Chapter 12
Carbon Foot Print of Products—Supply Chain Approach

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Abstract This Chapter explores the carbon footprinting process from a supply chain perspective. The overriding premise is that the footprinting exercise needs to encompass the product's entire life cycle from the extraction of raw material, to the manufacture, transport, and use of the product; ending eventually in the disposal and recovery of the product. This Chapter will also explore issues and challenges in (a) organizing for and establishing an accurate carbon footprint and (b) acting on it to have a lesser impact on the environment.

12.1 What is a Carbon Footprint?

A carbon footprint of a product or a service measures the total amount of carbon dioxide-equivalent (CO_2-eq.) gases that it produces throughout its life cycle. This typically includes the amount of CO_2-eq. produced in the extended supply chain: from the extraction of raw material, to the manufacture, transport, and use of the product; ending eventually in the disposal and recovery of the product. Other greenhouse gases—Methane, Nitrous Oxide, Sulfur Hexafluoride and others—are converted to its "CO_2 equivalent" weight so a single CO_2-eq. number can represent the environmental impact of the product. The primary objective of a footprint is to establish the impact of the product or service and take appropriate action to reduce this impact.

At the firm, and specifically at the supply chain level, there is an increased awareness of climate change as a major strategic priority. In addition to addressing the global problem of climate change, firms have multiple reasons to address greenhouse gas (GHG) emissions. First, customers and supply chain partners are now

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demanding an organized approach to carbon management. A firm may risk its reputation if it does not understand and act on the broader impact of its products and services—the embedded emissions of purchased goods and the downstream distribution, use, and disposal of its products. For example, Wal-Mart has indicated that it will reduce the GHG emissions by 20 million tons by 2015—a target that cannot be achieved without the full involvement of all its major stakeholders including suppliers and customers.

Many firms look at carbon management as an opportunity to mitigate risk and reduce possible disruptions in the supply chain. To maintain assurance of supply, for example, Starbucks Coffee Company initiated C.A.F.E. (Coffee and Farmer Equity) practices to evaluate, recognize, and reward producers of high-quality sustainably grown coffee. In the electronics sector, there is a move to follow RoHS and WEEE[1] guidelines even when not mandated by local laws. For example, in addition to significant reductions in the carbon footprint[2], the latest generation of Apple's products are Lead, Brominated Flame-Retardants, Polyvinyl chloride, and Mercury free.

Another driver for carbon management is both ecological and economic efficiency. Reducing the carbon footprint often translates to lower use of energy, reduction in waste streams, and using recycled material in the supply chain. Herman-Miller's Mirra chairs, for example, are manufactured at a LEED[3] Pioneer building and the production line utilizes 100% green power. No air or water emissions are released in the chair's production. The chair, made from steel, plastic, foam, and textile is 96% recyclable at the end of its life (approximately 12–15 years) and is currently made from 33% recycled materials.

Finally, firms are aggressively managing GHG emissions in anticipation of stricter laws that will curb emissions. For example, the European Union has the Emissions Trading Scheme (EU ETS) that functions as a "cap and trade" system. The 2013 cap is about 2.04 billion "allowances" (each allowance is the right to emit one ton of CO_2). These allowances will be allocated among member nations and each member state grants their companies allowances through what is called a national allocation plan (NAPs). The EU ETS covers power stations and other combustion plants, oil refineries, coke ovens, iron and steel plants and installations producing cement, glass, lime, bricks, ceramics, pulp, paper and board, bulk organic chemicals, hydrogen, ammonia and aluminum. Depending on their emissions, the ETS allows a firm to buy or sell allowances to meet specified targets. Installations that are non-complaint will be subject to stiff penalties. The cap will decrease each year by 1.74% of the average annual total quantity of allowances issued by the Member States in 2008–2012. While the US does not have a cap and trade scheme, there have been various attempts to introduce similar Bills and in all likelihood, climate legislation will be a

[1] EU legislation on the Restriction of Hazardous Substances (RoHS) and the Waste Electronic, Electrical, Equipment (WEEE).

[2] The carbon footprint of the 2010 160 GB iPod Classic is 50% of the footprint of the 2001 5 GB iPod Classic.

[3] Leadership in Energy and Environmental Design (LEED) is a third party green building certification developed by the U.S. Green Building Council (USGBC).

reality in the US in the near future. Such regulations may significantly impact supply chains and how firms view their trading partners. For example, potential taxes on energy or embedded carbon emissions in products and services may significantly impact the cost of purchased goods or components used in the manufacturing and production processes of a company. Measuring and managing these emissions help companies plan for such potential policy regulations and guide supplier selection and product design.

12.2 Tracking of a Supply Chain Carbon Footprint

The Greenhouse Gas Protocol (GHG Protocol) is the most widely used international accounting tool for businesses to measure and manage greenhouse gas emissions. Through a partnership between the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), the GHG Protocol sets standards for preparing the "lifecycle inventory," a mechanism via which carbon footprints can be measured, managed, and mitigated.

