entity, either focal firms or resource-owner to begin exerting influence, persuading/controlling the entity to take action on carbon reduction;

Implementation: The actual process of implementing the influencing action, applying tools, and collecting the feedback from the influence process. Some of the action happening in the implementing stage leads to the next round of influence.

The research then discussed some hypothesises on the relationship between resource ties and the effectiveness of the influence action. The capital links have a strong influence power in the developed market. The customer normative legitimacy has stronger power in both the developed and developing market. The industry normative legitimacy can influence more SMEs.

7.2.3 Measurement Process

In answering the research question "How can carbon emission be efficiently measured in supply network?" This research proposed a three-scenario measurement process model according to the focal firm's aim of measuring carbon emission. The three types of aims are classified as: "Pilot-Oriented", "Process-Oriented", and "Market-Oriented".

"Pilot-Oriented": aiming to make an attempt on carbon footprint measurement. This is a brief examination of the product carbon emission performance, and usually it is the firm's first attempt to measure the carbon footprint. The main aim for firms is to initially understand the new carbon footprint requirement, and prepare itself for a more detailed measurement in the future. So most of the emission data is collected from a database, rather than from actual activities;

"Process-Oriented" or "Hot-spot analysis": this type of measurement aims to implement continuous improvement along the supply chain, so most of data used are collected from primary activities rather than from using a secondary database;

"Market-Oriented": This type of measurement aims to gain a product carbon footprint certificate according to the available PAS2050/ISO14067 protocol, which may benefit the firm's brand. So every step of the footprinting process strictly follows the requirement of these standards.

According to the case data and PAS2050, this research advocates a four-step measurement model, namely "preparation", "data collection", "calculation footprint", and "post measurement". This four-step framework can be applied to different business levels, from plant level, corporate level to network level. Within each main step there are several mini-steps to fulfil the task.

Platts' 4P model has been applied to summarise the characteristics of these measurement activities:

Participants: internally the participants include different functions such as manufacturing, R&D, logistics, procurement, and marketing etc. On the depth level, the involvement of senior management is critical to the success of the measurement. Externally, consultants, industry associations provide the knowledge and skills needed for the learning process. Especially those consultants working in an environmental consultancy can best tutor firms to start from the beginning;

Point of entry: the method of entry into business unit and platforms. The effective measurement project should start from top-down, forming a special footprinting team that consists of professionals from different functions. Without the direct task from senior management, the measurement team suffers difficulties in communication with the multi-functional departments and also in the gaining of primary activities' data.

Project & Process Management: multiple groups should be formed to support the measurement project: managing group—the support from senior managers to enable communication & cooperation. Supporting group—the internal 'expert'/facilitators who embrace the actions of arrangement, guidance, and details-checking. Operating group—the people who do the real work by collecting data, and assessing the requirements of the footprint activity. They are supported by tools and methods that are specially designed for this purpose. A time scale is set in place in most cases, which last from 3 months to 9 months depending on the aims of the measurement and expertise of the team.

Procedure: the procedure of the carbon footprinting are explored in the three types of measurement described above.

7.2.4 Network Improvement Process

The research question "How can firms reduce carbon emission in supply network?" leads to the re-design/reconfiguration of not only the firm's own operation but also its supply network. Based on the analysis to answers from 1800 firms in the CDP's Supply Chain questionnaire database, this research summarized their carbon emission reduction activities into the 5 categories: Product Design, Procurement, Production, Logistics, and Building (see Table 6.18 in Chapter 6).

Four industries, automobile, electronics, chemicals, and food & beverage industries, are analysed because the products of these industries have a larger impact from their supply network compared to other industries.

The reduction practices focus on the production, according to the data shown in all four industries, because manufacturing is the easiest access part. Second focus is the building category, which is rarely mentioned in literature. The building-related improvement actions are easy to implement and the opportunities are 'low-hanging-fruits' which are usually taken by the firm in the first stage of carbon reduction. The design of products and packaging is an important part of the improvement due to its implication to all the other functions. Though the supply chain issue have raised awareness, practices towards procurement management are still in low. Recycling from waste is also not tackled much in all of the four industries but it has a lot of potential.

Based on the type of operation changes, and the source of carbon emission, an initial framework to classify carbon emission improvement projects is proposed in this research. This framework combined three dimensions. The first dimension is the 5-category gained from the CDP Supply Chain questionnaire: product design, procurement, production, logistics, and building. These 5 categories comply with the traditional supply network stages, except for the 'building' type. But since the 'building' type includes relatively independent practices along with the 'manufacturing' category, so it is also set as a parallel type. The second dimension of the model is the sources of carbon emission according to PAS2050: energy, material and waste. In the carbon footprint calculation guideline of PAS2050, the emission factors are mostly converted from energy consumption, the carbon footprint embedded in the material used during activities, and the emission of waste which is generated in the product's life cycle, except for some special occasions such as land-use change. The third dimension is the types of change, classified as behaviour change, management change, technology change and system change. This classification chosen can be traced back to the answers received in the CDP questionnaire. These three dimensions can grid most of improvement practices. Based on this framework, the initial reduction project implementing process model is built, together with portfolio generation and internal management support which are key to project success. This classification framework provides a practical guide for managers to identify potential spots of improvement for them. These indicators can also be widely used in the network performance (in terms of carbon emission) auditing, bench-marking, and capability evaluation.

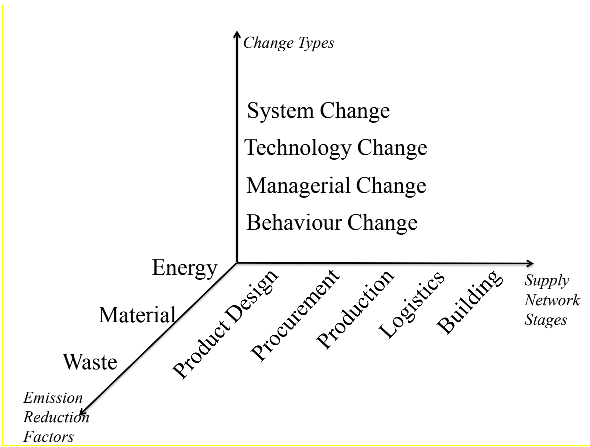


Figure 7.2. An Initial Framework to Classify Reduction Projects

7.3 Further Discussions

7.3.1 The Effectiveness of Influence Pathway under Different Context

The effectiveness of resource ties that are used in the influence process are discussed in the section 4.5.2. With the uncertainty affecting the firm's environment, firms are currently facing the institutional pressure for carbon reduction from multiple stakeholders and also industry rivals as well. What type of resource links are triggered can cause different pressure to the focal firms and how they respond. It is found in the cases that one effective resource link in a certain context is not applicable or much less effective in another context, while some of the resource links work powerfully in multiple contexts, for example the success of CDP Investor Program in western countries did not replicate itself in Asia, while the power from customer works equally effectively in both west and east. Olive (1991) discussed the predictors of an organization's response to institutional pressure, stating "Organizational responses to institutional pressures toward conformity will depend on why these pressures are being exerted, who is exerting them, what these pressures are, how or by what means they are exerted, and where they occur". These five antecedents are summarized as cause, constituents, content, control, and context. This research gives a different perspective of structuring these antecedents, from the view of Resource Dependence Theory (RDT), and the resource linkages between firm and its environment. It also provides a more practical view of the predictor of the firm's response to the pressure. Based on the section 4.5.2, the propositions are given as follow:

1. For influence pressure from government's guideline, regulation and legislation—firms in all markets, sectors and of all sizes are less likely to resist; For influence pressure from investor—exchange legitimacy from strategic resource, firms in developed market are less likely to resist;

2. For influence pressure from customer—exchange legitimacy from operating resource, firms in both developed market and emerging market are less likely to resist;

3. For influence pressure from certification organization—normative legitimacy from standards, firms in consumer-oriented sector are less likely to resist;

4. For influence pressure from media—cognitive legitimacy from general public, firms in developed market are less likely to resist;

7.3.2 A Potential Model for Low Carbon Supply Network

The examination of multiple cases shows that, in order to tackle the carbon reduction issue, the traditional supply network actors and structure are not sufficient to the new requirement. A new construct and configuration of the network should be considered under the new context. The new actors, including government, industrial association, consultants, etc. and new activities and new relationship between actors should be added. Figure 7.3. shows the expanded model of Low Carbon Supply Network.

