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# A Methodological Framework for Supply Chain Carbon Footprint Management

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Tackling the environmental impact of global supply chain networks has emerged as a key priority for governments and corporations. To that effect, regulatory interventions, such as the European Union Emissions Trading Scheme, have been proposed and are gradually being implemented. In addition, as consumers become more environmentally sensitive, corporate social responsibility related issues are also posing additional pressures on companies to develop green policies. At the same time, environmentally friendly supply chain practices enable firms to achieve economic sustainability by developing a competitive advantage. As a result, supply chain stakeholders need firstly to capture comprehensively the environmental footprint of their supply chains and then to bring sustainability into their growth strategy. To that effect, this paper proposes a first-effort methodological framework for the management of the carbon footprint across the supply chain and during the product's life cycle.

## 1. Introduction

As a result of the growing societal environmental awareness, governments, regulators and businesses are impelled to set environmental sustainability as a top priority. A recent survey showed that a product's environmental footprint is a critical factor for the 83 % of the European Union citizens when deciding to purchase (European Commission, 2009). Furthermore, environmental regulations such as the Kyoto Protocol and the European Union Emissions Trading Scheme (EU ETS), both launched on 2005 and still evolving, aim to ensure the protection of the environment through the reduction of greenhouse gas emissions. Therefore, more and more companies are gradually adopting sustainable practices, such as the integration of carbon footprint management (CFM) into their entire supply chain, in order to comply with the environmental legislation, while lowering waste and improving their green image factor and competiveness. At the same time, green business mentality has emerged as a profitability center and competitive advantage for companies (Kumar et al., 2012).
In practice, firms are using carbon footprint (CF) analysis so as to guarantee sustainability, which denotes both environmental friendliness of their products and cost effectiveness of their supply chain activities. Actually, CF has been widely discussed among the scientific community as well as the industry over the last few years. CF may be considered as a part of Life Cycle Analysis - LCA (Wiedmann and Minx, 2008), which is a methodology for measuring and evaluating the environmental impacts connected to the life cycle of a product, such as global warming, ozone depletion, smog creation, eutrophication, acidification, toxicity, as well as resource exhaustion (Rebitzer et al., 2004). As regards global warming, CF is as a key performance indicator of the climate change impact caused by human activities and is expressed in $CO_2$ equivalent units (Clark, 2012). Wiedmann and Minx (2008) define carbon footprint as a measure of the total amount of $CO_2$ emitted directly and indirectly during a single activity or over a product's life stages. Nevertheless, through the same study, it is evident that the majority of definitions regarding CF also include other non-carbon greenhouse gases. Consequently, according to a more elaborate definition, CF methodology estimates the total greenhouse gas emissions in carbon equivalent units across a product's life cycle, from the stage of raw material procurement, via manufacturing, packaging and logistics, to the recycling and waste disposal (Carbon Trust, 2007).

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The remainder of the paper is structured as follows. In section 2, a brief and up-to-date literature review on CF measurement and evaluation in supply chains is presented. In section 3, we propose a new integrated methodological framework for the strategic CFM in supply chains. Finally, in section 4, conclusions as well as recommendation for future research are discussed.

## 2. Literature review

CF has emerged as a useful environmental concept for the calculation and assessment of the greenhouse gas emissions of single operations or during the entire life cycle of products. Practically, a company's carbon emissions depend on its industry sector, its position on the value chain, as well as its specific characteristics concerning its products' nature or the technologies used across its whole supply chain (Lee, 2011). In literature, there are a plethora of scientific papers including case studies that deal with CF estimation. A representative sample of such papers is discussed below.

In the automobile industry, the Hyundai Motor Company case study presents the incorporation of the CF in the supply chain of a car unit (Lee, 2011). In this case, suppliers are considered as a key factor that influence the supply chain's CF, so their emissions should be incorporated into the total CF measurement. Regarding the textile industry, a recent study demonstrates that the recycling of the pre-consumer process waste could contribute to the reduction of the CF in the clothing supply chain; this is much more effective than the recycling of the post-consumer end-of-life waste (Muthu et al., 2012). At the same time, concerning the biofuel industry, the CF evaluation of two different supply chains, a soy-to-biodiesel one and a corn-to-ethanol one, indicates that the first supply chain produces lower greenhouse gas emissions than the latter (Young et al, 2012). Furthermore, through the case study of AkzoNobel's Plant in Saskatoon, Canada, it is evident that efforts have also been made for the evaluation and reduction of carbon emissions in the chemical industry (Stein and Khare, 2009). Finally, in the dairy feed supply chain in the USA, raw materials for the feed production are responsible approximately for the 80 % of the CF, while energy and transportation together contribute roughly for the 10 % towards the whole greenhouse gas emissions (Adom et al., 2012).