While there are many other protocols like ISO 14000 and UK's PSA 2050, they all have similar components. The GHG protocol[4], for example, specifies three "scopes" of emissions:

- **Scope 1:** Direct GHG emissions are from sources that are owned and operated by the company. This includes all "within firm" supply chain operations, including facilities.
- **Scope 2:** This accounts for GHG emissions arising from purchased energy.
- **Scope 3:** Includes all other indirect emissions related to the firm's supply chain. This can mean anything from employee travel, to embedded emissions in products purchased or processed by the firm, to "downstream" supply chain emissions such as distribution, retail, the use of the product, and the eventual recapture of the waste stream the product or service generates.

Firms typically report Scope 1 and 2 but often do not take detailed inventory of emissions of Scope 3 since one firm's Scope 3 are likely another firm's scope 1. There are also obvious difficulties measuring scope 3 since it is outside the firm boundary and often outside the firm's control. However, much of the product or service's GHG emissions are often in the supply chain (scope 3)—several orders of magnitude higher than firm-level emissions. Managing the embedded carbon in the supply chain is a more comprehensive approach and can help realize both economic and ecological efficiencies for the firms in the supply chain.

[4] We use GHG "Scopes" for illustration. Other protocols measure emissions similarly—PAS 2050 simply follows the product or service supply chain without formally designating scope.

12.2.1 Organizing for Footprint Analysis

Any carbon measurement and reduction process needs a "lead" or a "reporting" firm—a firm that owns the product or the service. For example, as the ensuing discussion will show, Pepsi Co. owns the footprinting process of Walkers crisps or Tropicana pure premium orange juice; Apple owns the process for the iPhone4; and Toyota owns the footprinting process of the Prius. The primary responsibility for the lead firm is to create an organization within the firm and related processes that will identify products and services to footprint, marshal data sources, create the footprint, have it verified, and finally engage supply chain partners for action. Typical participants in the footprinting project are divisions within the lead firm, suppliers, downstream distribution channels and customers, consulting firms, third-party accountants to verify footprint, research organizations and environmental watchdogs that help identify products and services for GHG reduction and audit and critique GHG mitigation efforts.

The governance structure for strategic sustainability efforts that sets overall goals and specific company-wide GHG reduction targets typically involves a cross-disciplinary committee or executive officers reporting to the Board of Directors (or a Board Committee).

Pepsi Co., for example, has formed the Environment Sustainability Leadership Team (ESLT) to address sustainability issues. The ESLT, which is led by Divisional Supply Chain chiefs, oversees the implementation of climate change mitigation in Pepsi Co.'s supply chains. The ESLT directly advises the CEO and the Board of Directors.

The ESLT's focus areas are energy, water, solid waste, packaging, and sustainable agriculture. The ESLT works globally with regional Pepsi Co. leaders to identify climate change mitigation opportunities and continuously assesses and implements mitigation strategies and processes.

Apple uses an "Executive Team" to addresses their sustainability strategy. The executive team is a group of the company's senior-most executives and regularly reviews each new product during its development, focusing on material and design choices, the supply chain, packaging, and product energy efficiency. They get inputs and advise from different Apple divisions on how best to devise a GHG emission mitigation strategy. According to Apple, they are the first technology company to publish the supply chain footprints of all their products.

Wal-Mart has organized its sustainability strategy around collaborative partnerships called "Sustainable Value Networks" (SVN). Their SVNs consist of Wal-Mart Associates, NGOs, government officials, academics and suppliers. Wal-Mart has SVNs dedicated to product categories, measuring climate impact, and supply chain efficiency.[5] Each network is lead by a "Network Captain" who is a Director or Vice-president level and guides the network towards meeting climate targets. Every

[5] Wal-Mart's SVNs are in Agriculture & Seafood, Textiles, Jewelry, Electronics, Wood and paper, Chemical-intensive products, Greenhouse Gas, Sustainable facilities, Logistics, Waste, and packaging.

quarter, networks report on their progress on their climate strategy through a network executive sponsor—typically at a senior vice-president level or higher—to the CEO.

An effective governance structure specifies the processes both at the strategic level as well as the operational level by which GHG reductions can be targeted. At Wal-Mart, for example, as part of the strategic directive to reduce 20 million metric tons from their supply chain, one operational program they have introduced is the "Wal-Mart Supplier Greenhouse Gas Innovation Program." The program was introduced in collaboration with non-profits (Environmental Defense Fund and Carbon Disclosure Project), consulting firms (ClearCarbon and BluSkye), academic partners (Applied Sustainability Center at the University of Arkansas) and auditors (PWC) with a charge to identify products for potential GHG reductions, achieve reductions by engaging suppliers and customers and quantify and verify any GHG reduction claim.