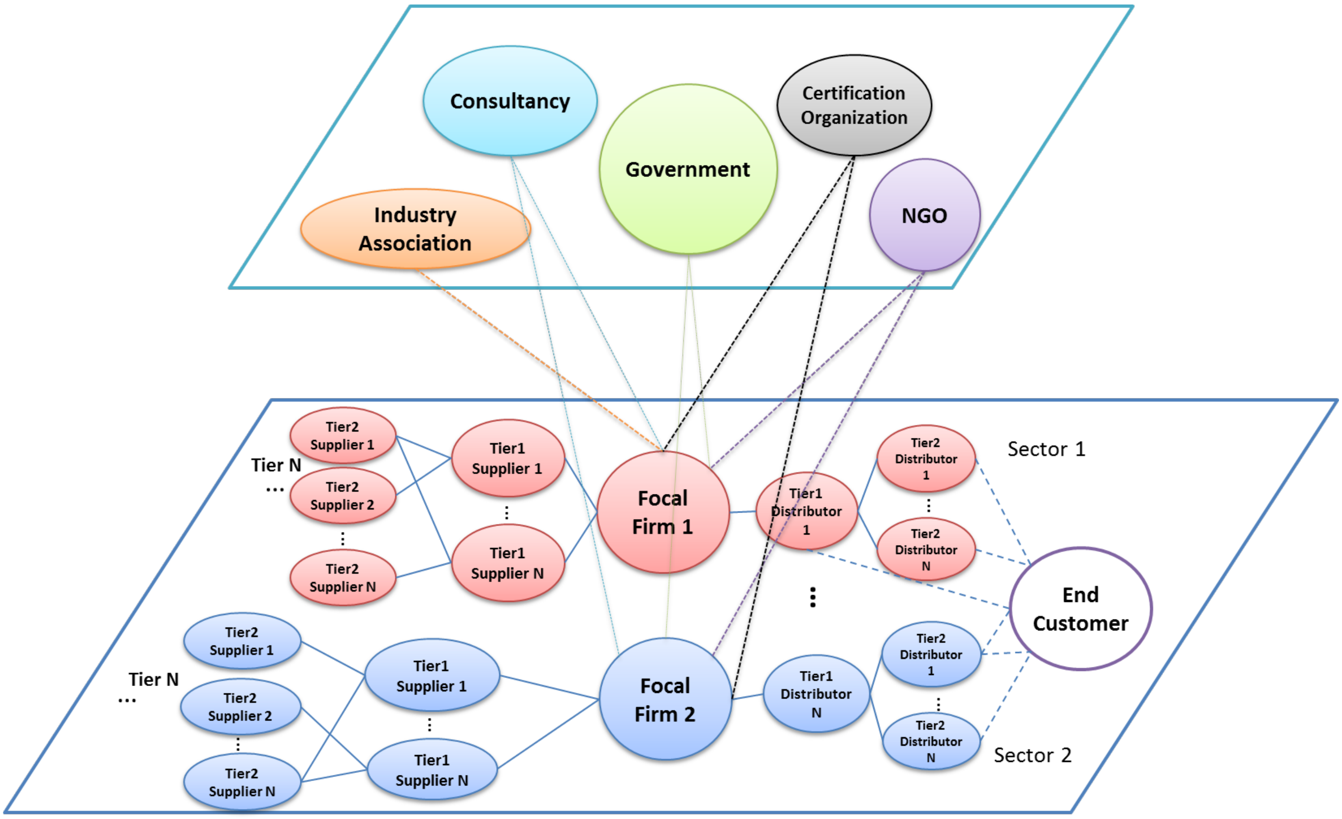


Figure 7.3. Expanded Low Carbon Supply Network

The added actors can generate the influence pressure for firms in the network to take action in carbon reduction. As well, other resources, e.g. knowledge and information flows into the firms to assist their projects of measurement, and improvement.

7.3.3 A Process for Shifting to a Low Carbon Supply Network

The above discussed the possible future of forming a low carbon supply network at the cluster level. At the firm level, the steps to change to a low carbon supply network has been partially discussed in Section 6.4 – the framework of the carbon emission improvement process as shown in Figure 6.23. In this improvement process, it has not clearly discussed the relationship between the different influential factors, and the selection of the low carbon practices, as it is not fully supported by the case data. In this section a further exploratory discussion is conducted.

From Figure 6.23 it can be shown that for the improvement process, after the general portfolio of a potential project is generated, there should be an assessment of the projects in order to select the implementation projects. In the following Figure 7.4, a process for this project assessment is presented. The resulting portfolio generation is the input of this process. Then these projects are selected step by step through three stages: effectiveness mapping, external pressure filter, and corporate strategy filter.

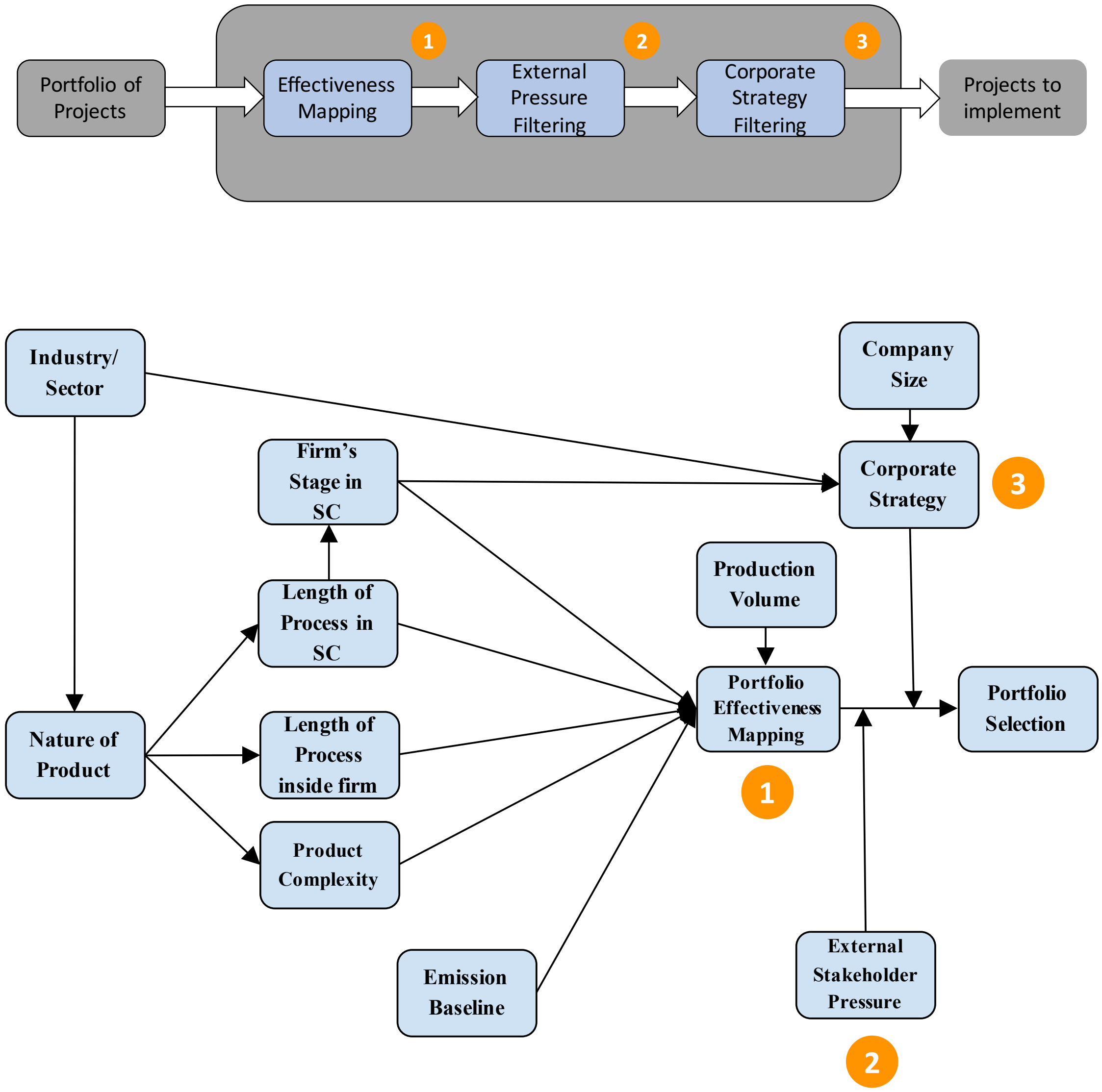


Figure 7.4. Steps for a Project Assessment

The first assessment step is to evaluate how effective is the potential implementing project on reducing carbon emission. There are many factors affecting the reduction performance of selected projects, e.g. the nature of the product, and the supply chain stage which the focal firm is in. The following effectiveness mapping section will discuss the related factors.

1. Effectiveness Mapping

- ➢ Industry/Sector

The sector/industry which the company is in will have a major effect on the nature of the product, though there is variance in the exact design of the product by different producers. The industry/sector also has a great impact on the corporate strategy on how this corporate decides on the selection of its decarbonisation practices, as discussed in Chapter 4. Not all industries have put climate change on the top of their agendas.

- ➢ Nature of the Product

The nature of the product is impacted by the industry or sector that the focal firm belongs to. And the nature of the product has a large impact on the effectiveness of these projects, as it reflects the product's complexity, the process length of the product inside a firm's scope and also the total length of the product process chain. As discussed in Chapter 6, the process-oriented product requires the firm to focus on improving its production stage, building a power system design, its energy source, and its waste reuse and technology/system change; the firms with an assembly-oriented product would focus more on the product design (including the consumer usage stage), procurement function, material efficiency/reuse, and behaviour/managerial change.

- ➢ Product Complexity

The more complex the product is the more opportunities there will be for decarbonisation at the product design stage. The less the complexity of a product is means more attention is given to the production stage practices.

- ➢ Length of Process inside a Firm

If the length of the process chain is short then the firm will be focusing more on the production stage, energy aspects and any technology change. If the length is long, then firms would more likely explore the potential at the product design stage, as well as material and waste efficiency, and systematic change.

- ➢ Length of the process chain in the Supply Chain

If the process chain is long, then it relates to the stage that the firm is located in, which is discussed in the following paragraph. If the length of the process chain is short then more attention should be paid to the production stage, as well as building management, energy and waste oriented management, and technology oriented change. Taking the case of steel manufacturing as an example, the overall supply chain for a steel product (not including the sub-products such as chemicals) is short, and companies, e.g. China Baowu iron & steel and China Steel, are focusing on their energy efficiency and industrial symbiosis practices.