Especially in the sector of food and beverages, there are plenty of case studies concerning CF in the context of supply chain management. Ziegler et al. (2013) compare the discrepancies in the CF among global supply chains of various Norwegian seafood products, while Rizet et al. (2012) calculate the $CO_2$ emissions comparing two supply chains, one for apples and another for yoghurt. According to Röös et al. (2013), CF can be considered as an indicator of environmental impact in the production of different types of meat, whilst according to Virtanen et al. (2011) the farming stage is responsible for the majority of the greenhouse gas emissions in animal-based food portions. Furthermore, in the case of a supply chain of honey in the USA, Kendall et al. (2013) document that truck transportation is the critical factor of carbon emissions during the life cycle of raw honey. In addition, Craig et al. (2012) present a case study of CF estimation in the supply chain of a leading importer of bananas in the USA. The results reveal that transportation produces more CF than the production of the bananas, while approximately 50 % of the supply chain's CF is due to indirect emissions outside the company's control. Finally, considering the wine supply chain, Patarra et al. (2012) contrast the results of a CF estimation tool and the LCA methodology, both applied in a real-case scenario, while Vázquez-Rowe et al. (2013) utilize a CF tool to evaluate the variation of results among different types of wine in Europe.

## 3. Description of the methodological framework

It is evident that all the aforementioned case studies are focused simply on the CF estimation and assessment of the supply chain activities by using various life-cycle-based tools. Nonetheless, to the best of our knowledge, in this highly dynamically moving field, there is a lack of systemic efforts which incorporate the CF perspective into strategic supply chain management. To that effect, in this section we propose a first-time integrated methodological framework for CFM in the entire supply chain. The proposed framework involves the steps that should be followed in order for a company to define, capture and evaluate their CF during the stages of a product's life cycle, as well as to make decisions for the reduction and monitoring of carbon emissions across the supply chain. The framework follows the natural hierarchy of the decision-making process and is essentially comprised of two echelons, namely a strategic and a tactical one (Figure 1). More specifically, the first phase involves the analysis of the company's internal and external environment and the setting of the strategic goals, while the second phase captures the decision-making process in conjunction with the implementation and execution of the strategy. The applicability of the proposed framework has been examined in a real-world case study of the supply chain

of a major manufacturer of insulating materials in Northern Greece (Aivazidou, 2013). Below, we provide a brief description of each of the nine involved steps.

### 3.1 Systematic Recording of the International Legislative Frameworks and Trends in CFM

Over the last years, governments are in a continuous consultation on CFM issues, leading to a number of evolving regulatory interventions. Hence, it is of utmost importance that a company systematically follow closely the enacted international environmental regulations and trends which concern the mitigation of the industrial CF, in order to effectively adapt its goals, processes and strategic decision-making to their requirements. The Kyoto Protocol, which was recently revised (United Nations, 2012), is an international treaty that obliges the industrialized countries to lessen their greenhouse gas emissions by trading their emissions quotas, as well as by receiving credit for financing emissions reductions in the developing countries. In addition, EU ETS, being now on its third phase, is the largest international cap-and-trade system in which power stations, industrial plants and commercial airlines operating in Europe receive or buy emission allowances within the cap and then trade them with one another as needed (European Commission, 2013). Further, as globalization gave a new impetus for the establishment of global supply chain networks with an increased need for lengthy transportation and up until now there is a lack of a relevant trading system, European Union is looking into creating various transportation-related emissions schemes for achieving substantial reductions in emissions by 2050 (European Commission, 2012).

### 3.2 Identification of the Best Practices in Supply Chain CFM

In order to 'green' their supply chain, companies should take into consideration the environmental policies that the elite organizations have already implemented on their supply chains and proved to be efficient in practice. In particular, a plethora of multinational organizations have embraced ambitious green practices for the supply chain's CF reduction in order to improve their sustainability. Indicatively, Samsung Electronics achieved a 40 % reduction in $CO_2$ emissions in 2011 compared to the 2008 baseline by developing a greenhouse gas emissions management system, which monitors both direct and indirect emissions associated with all the relevant supply chain activities (Samsung, 2012). Furthermore, Walmart, the largest multinational retail corporation in the world, accomplished a 20 % reduction of the greenhouse gas emissions of its stores and distribution centers in 2012 compared to 2005 by using renewable energy sources, while it is still improving its global transportation CF (Walmart, 2012). In addition, Toyota Motor Europe launched in 2011 its fifth five-year Environmental Action Plan, one of which main objectives was to establish a 'low-carbon society', which entailed enhancing hybrid technology for cars in the design phase, reducing energy utilization and emissions in the production stage, as well as optimizing route planning to limit emissions in logistics (Toyota, 2012).