The program identifies potential product categories by computing the "carbon intensity" of the product. Carbon intensity is simply the GHG emissions per unit multiplied by its sales. Categories with high carbon intensity are identified and projects for GHG reductions are initiated with the appropriate SVN Captains. The program team identified specific product(s), a Wal-Mart "Champion" (the lead project manager), upstream (supplier base), and downstream (customer base) activities to interact with. The Champion will lead the footprinting effort—map the supply chain, collect data, compute supply chain footprint, target areas for reduction, and clearly document actions and reductions in GHG emissions so they can be verified and audited.

Herman Miller's sustainability strategy has evolved around the Environmental Quality Action Team (EQAT), a cross-functional steering committee of Herman Miller employees that sets their environmental direction and priorities; and measures results.

The EQAT established several support teams to carry out specific tasks. A partial list includes: a Communications team (to better communicate their message), Design for the Environment (DfE) Teams (for setting environmental sensitive design standards), a ISO 14001 Team (focused on the continuous improvement of the Environmental Management System), and a Energy Reduction Team, committed to reducing the amount of energy necessary to produce Herman Miller products. According to Herman Miller, about 400 employees out of about 8,500 are involved directly or indirectly with EQAT initiatives.

When Herman Miller designed the Mirra chair, the DfE team was lead by the Director of Environmental Health and Safety with close partnership with a supply chain manager and a chemical engineer. The supply chain manager worked on supplier relationships while the chemical engineer provided input into the sustainability of the chemicals used[6].

Wal-Mart's Supplier Greenhouse Gas Innovation Program or Herman Miller's DfE teams are examples of operational execution of sustainability strategy, but for any footprinting exercise to be successful, the firm must (a) have an overall strategy

[6] The intent of this DfE team was to design the chair to "Cradle to Cradle" standards set by the McDonough Braungart Design Chemistry (MBDC) firm.

for sustainability and the responsibility must lie at the highest level—senior executive officers or the Board; (b) a process or program, like the Herman Miller's DfE team or Wal-Mart's Supplier Greenhouse Gas Innovation Program, by which such strategic objectives are executed and disseminated across the firm; and finally (c) operational details like the project manager, products or categories to be footprinted, timelines for GHG emission measurement, verification, audit, and its eventual mitigation need to be clearly defined prior to the start of the footprinting project.

12.2.2 Mapping the Supply Chain, Data Gathering and Lifecycle Inventory

Products or services to be footprinted are typically chosen based on the goals of the project. Cost savings, marketing opportunities, competitive considerations, ease of supplier engagement, and the potential time and effort needed are typically factored when considering products to footprint. Some companies (like Patagonia, Apple) footprint and publish GHG emissions for most products and facilities.

For the chosen product (service or facility), the project team needs to inventory the processes for which emissions are measured. Several standard accounting methodologies are now available such as ISO14040 and ISO14064 standards, WRI/WBCSD's GHG Protocol[7], and British Standards Institution's PAS 2050. The standards involve defining unit of product that is measured, setting boundaries on what gets measured, incorporating all appropriate supply chain activities, and accounting standards to allocate emissions to activities. This would necessarily involve engagement of supply chain partners and a framework by which footprints can be verified, analyzed, and action for reductions taken.

A typical lifecycle (Scope $1+2+3$ emissions) includes the following (See Table 12.1):

Raw Material Extraction: The raw material product phase relates to the GHGs embodied within the raw material inputs that makes up a product, the emissions associated with their extraction, and transportation to a processing plant. For example, in the electronics and computer industry, extraction of metals for use in electronics and their shipment to component manufacturers would be a part of this phase. For the construction industry, logging and the eventual transport to lumber mills constitute the extraction phase.

Manufacturing: The manufacturing phase relates to the emissions released while transforming raw materials and other inputs into a finished product. In the electronics industry, this is the GHG emissions released in making of the components like the circuit boards, disk drives, memory chips, etc. and the assembly of these components into finished products. It is typical, at least for the electronics supply chains, for

[7] The WRI/WBCSD's GHG Protocol is currently developing standards to measure Scope 3 emissions.

Table 12.1 Sample life cycle activities sample activity breakdown

Life-cycle stage	Sample activities	Examples
Raw materials	Impact of raw materials	Deforestation, etc. Land use change
	Inputs used in the product	Bill of materials or teardown reports
	Typical processes	Extraction/mining Farming Livestock Logging Processing Transportation Waste streams
Manufacture	Inbound logistics	Processing Shipment of raw materials to Manufacture/assembly Storage
	Outbound logistics	Packaging Storage Transportation
	Production processes	Facilities Inputs and outputs of production Intermediate and final products produced Waste streams generated
Distribution/retail	Distribution operations	Processing Shipment to distribution center Storage
	Retail operations	Display Processing Shipment to retail/customer Storage/refrigeration
Customer use	Use	Maintenance Repair Use of product
End of life	Waste streams	Composting Land filling Recycling Take back/remanufacturing, etc.
Other considerations	Capital goods	Any capital to enable lifecycle activities
	Employees	Business travel Commuting
	Facilities	Franchises Leased and owned assets

multiple companies to be involved in this phase with multiple echelons in the supply chain so tracking the source of all the components can be challenging. Often firms in the supply chain use estimates—industry averages – to compute this phase of the life cycle.