➢ Firm's Stage in the Supply Chain

For a long length supply chain, the closer it is to the origins of the value chain, the more likely the product will be less complex, and will become the raw material of later products; therefore, the firms will focus more on their production stage decarbonisation activities and on reusable material/material reduction. At the same time, these firms are less influenced by the end consumers, but are influenced more by institutional pressures; The closer the firms are to the end customers the more these firms will focus on their product design for the customer's usage, by demonstrating they are more carbon-efficient, and also in the procurement part because the carbon footprint from the upstream supply chain plays a significant role as well.

➢ Production Volume

The production volume is partially affected by corporate strategy; however, the main consideration, when deciding production volume, falls into customer demand rather than in its sustainability aspects. In terms of production volume, the more volume that is produced means that the firm will focus on the product design, and material oriented management, as the high volume accumulates carbon emission reduction potentials. If the product volume is small, the firm will focus on the production/building stage, and energy management.

➢ Emission Baseline

The result of a carbon emission baseline measurement gives out the emission profile of the firm's supply network, which can also be used as the baseline for setting targets and plans. The result shows the performance of each section in the supply chain. The hot-spot of a carbon footprint points out the focus of low carbon actions, e.g. the labelling stage for Tsingtao Beer and production stage for AUO screen manufacturing. However, these steps may not represent the first batch of actions because it may not be the focus of external stakeholders, or the cost/return of potential actions may not be positive. The emission baseline is just one of the factors demonstrating carbon reduction effectiveness.

2.External Pressure Filtering

The pressures from external stakeholder to the focal firm play a vital role in affecting the assessment of any project, which have been given in detail in Chapter 4 on the factors influencing firms. The pressures from different dependent-resources of firms will impose a unique impact on the firm's behaviour. And the behavioural changes of the firm place a reverse impact on the resources-holding stakeholders' further actions—to strengthen the pressure or loosen the pressure. Therefore, the firms' decarbonisation action reflects the requirements from the resources-holders.

In the CDP investor programme, the firms made changes to disclose their carbon emission profile. While in the CDP supply chain programme, the enrolled firms put pressure on their suppliers to disclose their emission profile. Also in the Greenpeace 'Dark Cloud' campaign, the IT companies were required to change the energy source supply of their datacentre to reduce carbon emissions. Then Apple gradually switched to using solar power in their Californian datacentres. In the Tsingtao beer example, as a requirement stipulated from a European retailer, the firm implemented carbon footprint labels, though it does not directly reduce carbon emissions. The pressure filter provides an indication to firms which projects should be targeted in order to satisfy stakeholders. However, these projects may not be either carbon reduction effective or cost effective. Some projects are carbon effective, but are not required due to external pressures, while for other projects they are required but are not carbon effective for the focal firm. The actual selection of the projects is still decided upon according to the firm's overall carbon strategy.

3.Corporate Strategy Filtering

The carbon-related corporate strategy is determined by many factors. Corporate size, the industry/sector, and supply chain stage that the firm is located in are the three main factors. Embedded in the same industry/sector and supply chain stage, firms play on the same institutional field suffering from similar institutional pressures (carbon reduction pressure). Then the firm's size determines how much bargaining power it has, and then this indirectly affects its selection of carbon projects.

- Company Size

Company size firstly plays an important role on corporate strategy. The large companies usually have more bargaining power in the industry; therefore, they would set up a corporate strategy to form normative legitimacy at the industry level. On the other hand, the small companies are at the beginning ignoring the requirements to reduce costs, and then only later are they following the industry's normative requirements to obtain the resources. The larger the company size is, the more likely the company will take decarbonisation as its top agenda.

The company size also affects the selection criteria of projects. In order to form normative legitimacy, the larger company would pay more attention to the supplier management—procurement management, because normally the large company has more power influencing the supply chain. As well as this the large company has more resources to tackle waste management, such as industrial symbiosis and the use of renewable energy, such as China Steel in Taiwan. In terms of the process change type, a large company would pay more attention to the behaviour change and managerial change rather than the system change. Due to the operation scope of a large company, the first two-level changes (behavioural change and managerial change) have provided sufficient space for an action-to-do. For a small size company, relatively, the operation scope is small; therefore, the firm would focus on innovative product design and energy usage, as well as some new technology changes to its decarbonisation.

The industry/sector in which firms are located determine the coercive institutional pressure and normative pressure. And the stage of the firm in the supply chain determines the normative and cognitive pressure. Both factors position the firm in the special institutional field with carbon-related pressure for action. But the forming of a firm's corporate carbon strategy is related to many other factors.

The firm's overall strategy and objectives also guide its carbon strategy. The firms which take on a 'cost leadership' strategy may focus on saving cost activities, such as switching to energy saving plans, etc. The firms with a 'differentiation' strategy may focus on carbon emission labelling and pay more attention to external communication. The firms with stronger power in the industrial system may pay less attention to external pressures. Firms which are market-oriented need to pay more attention to external requirements. A firm's corporate carbon strategy has a key impact on the selection criteria.

There are multiple dimensions of these criteria, while the fundamental two dimensions are the carbon emission reduction per product and the cost of implementation. Other dimensions include project feasibility, pay-back period of projects, risks, etc. As described in Chapter 6, Tsingtao Beer also considers the novelty of a project. Firms have their own rating to these different criteria: carbon effectiveness, cost, external pressure sensitiveness, novelty, feasibility, risks etc.. With different carbon strategies, the firms will select different carbon reduction projects, which usually will be high in carbon effectiveness, be cost efficient, and also will have complied to external pressure. And the next step will be executing these decarbonisation projects, which is also shown as the next stage 'Detailed Project Implementing' in Figure 6.23.

4.Detailed Projects Implementing

The carbon management committee performs the three filters especially the corporate strategy to determine the proposed projects. The next step is for the carbon special team to coordinate external support with the internal function departments for implementing decarbonisation projects. For the projects within the scope of a single department, they are implemented by staff from the department and the carbon special task team. For example, shifting to renewable energy in a production line is usually rolled out by the manufacturing unit, and shifting the building to solar power is rolled out by the facility management unit. The carbon special task team provides an external guideline, industry level specification, and project management supervision. For projects which are related to external parties, such as suppliers and customers, the carbon special task team will be involved in the external communication between the supplier/customer and the firm. These types of projects are usually handled by the procurement department and/or marketing department. Considering the 4P model proposed by Platts (1994), the following figure explains the participation of different function units for projects in the portfolio. The functions units are consistent with Porter's value chain model (Porter, 1998).

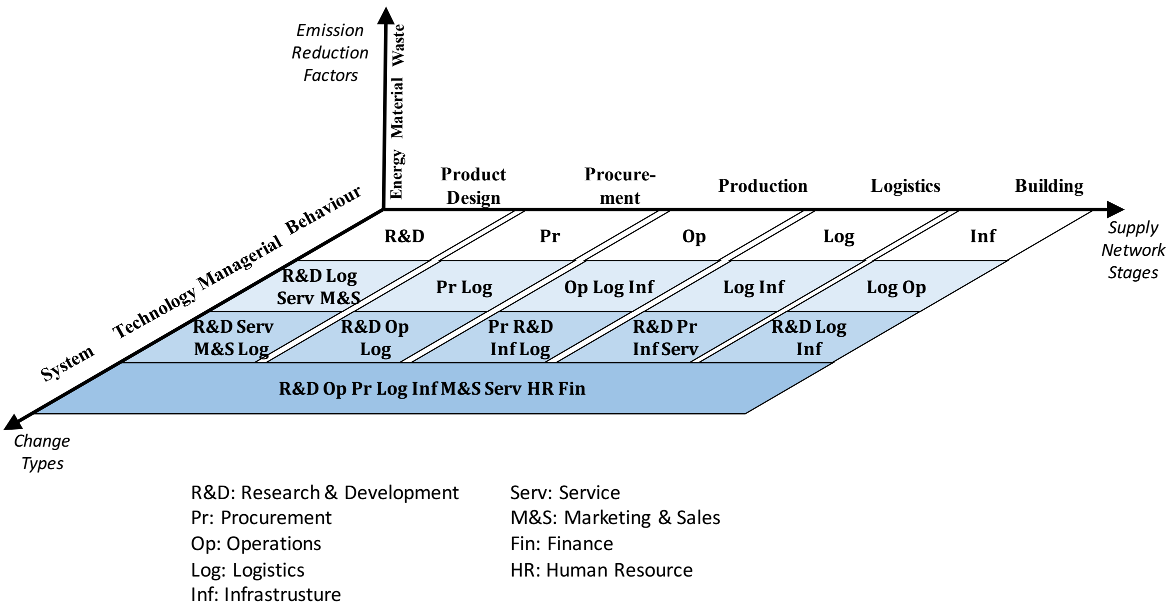


Figure 7. 5 The Participating Units in Detailed Projects Implementing

7.3.4 Differences and Similarities Between Chinese and Western Companies in Developing Low Carbon Supply Networks

In this section, the comparison between Chinese firms and western firms (taking UK & US as an example) will be discussed, including the differences and similarities.

1. Differences

In this section, these differences will be discussed in the three main themes of the overall framework, namely Influence, Measurement and Improvement.