### 3.3 Setting of the Strategic Goals for Supply Chain CFM

This step deals with the goals and objectives that a company should set so as to manage the CF of their supply chains concerning the environmental impact. To that end, companies have to consider: (i) the manner in which CFM affects their traditional business goals, such as operations' efficiency and profitability, and (ii) the new goals that emerge from CFM, such as the development of green supply chains and the establishment of a green image factor. In order to communicate their new environmental goals, such as the mitigation of CF across the entire supply chain, companies launch corporate social responsibility (CSR) programs. Nonetheless, apart from the environmental perspective of sustainability, the companies' fundamental objective is to achieve economic sustainability by creating a green competitive advantage in the marketplace leading to improved competitiveness.

### 3.4 Ranking of the Critical Operations and Identification of the Supply Chain Partners' Role

The current step is twofold, involving a thorough mapping of the company's supply chain through: (i) the identification of the crucial activities that mostly contribute in the greenhouse gas emissions, as well as (ii) the identification of the role of the supply chain stakeholders in the entire chain. When considering CFM from a product life-cycle perspective, companies should take into account the emissions of all the supply chain stages from the raw material extraction to the recycling or disposal of waste. Depending on the industry sector the company operates in, the ranking of the supply chain activities according to their CF contribution varies considerably. For example, in manufacturing plants production phase accounts for the majority of carbon emissions due to the high energy requirements (US Department of Energy, 2010), while in food industries the critical activities are the raw material extraction or the farming stage (Virtanen et al., 2011). In general, transportation generates significant amounts of CF in a product's supply chain. According to the Stern Review (2006), transportation accounts for the 14 % of the total greenhouse gas emissions, with three-quarters of them emitted due to the road transport. At the same time, since CFM is studied in a supply chain network context, the need for an integrated consideration, which involves all the stakeholders, is recognized. To that end, companies should extend their point of view towards upstream

and downstream of the supply chain, and identify the role of each partner (e.g. suppliers, third-party logistics providers, etc.) in the overall CF chain, their strength and weaknesses, as well as any new opportunities for improvement.

### 3.5 Measurement of the Total Supply Chain's CF

In this step, the company focuses on the CF calculation of each supply chain activity as well as in total. Given that the legislative CF measures are exogenously defined, the company should focus on: (i) the implementation of accurate data gathering mechanisms, (ii) the allocation of the relevant roles and responsibilities to the company's managers or departments, (iii) the acquisition of the necessary measurement tools and software, and (iv) the establishment of accurate and reliable procedures for measuring the CF and sharing the results to the rest supply chain partners. Regarding the calculation techniques, CF measurement, or else carbon accounting, is performed with life-cycle-oriented tools and software that quantify the greenhouse gas emissions. The most widely used international tools are the ISO 14064 and the Greenhouse Gas Protocol. The latter classifies the greenhouse gas emissions in three scopes, those of direct emissions, which are obtained from sources owned and controlled by the company, indirect emissions of purchased electricity or heat, as well as indirect emissions of the raw materials' extraction or transportation (WRI and WBCSD, 2012).

### 3.6 Evaluation of the Outcomes and Reconsideration of the Goals

It is suggested that companies check whether the outcomes verify that the supply chain activities, previously considered as critical, actually produce high levels of carbon emissions. In general, companies may be cautious when results indicate a high concentration of direct emissions, as they are exclusively responsible for their controlling. On the other hand, if the outcomes indicate an excess in the indirect emissions, this may be a sign that companies should scrutinize their relationship with the rest supply chain partners, such as suppliers or third party logistics providers. After the evaluation, the company's goals, set in the third step, should be reconsidered according to the gained up-to-date information and insights.

### 3.7 Centralized and Decentralized Decision-Making for Supply Chain CFM

This step includes the decision-making stage for the reduction of CF. Taking into account the related managerial insights obtained at the earlier steps of this framework, the company should firstly decide on the CFM strategies, as well as the relevant supporting procedures that will be implemented. Secondly, the company should define which department will be in charge of deciding the methodology to be employed for reducing the direct emissions during the internal supply chain activities, such as production or packaging. Finally, the company should appropriately select, negotiate and contract with the rest supply chain partners who are responsible for producing all the indirect emissions related to the procurement of raw materials and energy, as well as the distribution and transportation of the end products to the retailers. Consequently, the implementation of the final decisions requires the coordination among all the supply chain stakeholders, which is of crucial importance in the long-run concept of stable and harmonized relationships and common strategic planning regarding the supply chain's CFM.