Distribution: The distribution and retail phase details emissions from transporting finished goods to distribution centers and final retail locations. Typical emissions

include distribution center operations, fuel combustion, truck and in-store refrigeration, and retail energy consumption.

Consumer Use: These are the GHG emissions from product use. These include electricity use for consumer electronics, fuel and emissions for the transportation sector, land and building use emissions for facilities, etc.

End-of-Life/New Life (recycle or other): The end-of-life product phase captures emissions resulting from waste and reuse streams like land fills, composting, remanufacturing, refurbishing and recycling.

12.2.3 Data Collection Challenges

There are typically two types of data collection. Activity data is simply the data on the type, number, and quantity of inputs and outputs; energy use; and net GHG emissions in each activity in the life cycle. Emissions data, on the other hand, are standard factors typically available in government or industry-specific databases that provide information to covert all activity data into the CO_2-eq. measure.

Activity data could be a result of direct measurement (for example, KwH used in production) or an industry estimate based of quantities of inputs/outputs used. The primary challenge for most reporting firms is to obtain direct activity data from suppliers and downstream partners. First, the reporting firms need to decide which suppliers to poll for activity data. Large firms have tens to hundreds of suppliers each with varying levels of activity data. It is typical to prioritize suppliers based on spend, the potential for GHG reduction, and the level of relationship. For smaller suppliers (relatively small spend), secondary data from well-established life cycle databases can be used to estimate emissions. Second, reporting firms need to ally any confidentiality concerns supply chain partners might have. Suppliers typically have multiple customers—so any activity or emission data that is requested is aggregated across their customer base. The supplier, using consistent standards, is best suited to allocate its emissions to the reporting firm—this may require confidentiality agreements to reduce concerns. Third, the reporting firm needs to provide a simple and practical template for data collection—a template that informs the suppliers what is needed and why; and the resources it would take to complete the footprint exercise. Finally, a designated contact at the supply chain partner is essential to clarify the data.

The goal of data collection (and indeed the entire footprinting exercise) is having accurate, consistent, and repeatable protocol so process improvement and eventual reductions in GHG emissions can be accurately measured and tracked.

Once the supply chain activities are mapped and activity and emission data collected, the footprint can be computed by allocating emissions to each activity in the supply chain and adding over activities in each stage of the life cycle. The various protocols—WRI/WBCSD's GHG Protocol and British Standards Institution's PAS 2050, for example, specify in great detail how the process map and related activity data can be used to produce the footprint.

During the data collection process, there are typically a lot of unresolved issues, for example, lack of activity data from partners or lack of industry standards (for example, average use of a phone or a washing machine). Assumptions or workarounds need to be documented and steps taken to clarify such issues in future considerations. It also helps to run a sensitivity analysis of the footprint—so the "average" is reported but depending on assumptions of material and product usage, the footprint can be more or less than the reported number.

12.2.4 Verify, Evaluate, and Act

Once the footprint analysis for a product or service is completed, it needs to be validated both internally within the reporting firm and externally by supply chain partners and third-party organizations. Protocols such as the GHG or the PAS 2050 provide guidelines on validating, auditing, and reporting the footprint. The goals of the footprinting process can be multi-fold. First, the reporting firm can use this as a baseline for carbon emissions. Any changes to product or process can be compared to this baseline to gauge the effectiveness of carbon mitigating projects. Second, the reporting firm can file the results in a public forum like their CSR reports or third-party programs such as the Carbon Disclosure Project to address the needs of their stakeholders. Third, they can use the footprint as tool to manage climate risks and act on carbon mitigation opportunities.

12.3 Using the Footprint as a Tool to Reduce Life Cycle Carbon Emissions

Footprints identify "hot spots" of carbon in a product's life cycle. Depending on the overall goals of the firm—risk mitigation, cost savings, brand image, etc.—changes can be made to the supply chain that reduces the footprint.

Since 2007, carbon footprinting has been promoted as an important tool for consumers to make sustainable consumption choices. However, sustainable development requires a fine global balance between the environment and development agendas of organizations. Food products are some of the first of "short life-cycle" products that organizations have used for consumer facing carbon footprinting efforts. For many developing countries, complete carbon emission based food pricing would be a desirable option wherein crops that are grown under the sun with limited chemical inputs tend to have lower emissions. But methodologies such as LCA that are used tend to favor easy measurement and examine only product-based emissions without involving systemic emissions.