1. Influence Stage

- *Most Influential Resource Tie*

As we discussed in Chapter 4, the firms are influenced to take decarbonisation action by the control of the resource input. Therefore, the external stakeholders try to control the critical links of resources in order to obtain a strong influential impact. When comparing Chinese and Western firms' cases, one of the obvious differences is the power of the shareholder in public listed companies, which is the 'Capital' resources link. For western firms, the capital resource link seems to be much stronger than it is for Chinese firms. This point is demonstrated clearly in the CDP Global 500 project and CDP supply chain case project: The western public-listed companies, such as Dell and Shell, are actively attending the CDP project, while most of the listed companies in China are not attending this project to reveal their carbon emission. It is due to multiple reasons, which have been discussed in Chapter 4. The second difference we have noticed is that the cognitive legitimacy resource link works better for western firms. This is partially due to the fact that the education of sustainability to the general public is more advanced, and has a longer history in the western world than in developing countries such as China. Normative legitimacy is more powerful for Chinese companies, and this is the third difference we have found. As many of the Chinese and Taiwanese companies' products are exported to western countries, the normative pressure from the customer and rival competitors is critical for them. Therefore, the resources link works well for Chinese firms, which is demonstrated in the CDP supply chain project.

- *Influence Process Model*

In the influence process model (Figure 4.22 and Figure 4.23), we compared the reaction of Chinese and Western firms and found that the first difference is that Chinese firms are more reactive to the indirect influencing mode, which means the external stakeholders have to start the influential process from the resource owner first rather than directly contact the focal firms. The reason for this can be that most Chinese firms are taking a 'Passive' strategy in their carbon-related actions, when compared to many of their western peers who are taking a 'Proactive' strategy. The second difference is that the 'Stick' mode (or stated as the 'Punishing' mode) is more effective for Chinese firms compared to Western firms. Chinese firms are more focused on the short-term economic benefits; therefore, the direct reduction of income will put the carbon agenda as a priority. While the western firms usually take a longer-term consideration to the future trend of the industry when making strategic planning.

2. Measurement

There are also many different points between Western firms and Chinese firms when conducting product carbon footprinting.

- *Measurement strategy*

In the three types of product carbon footprinting strategies, western firms have tended to apply process-oriented ones, while the Chinese firms would either take the pilot-oriented strategy or market-oriented strategy. There are several reasons for this strategy selection: 1. Western firms are usually taking the long-term development perspective, and are therefore more likely to adopt a ‘Proactive’ attitude on the carbon issue, while Chinese firms are likely to adopt a ‘Passive’ attitude; 2. Western firms have long been educated with climate change related knowledge, and are relatively familiar with carbon footprinting guidelines and specifications. It eases the difficulties for implementing a product carbon footprint, which currently hinders Chinese firms. Chinese firms need more external resources to start their footprinting practice; 3. The well-informed end customers in western society are imposing high pressure on western firms to reveal their product carbon footprint which the Chinese firms are less exposed to. Therefore, western firms are inclined to conduct more detailed footprinting practices rather than their Chinese peers. However, the Chinese companies, which adopt a market-oriented strategy, are those that export most of their products to western countries. Therefore, they are keen to put on a carbon footprint label as a market requirement.

- *Measurement Process*

It is observed that carbon footprinting in a western firm is usually initiated and supported by the VP-level or Chief Sustainability Officer, which are relatively a senior level management team. In their Chinese peers the product carbon footprinting is supervised by the Chief Officer of production or quality management department. This reflects that the importance of the carbon issue has a different priority level in a firm’s strategy. Some western firms have incorporated the carbon consideration into their long-term strategy, while most of the Chinese firms regard product carbon footprinting as compliance. The other difference is that Chinese firms take a shorter time to finish their footprinting project when compared to western firms, because the communication between departments and external partners is more efficient in Chinese firms.

3. Improvement

In the decarbonisation project selection and implementation, the differences between Western and Chinese firms are also significant.

- *Decarbonisation Project Portfolio*

Reflecting on the framework generated in Chapter 6 (Figure 6.17), several differences on the selection of decarbonisation projects can be identified between the Chinese and Western firms' practices: 1. On the supply network stage dimension, Chinese firms focus on the production and building stage, while their western peers have a more extensive portfolio on their product design, procurement and logistics stages. As the manufacturing centre for the world, it is normal for Chinese firms to put more attention on the production part, which is more effective on the reduction of carbon emissions; 2. On the emission reduction factor dimension, western firms concentrate more on the waste treatment and reuse, while Chinese firms put more attention on energy efficiency and material reuse; 3. On the change type dimension, behaviour and managerial change are adopted more by Chinese firms, and systematic change is considered more by their western rivals. Especially in the case of British Sugar, the firm has developed an innovative industrial symbiosis system to fully reuse material and energy. It is due to the fact that behaviour changes and managerial changes are easier to pick up in the manufacturing context.

- *Portfolio Generation*

When considering the project idea generation, Chinese firms have a tendency to use the bottom-up strategy, as many energy efficient projects, and the reusing of projects with potential, are easier to spot in the production and building context. While fundamental product design type projects are found more in the western firms which belongs to the top-down strategy.

- *Internal Management*

Similarly, when conducting product carbon footprinting, Chinese and western firms usually both construct a Carbon Special Task Team to facilitate the implementing of improvement projects. However, the difference is that this special team is usually under the management of the Sustainability department in western firms, while it is under the Production or Facility department in Chinese firms, which has been explained above.

- *Improvement Process*

In the actual rolling out of reduction projects, the similarities of the process have been summarised in Chapter 6 (Figure 6.23) and are in four stages: measurement, set goal & strategy, implement project, and feedback. The first difference between Chinese firms and western firms is the application of the emission baseline. In western firms this result has a higher impact on the selection of the project portfolio, while for Chinese firms the economic return factor will have a higher impact. The second difference is that the continuous improvement principle is practised more in western firms after the first round of improvement. The feedback of reduction projects imposes an effect on the long-term sustainability strategy in western firms, and taking Dell as a good example the firm continuously monitors and funds its suppliers to go greener. While for Chinese firms the focus still falls into cost-saving; therefore, the improvement process stops after the first-round of implementation, without exploring any further possibilities of cutting carbon emissions in a continuous improvement manner.

2. Similarity

In fact the similarities of western and Chinese firms have been reflected in the overall framework, because it emerges from the cross-case analysis without considering the regions of firms. In general we have found that both Chinese and western firms are gradually incorporating the carbon reduction issue into their business strategy making, rather than it just being complied to due to legislation. Senior management officers have realised that the climate change issue is presenting not only risks, but also opportunities for business; and therefore action and innovation to develop a low carbon supply network should be one of their business goals. Although the direct carbon legislations are still not in place, the carbon legitimacy field is already formed separately in Asia, Europe and America. When firms are implementing carbon reduction projects along their supply networks, including multiple tiers' suppliers, down-stream customers, industrial partners, and other business ecosystem complimentors, the legitimacy is spread and diffused in the global industrial system. This legitimacy forms the necessary pressure for the rest of firms to gradually change their supply network to a low carbon status.

7.4 Theoretical Implication

7.4.1 The Relationship of Industrialization, Development and Climate Change Mitigation

This research provides a discussion on the conflict between industrialization development and environmental protection especially the global warming issue.

Manufacturing Paradigms

Manufacturing paradigms have in time by time attracted attention as a way of illustrating the holistic changes of manufacturing systems as they respond to dramatic changing environments (Doll and Vonderembse 1991). in 1990 Doll proposed the three stages of manufacturing paradigms shifting namely craft paradigm, mass manufacturing paradigm, and post-industrial manufacturing paradigm. New paradigms reflect practices but also guide industry in their re-structuring or re-engineering. Griffiths (2012) summarized the shifts according to different drivers: productivity, efficiency, customer, and sustainability, respecting the craft, mass, post-industrial, and sustainable manufacturing paradigms sequentially. From 1990s researches have begun to explore the impact of environmental requirements on the manufacturing system, but not until Sarkis's (2001) first systematic review of sustainable shift in manufacturing research has it been identified that sustainable paradigm is one of manufacturing development trends. According to the review in the literature review part. Figure 7.4 illustrates the key milestones in manufacturing system development and paradigms.