### 3.8 Monitoring and Reporting of the Supply Chain's CF

Apart from the officially existing provided tools (e.g. the reporting tool for National Implementation Measures under the EU ETS), the company should be able to monitor its internal procedures on a more frequent basis, rather than the one year period during which it is usually obliged to report its CF performance to the related authorities. To that end, managers should agree on a solid information reporting scheme within the company's borders, as well as between the company and each of its supply chain partners. Partners have a crucial contribution to the overall environmental footprint and thus cooperation in terms of reporting and meetings is a prerequisite for the efficiency of the entire effort.

### 3.9 Re-evaluation and Update of the Decisions

In the light of such a dynamically changing global environment and due to the upcoming amendments of the international environmental legislation, companies need to re-evaluate and update periodically their CFM adopted decisions. In the case of greenhouse gas emissions for example, companies should take into account the potentially lower regulatory boundaries in order to reassess their decisions and apply new green technological advancements for further reducing the CF across the supply chain. Finally, apart from the regulation-driven changes and in terms of the economic sustainability, companies should develop any profitability-driven action (e.g. contracts with environmentally friendly partners, implementation of green production technologies or recycling policies, etc.) that targets to improve their performance through the efficient supply chain CFM.

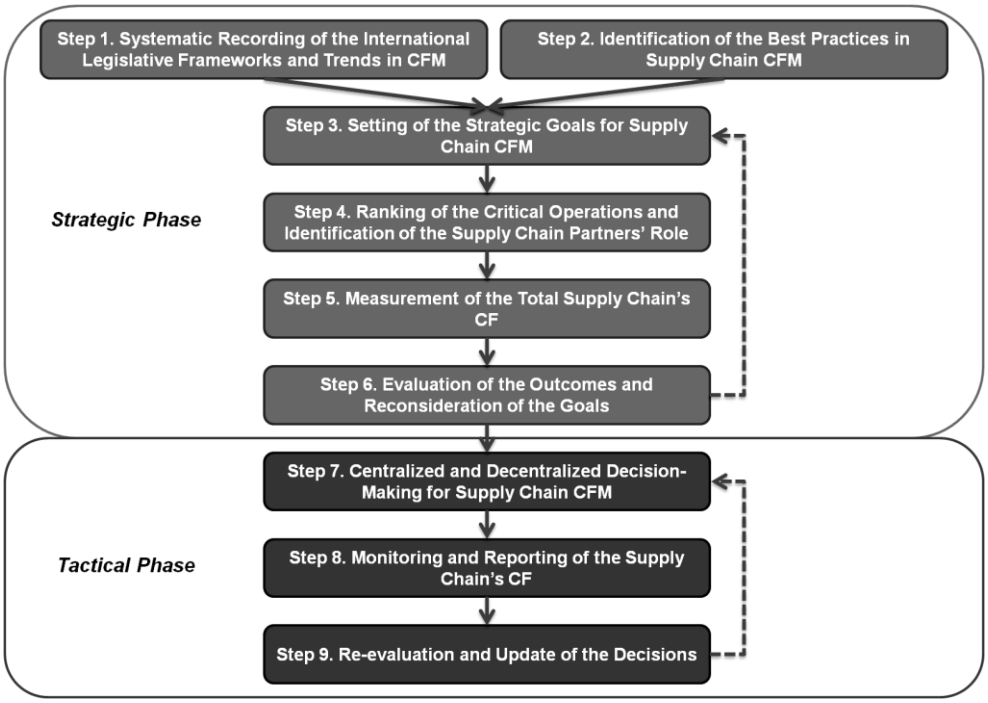


*Figure 1: The Supply Chain CFM Methodological Framework*

## 4. Conclusions

In this manuscript, we propose a novel methodological framework for the supply chain CFM. The proposed methodology follows the natural decision-making hierarchy and it can be employed to aptly manage the supply chain's CF, as well as to achieve environmental and economic sustainability in a supply chain integration context. The framework is generic enough in order to be applicable to companies across various industries. Finally, we intend to further customise and hone the framework, given our ongoing research with the major manufacturer of insulating materials that has led to the development of a real-world case study.

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