The footprint gives a way to meaningfully engage supply chain partners to mitigate climate change issues. Depending on where in the supply chain the best returns in carbon mitigation investment are, firms can prioritize whom they engage and what the engagement should entail.

Table 12.2 Sample footprint reduction strategies

Category	Action steps
Material inputs	Use fewer variety Use less quantity Eliminate hazardous substances Use materials that can be reclaimed Use materials that can be "upcycled" Sustainable extraction (logging, seafood, mining, etc.)
Energy use	Move to renewable energy Reduce energy consumption Move to efficient fuels (Electricity to Gas)
Production process	Locate production close to supply Use fewer processing steps Increase efficiency in process Reduce waste streams (solid, water, etc.)
Distribution/retail	Reduce distribution distances Fuel efficient transportation, backhauls Energy efficient distribution/retail refrigeration Low GHG retail design
Facilities/employees	Energy and water efficiency (e.g., LEED certification) Employee commute programs Expansion of green spaces Active involvement from employees
Consumer use/end of life	Design for energy efficient use Establish product recovery steams at end of life
Supply chain relationships	Select suppliers based on GHG criteria Educate suppliers on GHG reduction benefits Joint programs for carbon reduction Invest in supply chain partner process to mitigate carbon Educate consumers, drive low-GHG product choice

Common strategies are illustrated in Table 12.2. One class of strategies involves changes to material (raw material) inputs into processes. Choosing sustainable inputs that are safe and reclaimable, responsibly extracting it, and its parsimonious and efficient use are all finding their way into supply chain strategies. Wal-Mart, for example, is working with its seafood suppliers to have its Atlantic salmon Marine Stewardship Council (MSC)-certified, a protocol that ensures responsible fishing and farming practices[8]. Nokia's N8 Smartphone[9] uses bio plastics and is free of toxic substances like PVC, BFR, and RFR, making all the materials recyclable. Nokia requires its primary suppliers to clearly state the chemistry of components it sources. Although Apple's current 21.5 in. iMac is more powerful and has a much larger screen than the first-generation 15 in. iMac, it's innovative design uses 50% less

[8] http://walmartstores.com/Sustainability/10607.aspx?p=9173.

[9] http://www.nokia.com/environment/devices-and-services.

material and generates 35% fewer carbon emissions[10]. Shaw's EverTouch® nylon flooring products are made from Type 6 nylon that can be recycled back into carpet fiber again and again, endlessly (also called "upcycling"), closing the loop in the material supply chain[11].

A second major direction in reducing footprint is to move towards renewable energy (or reduce energy reliance on fossil fuels), simply reduce the use of energy and eliminate any waste (including water and direct GHG emissions) from supply chain processes. This involves not only the reporting firm's processes but also relevant activities in the supply partners' processes. Such efficiency-related projects can provide quick short-term gains to the firm. For example, as of 1 May 2010, Herman Miller uses 100% renewable electrical energy in all their facilities worldwide[12]. They also reduced their electricity consumption from 100 million KwH in 2007–2008-85 million KwH in 2009–2010. In 2010, Wal-Mart's China operations, for example, reduced plastic shopping bag waste in their stores by 84% when compared to a 2007 baseline. Through water conservation programs they have reduced water usage by 54.2% since 2005[13]. Google uses efficient servers and innovative cooling methods in their data centers to save 50% energy over comparable data centers[14].

A third thrust in reducing GHG emissions is making facilities energy efficient and employees engaged in the carbon mitigation strategy. Several third party certification systems exist for green buildings. The most recognized among them is LEED, developed by the U.S. Green Building Council (USGBC). According to the USGBC, LEED provides "building owners and operators with a framework for identifying and implementing practical and measurable green building design, construction, operations and maintenance solutions." Examples include Herman Miller and Adobe's corporate headquarters, Patagonia's Reno distribution center, and the World Financial Center in Beijing, China.

Hand-in-hand with facilities design, firms are also increasingly getting employees engaged in carbon mitigation activities. Google has bio-diesel commuter buses to transport employees to work. Within the Google campus, Google has a program called "GFleet"—a fleet of plug-in cars to shuttle employees across their campus. According to Google these programs have saved 5,400 tons of CO_2 or an equivalent of 14 million cars off the road[15]. Programs at other companies include providing incentives for public transportation, carpooling, committing to a green lifestyle (for example, Saatchi and Saatchi's "Do One Thing" (DOT)). The goals are not only carbon mitigation, but also to boost employee morale to increase productivity.

Finally, carbon mitigation programs also involve consumer education and engagement to help save energy, reduce direct emissions, and close the material loop in the supply chain. Patagonia's "Common Thread Initiative" encourages customers not only to reduce, repair, reuse their products to extend the life of the product (they

[10] http://www.apple.com/environment/.

[11] http://www.shawfloors.com/Environmental/EnvironmentallyFriendlyDetail.