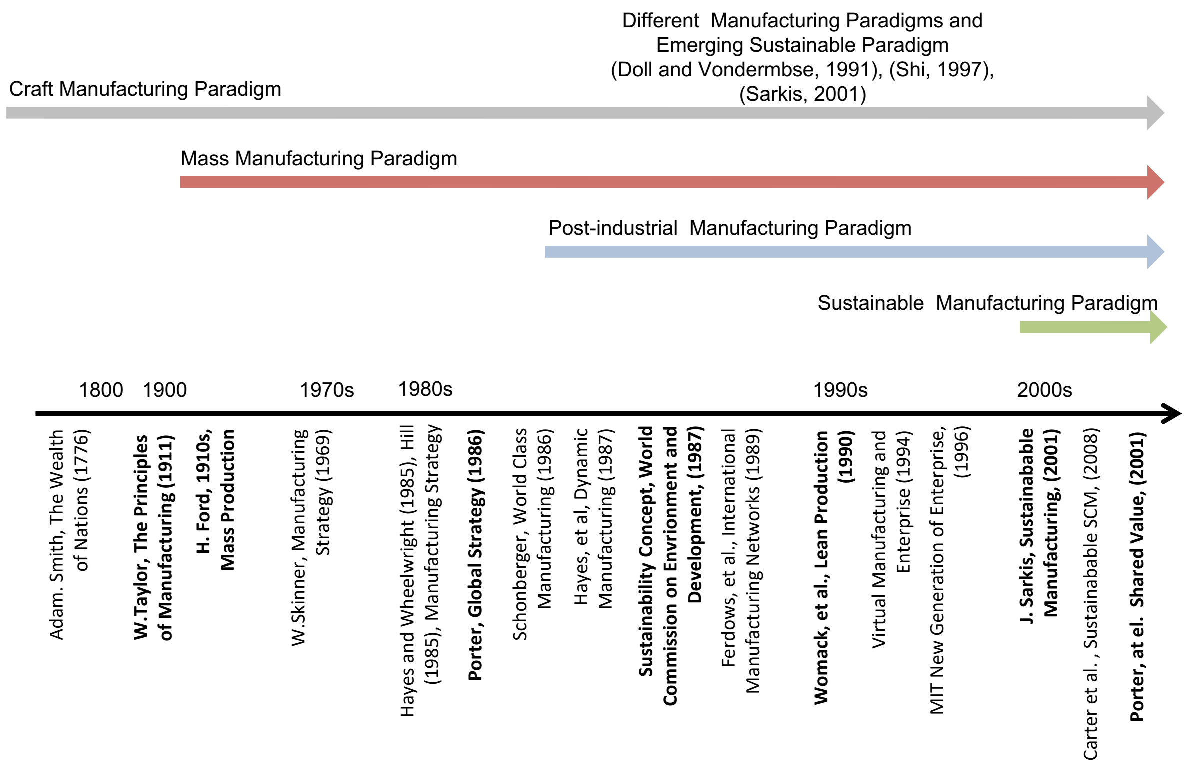


Figure 7.6. Milestones of manufacturing system development and Paradigms

(Source: adapted from Shi, 1997)

Low carbon emission is one of the requirements in sustainable manufacturing, and the most exigent one due to the irreversible global warming problem. The low carbon supply network, serving as a crucial format of sustainable manufacturing, represents totally different operation activities and design mind-sets from the traditional manufacturing paradigms. This research demonstrates these distinctive internal interacting, operation and re-configuring activities and patterns, which need to be considered in manufacturing strategy and system design during the transition to sustainability.

Even though the carbon issue has been targeted in the recent decade, there is still plenty of scope for research in the supply network research and issues to be addressed. Due to the lack of empirical data (there are still limited number of organizations with low carbon excellence) and the difficulties of covering multiple stage companies along the supply chain, most of the extant literature apply analytical modelling methods (Sundarakani et al. 2010; Ramudhin et al. 2008) . The empirical study on low carbon supply networks, including ones that apply a theoretical lens and conceptual theory building, can be of sufficient importance to build up the emerging manufacturing paradigm. The successful operation and design of low carbon supply network provides a foundation for leveraging the companies' internal resources and capabilities and developing external cooperation.

The manufacturing paradigms provide the alternative logic for manufacturing professionals and companies to change manufacturing structures conforming to the changed environments. But only the paradigm is not sufficient and adequate to guide companies on detailed manufacturing strategy and supply network redesign. A process oriented theory is an essential approach for practitioners, which this research aims to offer.

7.4.2 A Process Contributes to Sustainable Manufacturing Systems Paradigm

The IMI model proposed in this research contributes to the core step of the realization of sustainable manufacturing system paradigm. The developing countries have a large and still-growing population. Though the GDP per capita in these countries are still at a small amount, the aggregated GDP is larger than most of the developed countries. Most of these emerging economies follow the traditional industrial development model of Britain and US, these developments focus merely on economic development, while the environmental problems that come along with it is a exigent issue. The influence process in this research can contribute to the involvement of firms in these developing countries.

7.4.3 A Larger Theoretical Framework: How Does IMI Fit Into Industrial Systems

In the industrial system, there are different levels of unit of analysis, namely egocentric firm level, dyadic level, supply network level and the holistic business network level that includes several supply networks and their relevant stakeholders.

The IMI process, "Influence, Measurement and Improvement", can be applied at the multiple levels to serve the purpose of low carbon transition. Starting from the single firm level, the external organization can apply the influence strategy to exert pressure towards the focal firm. And the measurement and improvement processes method can be used to support a firm's improvement activities. The IMI-process diffuses to the dyadic relationship between a focal firm and other stakeholders. Other actors along the supply network are involved because of the linkages between actors along the chain of material flow, as well the measurement of the product carbon footprint and carbon reduction activities which should be conducted with the attendance of these actors. At the business network level, the influence activities diffused outside one sector to other sectors in the format of carbon reduction knowledge and social network connections. The measurement of carbon emission turns out to be the regional or multi-sector emission audit process, while the improvement projects can be organized in a broad scope with optimization/configuration to all relevant supply networks together. So, along the iterative process in different levels of industrial systems, IMI serves as a method of industrial system transition, starting from the basic granularity which is the focal firm.

Some outstanding companies, like China steel and TSMC, have started the diffusion process of carbon related practices. Some of them cooperate with their customers to develop low carbon products; Some of them argue with their equipment manufacturers ways to improve the production process energy efficiency; Some engage with the local government policy makers to set up a more aggressive policy on carbon reduction; Even sharing knowledge across industries, some firms have set up a team of experts with carbon reduction experience to tutor firms in irrelevant sectors.

firm and successful experiences to operate carbon reduction practices internally. Without the strong power over suppliers, it is difficult to pressure suppliers to take action, and the customers as well. Successful implementation of carbon reduction practices strengthens a focal firm's internal capacity on communication and operation re-design. Also the low carbon knowledge and skills need to be gained through previously successful experiences. This research suggests that the first step for focal firms should be to optimise the internal structure on environmental issues, to establish a corresponding team, group or even department, and then consistently conduct low carbon practices in different aspects to accumulate experience, and then finally extend its attention to influence external business network members and cooperate with them on carbon reduction projects. This dynamic evolution of industrial systems toward a low carbon status needs more detailed case studies so as to further explore this issue.

7.4.4. Providing an Goal-based Approach to Carbon Footprint Measurement Activities

This research contributes to the life cycle assessment research on its application to the carbon emission measurement, especially providing a scenario approach based on the aims of measuring the carbon footprint. Different aims format the choice of activities conducted in each steps of the LCA. Although there is research on modification to the Life Cycle Assessment, such as streamlined LCA(Huang, Weber, and Matthews 2009; Hochschorner and Finnveden 2003), the condition of using a relevant LCA method and the engagement of suppliers during the LCA process is rarely discussed in extant literature (Pujari, Peattie, and Wright 2004; Brent 2005). This research probed into the coordination process of the LCA in the context of measuring the carbon footprint, as well as filling gaps in the carbon footprinting literature.

7.4.5 Theory Contribution to Operational Improvement

This research contributes to the operation improvement processes in the context of carbon emission performance. From the green supply chain perspective, the discussion on carbon reduction at the supply chain level is also rare in the supply chain management literature. The carbon issue provides a special view towards supply chain performance improvement, because the carbon footprint links all of the participants in the supply network, so the improvement practices in the supply chain also involve all related participants. The cooperative improvement practices are discussed in the literature of Life Cycle Management (LCM)(Balkau and Sonnemann 2010; Fullana & Palmer et al. 2011), product design with LCA methods (Zhang, Wang, and Zhang 1999), and supply chain coordination (Kumar and Putnam 2008), but the focus of research falls into chain-level interactivities. The carbon-related improvement activities that are analysed in this research provide a multi-level model of cooperation possibilities between participants in the supply chain and across the chain.

7.4.6 Re-examine the Network Theory

One of the contributions shown in this research is that we examine the network with a tangible/specific goal, and through this lens it will illustrate how the network linkages will be viewed. In the social network theory, the linkages/links are built without specific purposes. In the supply network, the links/linkages are examined with focus on the value creation and value flows through the linkages. Under the new environment requirements and context for the purpose of low carbon, sustainability, the network need to be re-visited and re-examined due to the expanding of parties/organizations involved. And this research provides a special lens to view the network, providing a specialized method to adjust the network towards a low carbon emission mode, and more importantly providing a potential solution for improvement actions. Hakansson (1987) advocated the network approach of business relationship with the triangle model of three layers of business relationship interplay: activity links, resource ties, and actor bonds. This research furthers the understanding to the linkages within each network, and more than just the resource ties. The social network links and institutional legitimacy links are both considered in this research.

7.5 Practical Implication

This research also supplies useful suggestions to practitioners whose work is related to the transition of supply network to a low carbon status, including firms' managers, consultants, governments, and non-government-organizations.

7.5.1 Exploring Appropriate Mechanism to Drive Non-economic Change in Supply Network

This research discusses the potential links between firms and external organizations, and provides two typologies in influence options and influence process which describes the potential paths for external organization or individuals. They are informed of the firms' resources model, the potential stimulating arguments that can be built upon, and the strategies that can be applied to influence focal firms. There are also examples demonstrating how this influence process is likely to vary under different circumstances. In this sense, the findings of this research serve as a guidebook illustrating the firm influencing process.

It should be noted that, however, considering the case study nature of this research that the findings in the research are not intended to be generalized to such an extent that it can cover every possible activity that affects firms, and any influence process should carry out all the steps in my proposed framework, to follow the influence strategies. Rather, the findings provide a reference for organizations or individuals to understand the potential solutions and the underpinning drivers for firms to implement non-economic-driven change. Especially, which influence strategies are more powerful in which circumstance still highly depends on the special situation.