[12] http://www.hermanmiller.com/About-Us/Environmental-Advocacy.

[13] http://www.apple.com/environment/.

[14] http://www.google.com/green/operations/data-center.html.

[15] http://www.google.com/green/operations/transportation.html.

back this up by making high-quality products with sustainable inputs), but provides a network of retail outlets through which customers can recycle their garments. Electronic manufacturers like Dell, HP, Apple all design energy efficient products and provide guidelines on how to use the product in an energy-efficient way. At the end of life, they all take back their products so they can be recycled and/or disposed in an environmentally safe way.

12.4 Examples of Complete Life Cycle Product Footprints and Actions

12.4.1 NIKA: Bottled Water

NIKA's published mission is to fight global poverty by selling premium bottled water. They donate 100% of their profits to support clean water projects in under-developed countries. According to NIKA they "will provide the basic tools and critical assistance to help thousands of families improve their lives in a meaningful way and end the cycle of poverty."

NIKA has undergone a rigorous third-party audit of their manufacturing and distribution process to determine their GHG emissions. What they discovered were the following per-bottle CO_2-eq. emissions[16]:

- Raw materials—73 g
- Materials manufacturing and transport—43 g
- Product manufacturing and transport—105 g
- Consumer use—2 g
- End of life—3 g
- Total—226 g

Since product manufacturing and transport are the largest part of the footprint, NIKA is lowering their footprint by localizing their bottled water production facilities. By sourcing, purifying, and bottling their water in a handful of geographically differentiated locations throughout North America, they are able to minimize the use of transportation.

They also have a "One-for-One" recycling program, where they pledge to recycle one plastic bottle for each one they sell. They also pay schools a fee (to be donated to charities) to recycle plastic bottles.

Working with Carbonfund.org, NIKA now offsets their product's carbon footprint by contributing to a reforestation project in Nicaragua. As a result, they have achieved "CarbonFree" certification from Carbonfund.org, allowing them to claim that they are a carbon neutral company—the first of its kind in the bottle water industry in the US.

[16] http://www.nikawater.com.

12.4.2 Pepsi Co.: Tropicana Orange Juice and Walkers Crisps

Pepsi Co., working with the Columbia Earth Institute computed footprint of a half a gallon carton of Tropicana orange juice as 3.75 lb.[17] of CO_2-eq.

By far, the largest GHG contribution actually came from the cultivation of orange trees. According to Pepsi Co., 60% or 2.25 lb. of the carbon footprint of a half gallon of Tropicana orange juice are produced during the fruit growth and juice production stage.

The production-related emissions include the production and application of the nitrogen fertilizer, picking and transporting the oranges to the Bradenton, FL processing plant, as well as the use of energy to squeeze, pasteurize, and pack the juice.

The 64 oz. cartons are shipped by train throughout the country—22% of the GHG emissions are produced during the distribution phase. And finally, they calculate the packaging at 15% and use and disposal at 3%.

Since 35% of the footprint is from nitrogen fertilizer applied to orange groves, Pepsi Co., in collaboration with one of its growers, SMR Farms in Bradenton, Fla., has launched pilot studies to test two low-carbon fertilizers to determine whether using either could significantly reduce the carbon footprint of growing oranges. If successful, Pepsi Co. projects that this change could reduce the total carbon footprint of Tropicana Pure Premium by as much as 15%.

Walkers Crisps Walkers[18] is another of Pepsi's biggest brands, and a best selling item is the cheese and onion potato chips (crisps in the UK).

Pepsi Co. examined every stage in the production of these crisps, beginning with growing potatoes, sunflowers (for oil), and seasoning, which made up 34% of the footprint. Production of the chips was responsible for 17% and packaging accounted for 36% of the total footprint.

Transportation of the crisps to grocery shelves comprised 10% of the footprint. The remaining 3% goes to disposing of the empty packaging from the crisps. All in all, they estimate that one bag of crisps results in the emission of about 80 g (about 0.18 lb.) of CO_2-eq. emissions.

Since a third of the greenhouse gas emissions are during the production cycle of the supply chain, PepsiCo has been working with its suppliers to develop methods of reducing energy consumption in this phase of the project such as capturing water extracted from potatoes to achieve zero water intake, using renewable energy at some sites, and reducing waste sent to landfills by 39%. The footprint also helped redesign some procurement practices. Since Walkers was buying its potatoes by gross weight, farmers were storing their potatoes in humidity controlled facilities to increase water content. This necessitated Walkers to fry the sliced potatoes longer to remove the extra moisture. Buying potatoes by dry weight provided a win–win situation—Walkers could reduce frying time and farmers could avoid the cost of

[17] http://www.nytimes.com/2009/01/22/business/22pepsi.html?ref = business.

[18] http://www.walkerscarbonfootprint.co.uk/walkers_carbon_footprint.html.

humidification. All these process changes resulted in a reduction of greenhouse gas emissions by about 7% between 2007 and 2009, saving the company £ 400,000.