7.5.2 Providing a Preliminary Carbon Management Strategy in Supply Network

The "Influence-Measurement-Improvement" framework provides a logically executable guideline to manage transition of supply network towards the reducing carbon emission target. Process models in each section are given out as a guideline to managers, of approaches to achieve the embedded aims in each steps, namely influence other firms to take actions, measure the carbon performance at network level, and implement suitable projects to improve the performance. Especially for the measurement part, the goal-based approach illustrates the detail steps in carbon emission measurement. The action suggested in the each steps are tailored according to the aims and carbon footprint measurement principles. And compared to the PAS2050 guidelines, this research presents a more practical and handy approach for managers to conduct relevant projects. These approaches cover the advice for the preparation of a project, coordination with suppliers and contractors, and project management during the whole life cycle. These approaches are particularly relevant to the aims of companies who want to conduct a carbon footprint for their company, so it has practical significance to guide managers. The effective implementation of the measurement gives a mapping of the hot-spots of carbon emission in the operation, and also lays a foundation for the improvement focus and overall management of network as well. The successful implementation of the measurement project can enhance the supplier management, and transparency of the supply network as well.

7.5.3 Providing an Initial Guideline and 'Best Practices' for Carbon Footprint Improvement

The project classification framework advocated in this research provides a reference for managers to consider potential improvement practices. Compared to traditional thinking in supply chain management, the model emphasizes the 'Building' as one of the categories to consider, which includes the lighting, air control related issues in both the production plant and office environment. The 'building' related improvement, though obvious, still include a majority of the practices implemented by companies according to the findings in this research. The "Types of Change" dimension, namely behaviour change, management change, technology change and system change, provides another viewpoint for managers and senior management level to examine their operation efficiency. The decision concerning which practices to implement still involves multiple factors including input cost, firm's strategy and external coordination, etc. The findings in this research does not intend to be generalized to an extent that it covers every aspects of improvement, but is instead a suggestive platform to stimulate the ideas of 'best practices'.

7.6 Research Limitations and Future Research

7.6.1 Research Limitations

Discussion about the limitations may help to have a more comprehensive understanding of this study, and the researcher to identify research opportunities.

Firstly, the findings reported here are based on the study of a relative small number of companies in the industry sectors of ICT (Information, Communication & Technology), including steel, and beverage and business/non-business organizations . More practices gained from a broader range of industry sectors will improve the validity and reliability, particularly the ones that have significantly different structure of supply network and practices in reducing their carbon emission, such as some of the service industries.

Secondly, the international issues are not specially covered in this research. The nature of the climate change problem is a global issue. And also the production of MNC distributes in a multi-nation context, with patterns of international manufacturing networks. The life cycle of the product also covers internationally dispersed supply networks. All these determine that managing the carbon footprint of a supply network should be studied in an international scope. However, from the primary, secondary case studies, and large dataset, it is found that carbon emission management is an emerging issue to most of the corporates, even for the large MNCs. There is a clear lack of empirical evidence of the firm's practices to tackle carbon problem at the global supply network level, especially shown in 2009 the date when this research started.

Thirdly, the range of interviewees are relatively limited in this research. Only a small number of senior managers and operational managers of focal firms were interviewed in most of the cases due to two reasons: whether they admit it or not, to most corporates the low carbon issue is still not in the core lists of their strategy priorities, so the top senior people are not much involved in the transition. The bulk of project decision making and execution are made by middle level operational managers, in most situations they are the sustainability managers/carbon specialist. They also act as the operational hub of data analysis and bringing out solution proposals. Managers in other functions are serving as data collectors and project implementers. So broadening the scope of interviewees within the focal firm did not seem to significantly improve the richness and accuracy of data collection. However, a valid improvement can be made to expand the interviewees' scope to suppliers, OEM and downstream clients. The attitude, response, coordination and actions from these stakeholders from the focal firm can enrich the understanding of the diffusion process for low carbon practices, and the embedded practical mechanism.

7.6.2 Directions for Future Research

Drawing upon the contributions and limitations of this research, a few avenues can be explored further in the future research.

A closer look at the links and delinks among influence, measurement and improvement should be enforced. The firms' supply network improvement are identified to be linked to their strategy aims in this research, but the relationship between environmental pressures enforced to the focal firm and their strategic aims are still not explored. The mapping of supply network emission hot-spots can be applied to identify an improvement practices focus, but they are not necessarily the case of a focal firm's actual projects due to other factors such as the ratio of benefits to cost, feasibility assessment, and operation priorities. As well the links between measurement and improvement should be further explored.

The larger framework of the low carbon business system can be investigated in the future. As the institutional pressure diffuses, the low carbon practices diffuse in different layers of the manufacturing system, from the small granularity to larger ones, namely technology level, plant site level, company level, product value chain level, sector level and country level. The research into the interaction between actors, mechanism of diffusion, cross-level interplays can significantly enrich the network theory and institutional theory.

The performance improvement triggered from the view of reducing carbon emission is the third area. Manufacturing system has shifted and evolved due to the change of aims orientation. Production managers have continuously improved the system with the purpose of reducing cost, boosting revenue, increasing flexibility and robustness. It is worthy of more research effort to examine whether carbon emission can be an effective new trigger or dimension to explore tacit opportunities of supply network overall performance improvement.

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APPENDIX I-1 General Information of Lenovo

Lenovo

General Information

- Lenovo Group Ltd. is a multinational computer technology company with headquarters in Beijing, China, and Morrisville, North Carolina, United States. It is main headquarter located in Beijing, China. Lenovo is listed on the Hong Kong Stock Exchange from 1994
- Its main products include PC (personal computers), tablet computers, smartphones, workstations, servers, electronic storage devices, IT management software and smart televisions. Laptop ThinkPad and desktop ThinkCentre are the two main product lines
- Financial and Market: From 2013 onward, Lenovo becomes the world's largest PC vendor with a market share of 16.7 percent. In the Financial Year 2013-2014, Lenovo had a revenue of 38.7 Billion HKD with 5.6 B gross profit.
- Lenovo has operations in more than 60 countries and sells its products in around 160 countries, with 54,000 employees globally. The principle manufacturing facilities sites are in Beijing in China, Morrisville in US and Singapore. It operates two joint ventures, one with EMC, and the other with NEC.
- Lenovo owns PC manufacturing and assembly facilities in Beijing, Shanghai, Huiyang and Shenzhen, China; Pondicherry, India; Monterrey, Mexico; Whitsett, North Carolina, USA; And Lenovo works with contract manufacturing and OEM in a worldwide scope.

Special Points

- In 2013 Lenovo was the world's largest personal computer vendor by unit sales, followed by HP and Dell.
- Lenovo works closely with international organizations to set up carbon standards in ICT industry. And Lenovo is the first Chinese ICT company to measure product carbon footprint

APPENDIX I-2 General Information of Tsingtao Brewery

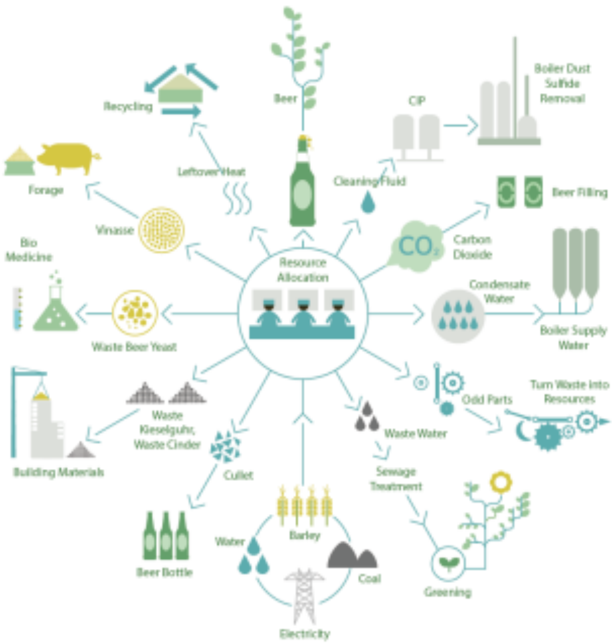
Tsingtao Brewery

General Information

- Tsingtao Brewery Co.,Ltd.is China's second largest brewery. It was founded in 1903 by German settlers and now claims about 17.2% of domestic market share in 2013. The beer is originally produced at Qingdao in Shandong province. Tsingtao brewery is listed in both Hong Kong Stock Exchange and Shanghai Exchange.
- Tsingtao is the 6th largest brewery worldwide in terms of production, producing 8.7 billion kilolitre of beer at 2013.The Tsingtao brand is sold in 85 countries and regions around the world and accounts for more than 50% of China's beer exports.
- Financial and Market: In 2013, Tsingtao takes up 17.2% of China domestic beer market. In the Financial Year 2013, Tsingtao had a revenue of 28.3 Billion CNY with a 1.9 B gross profit.
- Tsingtao Brewery owns 54 brewing subsidiaries and 11 jointly run breweries in 20 provinces, municipalities and regions of China, employing 42,235 totally. It has not manufacturing facilities abroad.

Special Points

- Tsingtao Brewery was the earliest Chinese brand entering international markets, and has topped the list of export volume among Chinese breweries.
- Tsingtao Brewery set up a position named carbon officer as the internal professional who specialises solely on carbon management issues.



APPENDIX I-3 General Information of ZTE

ZTE

General Information

- ZTE Corporation is a multinational telecommunications equipment and systems company headquartered in Shenzhen, China. ZTE was founded at 1985, and made public traded on the Shenzhen stock exchange in 1997 and Hong Kong stock exchange in December, 2004.
- ZTE's core products are wireless, exchange, access, optical transmission, and data telecommunications gear; mobile phones; and telecommunications software. ZTE primarily sells its own products but also works as an OEM, such as making mobile for network carrier Vodafone in UK. With its own brand name, ZTE is one of the 4th handset manufacturers in the world.
- Financial and Market: In 2013, ZTE had a revenue of 75.2 billion CNY with 1.8 billion at profit. During 2013, ZTE was one of the top three LTE infrastructure vendors with 17.9 percent market share
- ZTE has operations in 160 countries, 107 subsidiaries, and 18 R&D centres in the China, U.S., France, and India, hiring 78,402 people globally.
- As of the end of 2012, ZTE has filed applications for 45,000 patents globally, with more than 11,000 patents granted. According to the official report released by the World Intellectual Property Organization (WIPO), ZTE was ranked first in international patent applications for two consecutive years (2011 and 2012). As of the end of 2012, ZTE has filed applications for more than 11,000 PCTs.

Special Points

- The request from European customer triggers ZTE to consider low carbon issues.
- Due to the manufacturing stage only takes up a small amount of ZTE's operation, it focuses on the product energy efficiency and data centre energy efficiency as its de-carbonization strategy.

APPENDIX I-4 General Information of Acer

Acer

General Information

- Acer Inc. is a multinational hardware and electronics corporation headquartered in Xizhi, New Taipei City, Taiwan and Irvine, California.
- Acer manufactures desktop and laptop PCs, tablet computers, servers, storage devices, displays, smartphones and peripherals. In 2012 Acer was the fourth largest personal computer vendor in the world, after Lenovo, HP, Dell, taking a market share of 9.6% total market. Acer ranks No. 3 for notebooks shipments.
- In the early 2000s, Acer changed from a manufacturer to a designer, marketer and distributor of products, while outsourced the production processes to contract manufacturers.
- Financial and Market: In 2013, Acer sees a revenue of 12 billion USD down from 14.3 B in 2012, with 751 million. EMEA market contributes the most of its sales, with 38% of the total, coming after with Asia at 33%, America at 24%, Taiwan at 5%.
- From 2000, Acer cut off its manufacturing facilities and focused on the marketing and channel development of its products. Acer has a global workforce of 8,000 employees with a majority in Taiwan.

Special Points

- Due to outsourcing manufacturing, Acer focuses its low carbon effort on product design.
- EMEA area takes up 38% of Acer's total sales, this fact makes Acer sensitive to low-carbon request.

APPENDIX I-5 General Information of TSMC

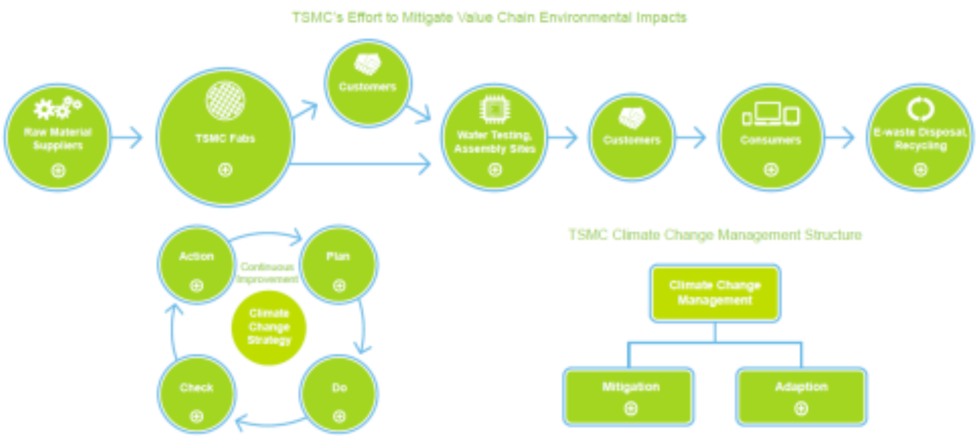
TSMC

General Information

- Taiwan Semiconductor Manufacturing Company, Limited (TSMC), also known as Taiwan Semiconductor, is the world's largest dedicated independent (pure-play) semiconductor foundry. TSMC had its headquarters and main operations located in the Hsinchu Science and Industrial Park in Hsinchu, Taiwan. TSMC was initially founded at 1987, listed on both the Taiwan Stock Exchange and the New York Stock Exchange. It has account management and engineering service offices in China, Europe, India, Japan, North America, and, South Korea.
- TSMC's main products are different kinds of wafer. It works as a semiconductor Dedicated IC Foundry firm, manufacturing more than 11,000 products for various applications covering a variety of computer, communications and consumer electronics market segments. Total capacity of the manufacturing facilities managed by TSMC, including subsidiaries and joint ventures, reached 16.4 million eight-inch equivalent wafers in 2013.
- Financial and Market: In 2013, TSMC had a revenue of 20.11 Billion USD with 9.44 billion at gross profit. TSMC is the world's biggest contract chipmaker, expected to expand its global market share to more than 50 percent in 2014. As early as 2003 it takes up 35-38% world market share.
- TSMC owns its corporate headquarters and 13 fabrication factory in Taiwan. Out side Taiwan, TSMC also has substantial capacity commitments at its wholly-owned subsidiary, WaferTech in the United States; TSMC China Fab 10 at Shanghai; and its joint venture fab SSMC in Singapore. In 2013 TSMC employs 37,149 people globally

Special Points

- TSMC is the world first of its kind and also largest dedicated independent semiconductor foundry company.
- TSMC is the first Taiwan company to be named as Dow Jones Sustainability Index (DJSI) Industry Group Leader, showing its excellence in sustainability performance.



APPENDIX I-6 General Information of CSC

China Steel Corporation

CHINASTEEL

General Information

- China Steel Corporation (CSC) is the largest steel maker in Taiwan. CSC's main steel mill locates at Kaohsiung, south of Taiwan. The corporation was officially established at 1971. CSC is listed in the Taiwan Stock Exchange.
- CSC makes steel plates, wire rods, steel sheets, hot-rolled and cold-rolled coils. CSC also makes hot-rolled bands, coils, sheets, and hot-rolled pickled and oiled coil. In 2013, CSC reached an annual producing capacity of 9.9 million metric tons of steel. The domestic market takes roughly 65% of CSC's production, ana d the export takes the remaining 35%.Major export destination are Mainland China, Japan and Southeast Asia.
- Financial and Market: In 2013, CSC had a revenue of 11.5 billion USD with 1.2 billion at profit. According to the World Steel Association report, China Steel ranked the 27th in the crude steel producer globally in 2012.
- CSC group has 21 subsidiaries in five business areas: steel, engineering, construction, industrial materials, logistics, and service & investment. For the steel manufacturing business, except for the plant in Kaohsiung, there are subsidiaries in Malaysia, Vietnam, and India. Globally CSC hires 23,000 employee in 2013.

Special Points

- CSC actively involve with the De-carbonization projects of World Steel Association (WSA), and was awarded 'WSA Climate Action Star Member' in 2013.
- CSC forms a strong network with its local partners to put industrial symbiosis into a practice, gaining high reuse efficiency of waste energy and materials.

APPENDIX I-7 General Information of AUO

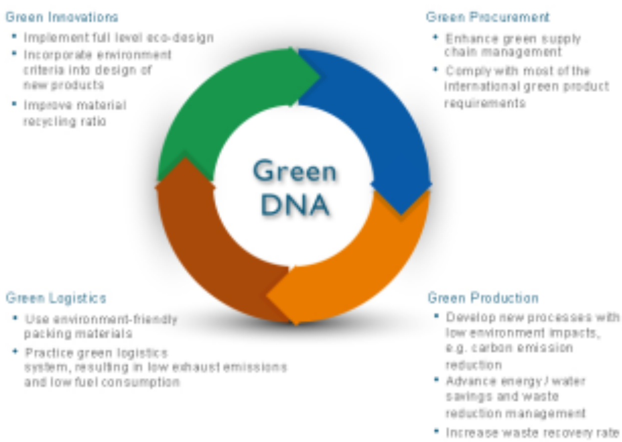
AUO

General Information

- AU Optronics (AUO) is a manufacturer of TFT LCD. It was formed in December 2001 as the result of the merger of Acer Display Technology and Unipac Optoelectronics Corporation of BenQ Electronics. AUO was the first pure TFT-LCD manufacturer to be listed on the New York Stock Exchange.
- AUO manufactures Thin Film Transistor - Liquid Crystal Display (TFT-LCD), Low Temperature Poly-Silicon (LTPS), Organic Light Emitting Display (OLED) for companies including Samsung, NEC, Lenovo, LG, Dell, Apple, Viewsonic, Acer, etc.The panels size ranges from 1.2 inches (30 mm) to greater than 65 inches (1,700 mm).The company also operates in solar segments in a much smaller scale.
- Financial and Market: In 2013, AUO had a revenue of 13.9 billion USD with 1.14 billion at gross profit. In 2013 AUO's large-sized TFT-LCD panels hold a global market share of 16.7%.
- AUO's global operations spread across Taiwan, China, Japan, Singapore, South Korea, U.S. and Europe, with 3 PV manufacturing sites, 13 display manufacturing sites and 8 overseas subsidiaries. Globally AUO employs around 45,000 people.

Special Points

- AUO performed the world's first product carbon footprint measurement for TFT-LCD panel which was the most complicated product that has been measured.
- AUO has been in member of Dow Jones Sustainability World Index for 4 consecutive years since 2010.