12.4.3 Apple: iPhone4

Apple reports the iPhone4's greenhouse gas emissions[19] as follows:

- Production—57%
- Customer use—34%
- Transport—8%
- Recycling—1%

Apple has suppliers scattered throughout the world[20]. For example, the iPhone4's display (LG), processor and memory (Samsung) are sourced from Korea. The electronics come, among other countries, from Japan, Germany, Taiwan, and the US. The phone is assembled in China and shipped via air worldwide. The sourcing, manufacture, and assembly accounts for 57% of the 99 lb. CO_2-eq. footprint. Transportation for final sale to the customer contributes 8%. Customer use accounts for 34%[21] and recycling at end of life 3% to the footprint.

Since the energy consumed during product use is a major source of GHG emissions, Apple has designed the iPhone4 with power conservation in mind[22]. For instance, the power adapter is ENERGY STAR qualified, and the components and power management software of the iPhone4 are configured to use energy as minimally as possible.

The compact design uses less material inputs, and the packaging is minimized and is almost 100% recyclable. The iPhone4 also makes disposal and reclamation of raw materials easier by designing the phone free of toxic materials such as arsenic, BFR, mercury, and PVC.

Apple also has a comprehensive take back program—customers can mail in their product to Apple and Apple will recycle it in a responsible way.

12.4.4 Patagonia's Nano Puff Pullover Jacket

Patagonia tracks the footprint of its products and publishes them as "Footprint Chronicles" on their website. Their Nano Puff Pullover Jacket[23], for instance is designed in

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[19] http://www.apple.com/environment/reports/.

[20] http://operationsbuzz.com/2010/11/the-iphone-4-supply-chain/.

[21] Apple assumes a use phase duration of 3 years for the calculation of handheld power consumption. Since there is a lack of a universal benchmark, Apple estimates of the amount of time and the intensity of power drawn during the use phase.

[22] The previous model iPhone3GS had a footprint of £ 121.

[23] http://www.patagonia.com/web/us/footprint/index.jsp.

Ventura, CA. Its design objective was to provide the most warmth to weight ratio, yet make it sustainably. Fibers and fabric for this jacket are sourced in Nobeoka, Japan and the "Primaloft," a polyester-based lightweight insulation, is made in Rudong, China. The garment is sewn in Ho Chi Min City in Vietnam and finally distributed to the retailers via their distribution center in Reno, NV.

Patagonia estimates that it consumes about 43 MJ to make the jacket, which is equivalent to burning an 18 W light bulb 24 h per day for 28 days.

The reported footprint for this garment is about 5.5 lb. Patagonia has included much of the upstream activities covered by GHG Protocol including pick-up of the original fibers to manufacturing power consumption through its 12,545 mile journey to the distribution center in the US. This footprint does not include downstream GHG emissions of retail operations, customer use, and recycling and retrieval of the garment at the end of its life.

The Nano Puff uses 63 L of water and the waste stream is 2.7 oz, about the third the weight of the Jacket. According to Patagonia, transportation was only a small portion of the footprint—so as long as the jackets are transported by ship, making them in Ho Chi Min City provided the economic benefit of lower labor cost. The largest portion of the footprint was in the manufacturing process. The company is working with their suppliers and their manufacturing partners to improve processes.

The jacket is fully recyclable at the end of its life. Patagonia can reclaim the shell and lining (which are made from recycled content) and convert it back to virgin raw material. The PrimaLoft insulation as part of the Common Threads Initiative is completely recyclable; but virgin polyester is used to make the insulation in the jacket. Patagonia is working with Albany International, the maker of PrimaLoft, to develop lightweight and compressible insulation from recycled materials. A coating on the jacket (Patagonia calls it DWR) to repel water produces Perfluorooctanoic acid (PFOA), which is considered toxic. Patagonia is also working with suppliers to eliminate PFOA in the production process.

12.4.5 Toyota Pruis

The best selling Toyota Prius has a footprint of 44 metric tones or 97,000 lb.[24] over its 120,000 mile life. The footprint includes sourcing of parts, car assembly, customer use, and the eventual disposal of the car. Upstream supplier operations and assembly accounts for 18.6% of the footprint. The largest part of the footprint is making of the fuel and its use in the car, which accounts for 68.5% of the footprint.

In this case, fuel efficiency of the car primarily determines the footprint. The fuel efficiency of the Prius is estimated at 42 miles per gallon. In comparison, the Toyota Camry with an efficiency of 29 miles per gallon has a footprint of 64 tons.

[24] http://online.wsj.com/public/resources/documents/FOOTPRINT.pdf.

The 4 Runner, an SUV from Toyota has a fuel efficiency of 16 miles per gallon and a footprint of 118 tons[25].