APPENDIX I-8 General Information of BenQ

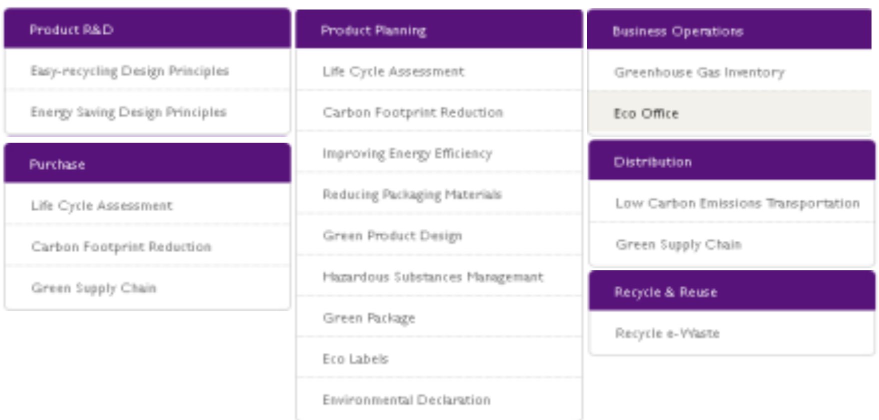
BenQ

General Information

- BenQ Corporation is a Taiwanese multi-national company that sells and markets consumer electronics, computing and communications devices, which stands for the company slogan Bringing Enjoyment N(and) Quality to life. BenQ's headquart is located in Taipei, Taiwan. It was spun off from Acer at 2001. And after 2007 it was spun off as a subsidiary of Qisda Corporation, and focuses on marketing/branding, while Qisda serves as OEM.
- BenQ sells and markets technology products, including consumer electronics, computing and communication products. Its principal products include TFT LCD monitors, digital projectors, digital cameras, and mobile computing devices.
- BenQ's head office is located in Taipei, and the company operates five branch offices in the Asia-Pacific, Europe, China, Latin America and North America, and employs over 1,300 individuals.
- Financial and Market: In 2013, BenQ owns a revenue of 690 million USD. For projector, BenQ takes up a global market share of 10.4% at 2012, camera at 4.3%.
- Since BenQ outsources the manufacturing, it only operates one headquarter in Taiwan, with 43 offices in 23 countries

Special Points

- BenQ focuses on product design, logistics, and especially the supplier management.
- At 2012 BenQ gained the Carbon Neutral certificate for its LED product according to PAS2060 standard.



APPENDIX I-9 General Information of Tung Ho Steel

Tung Ho Steel

General Information

- TUNG HO STEEL ENTERPRISE CORPORATION is a Taiwanese steel manufacturer, principally engaged in the smelting, manufacture and distribution of steel products. It was firstly incorporated in 1962 in Chiayi, Taiwan. It is listed in Taiwan Stock Exchange.
- The Company provides five categories of products: steel bars, which are applied in civil engineering and building construction; steel billets, which are semi-finished products for the production of reinforcing steel bars, steel wires and sheets; H-beams, which are applied as the structural steels in civil engineering and building construction; multifunctional steel plates, which are used for the manufacture of combined sections, as well as large-size U-sections, which are mainly used for the steel-structure buildings, mechanical equipment and electrical equipment. Tung Ho Steel has the annual rolling capacity of 800,000 metric tons for construction re-bars and 1,200,000 metric tons for section material.
- Financial and Market: In 2013, TungHo Steel had a revenue of 1.17 billion USD with 123 million at profit. Tung Ho is ranked as No.2 steel producer in Taiwan after China Steel Corporation. Tung Ho owns about 70% of H-beam market shares in Taiwan
- All four steel mills of Tung Ho is located in Taiwan, in Taoyuan, Miaoli, Kaosiung, and Yunlin. And it employs around 1,900 people.

Special Points

- Tung Ho is first steel manufacturer that participated the product carbon footprint measurement tutorial project from Taiwan Industrial Development Bureau, together with its 10 suppliers.

APPENDIX I-10 General Information of British Sugar

British Sugar

BRITISH SUGAR

General Information

- British Sugar Plc. is a subsidiary of Associated British Foods and produces sugar from sugar beet. British Sugar processes all sugar beet grown in the UK. The corporation was formed in 1936, and brought by Associated British Foods at 1991.
- British Sugar's main product is an extensive range of sugar products: Granulated (under the famous name 'Silver Spoon'), Screened, Dry Blending, Icing, Brown, Inverts, Bold & Decorative, Liquids, Fair Trade, Pharmaceutical. And since it performs many measures to make a full utilization to input raw material, British Sugar also sells the co-products that generated along the sugar processing line—aggregate, animal Feed, bioethanol, electricity, tomatoes, TOPSOIL, LimeX. In 2013, British Sugar produced 1.15 million tonnes of sugar. The UK consumes an approximately 2 million yearly.
- Financial and Market: since British Sugar belongs to AB Food group's sugar business, the financial detail is revealed for the group rather than British Sugar alone.
- British Sugar operates 4 factories in UK which are located at Bury St Edmunds, Cantley, Newark-on-Trent (Nottinghamshire) and Wissington. Wissington is the largest beet sugar factory in the West Europe.

Special Points

- British Sugar is famous for its extensive and innovative material utilization (e.g. raise tomato by using residual CO_2 from CHP plant) in sugar beet processing of Wissington factory. The recycle and reuse to co-products that generated in this process makes up the staggeringly high process efficiency: for every tonne of product, less than 2kg of waste is made.

APPENDIX I-11 General Information of Dell

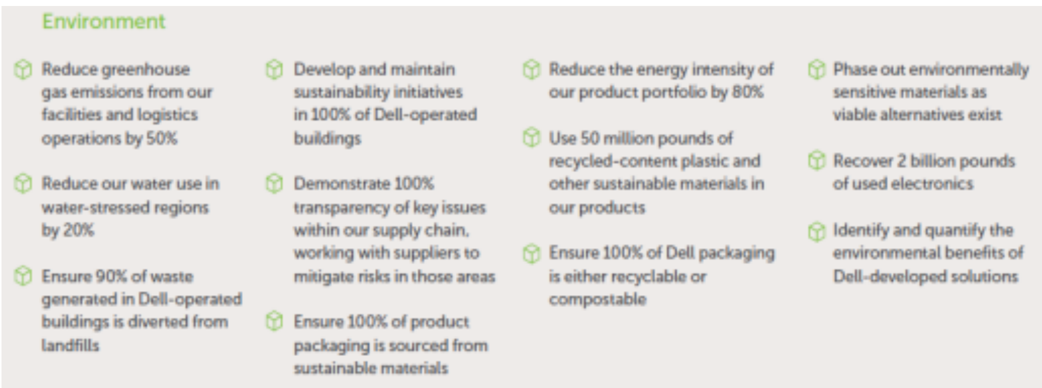
Dell

General Information

- Dell Inc. is an American privately owned multinational computer technology company based in Round Rock, Texas, United States (recently privatized on Oct. 2013). Dell gets its name from the founder Michael Dell, and was set up in 1984. Dell is currently ranked the 3rd largest Personal Computer manufacturer globally, after Lenovo and HP.
- Dell sells personal computers, servers, data storage devices, network switches, software, computer peripherals, HDTVs, cameras, printers, MP3 players and also electronics built by other manufacturers. Dell sells No.1 largest amount of PC Monitor until Jan, 2014.
- Financial and Market: In 2013, Dell generated a revenue of around 60 billion USD with 12.2 billion at Gross Profit. In 2013, Dell is estimated to own 11.6% of global market share in PC shipment, with the amount of shipment to 36,788,285
- In its early time Dell manufactured desktop machines in-house and contracted out manufacturing of base notebooks for configuration in-house. But after 2006 as the low cost of manufacturing in Asia, Dell changed its operation model to contract with high-volume Asian ODM/OEM manufacturers. Dell has Most of the work transferred to contract manufacturers in Asia and Mexico, or some of Dell's own factories overseas. Dell has assembly plants in Poland, Penang, Malaysia, Xiamen in China, Chennai in India, and Hortolandia in Brazil. It employs more than 103,300 people worldwide.

Special Points

- The company is well known for its innovations in supply chain management and electronic commerce, particularly its direct-sales model and its "build-to-order" or "configure to order" approach to manufacturing—delivering individual PCs configured to customer specifications.



APPENDIX II Interview Questions

Construct	Questions
Influence	What kind of external pressures the firm has received for carbon management? What kind of regulations or legislations for carbon management is imposed to the firm? How does the firm engage with external requirements about carbon management? What are the firm's carbon targets & missions? Why? How does the carbon strategy related to the external pressures?
Measurement	Which carbon measurement methods are applied? Does the firm consider carbon emission along supply chain? How does the firm engage supply chain partners to implement carbon measurement? What kinds of tools & processes are applied in measurement project? How does the firm evaluate these measurement methods, considering the feasibility, utility and usability?
Improvement	According to carbon strategy, what projects are implemented to reduce carbon emission? Explore these projects' timeframe, scope, attendee, procedure, project management and results. The criteria to select projects, consideration factors including cost, feasibility. How does the result of measurement link to improvement project selection? What are the carbon reduction projects in different supply chain stages (product design, product packaging, procurement, logistics, distribution, etc.) and what are the projects the firm cooperated with supply chain partners—supplier, service provider, distributors, etc. Whether does the firm consider carbon reduction as a factor in the supply chain re-design? Whether does the firm implement low carbon supply chain management system?

Other	How does the firm evaluate carbon reduction projects on cost & benefits in short term & long term scope? What are the barriers and difficulties in carbon management? How can these difficulties be overcame by the firm in future?