12.5 Concluding Remarks on Working with Supply Chain Partners

Working with supply chain partners on carbon mitigation projects can be challenging. First, suppliers may not track activity data or their GHG emissions and as a result may not have reduction targets in their strategic plans. Large reporting firms, however, can use GHG criteria to select suppliers, in effect forcing many of the suppliers to comply[26]. Dell expects its primary suppliers to track and manage GHG emissions. In fact, Dell insists that their key suppliers report their emissions in public third party programs like the Carbon Disclosure Project. Dell also expects its suppliers to set specific goals not only for GHG reductions in its own operations but enforce GHG reduction on its suppliers (Dell's Tier 2 suppliers). Lack of compliance could entail a lowered quarterly business review score, crippling their ability to compete for Dell's business.

Proctor & Gamble (P & G) has a supplier scorecard that tallies the performance of suppliers on multiple sustainability criteria like the use of energy and water and the management of material and waste, and rewards suppliers with higher ratings if they collaborate with P & G initiatives on climate-change issues. An added benefit of this scoring system is that the suppliers not only align their GHG emission strategies with P & G but also use the scorecard to assess their own suppliers, as it directly impacts their rating with P & G.

Wal-Mart, is developing a Sustainability Index that asks 15 questions on various areas of sustainability to its 60,000 + suppliers. Wal-Mart wants the suppliers to report their results directly through the CDP Supply Chain Program. The sustainability index will be used as tool to score suppliers and products as well as identify opportunities for future collaboration.

For smaller firms who cannot use their size as leverage—if larger suppliers find it uneconomical to change their process for its smaller volumes—the solution is to redesign products with a different set of more sustainable materials that are readily available. For example, Nau, a small apparel manufacturer based in Portland, OR, uses wool, recycled polyester, and organic cotton as inputs to their garments to make them sustainable. They set standards for suppliers to follow, but to a large extent they use off-the-shelf fabric and existing supplier processes to manufacture garments. They engage their customers by donating 2% of every purchase to sustainable causes.

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[25] The Camry and 4Runner footprints were reported in http://online.wsj.com/article/SB122304950601802565.html.

[26] According to the 2011 Carbon Disclosure Project's Supply Chain Program, 12% of respondents indicated that they are deselecting suppliers based on GHG criteria. More importantly, 56% of them reported that they would use sustainability criteria to select suppliers in the next five years.

By far, the most prevalent model[27] is one of collaboration where the supply chain partners jointly collaborate on projects to reduce GHG emissions. The reporting or the lead firm initiates the project, opportunities are recognized, and a joint program is developed with agreed upon targets (both qualitatively and quantitatively). For example, in 2005 Wal-Mart initiated a project with Unilever to design and market "all® small-and-mighty," in 32 oz. containers which is three-times concentrated, and lasts the same 32 loads as a 100 oz. bottle[28]. The success of this initiative led Wal-Mart to work with other detergent suppliers like P&G, Dial, Huish and Church and Dwight, to transform their production processes to produce concentrated detergent. According to Wal-Mart this initiative saved 430 million gallons of water, and eliminated the use of 80 million lb. of plastic resin and 125 million lb. of cardboard.

Such examples of collaboration are numerous—supply chain partners need to align their sustainability-related incentives to make the project a success. P & G spent almost $ 200 million to retool its processes to make concentrated liquid detergent to meet Wal-Mart's goals—but anticipates that savings in materials, energy, water, and waste reduction will pay for such investments over time.

Often, reporting firms work and invest in their supplier's processes to transform them. Herman Miller's DfE team had to work with their suppliers to identify sustainable material for the Mirra chair. The furniture industry had well-established supply chains for materials (for example, plastic—its manufacture and molding into shapes) and any change will necessitate suppliers to invest in technology and material development. Herman Miller worked with over 200 suppliers to help identify sustainable materials and possible substitutes—a significant investment in time and resources.

Firms also face a number of operational challenges when working with partners. First, they have to agree on data and reporting standards. Since multiple standards are in use around the world, they need to reconcile GHG emission assumptions. Second, firms also need to prioritize how to set reduction targets. For example, targets can be low but can involve more partners in the supply chain; or they can aim for larger reductions working with select suppliers in a narrow slice of the supply chain. Third, firms also need to agree on how to report emissions, reduction targets, mitigation actions, and how if any, share the benefits of joint sustainability programs. While there are several industry-wide or third party based initiatives to resolve such issues, standards and protocols that tackle the measurement of GHG emissions, mitigation, and reporting from a supply chain perspective are still in their infancy.

However, as stakeholders demand life cycle emission information, and as firms discover the benefits of sustainable production by reducing their footprint, we expect the supply chain or the life cycle approach to gain wide acceptance in the near future.

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[27] 46% of CDP Supply Chain Program respondents have collaborative projects. In five years this number is expected to rise to 86%.

[28] http://walmartstores.com/media/factsheets/fs_2328.pdf.