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Carbon Efficient Logistics: A Case study in Modal Shift

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Peter Oberhofer and Edgar E Blanco

Abstract

Corporate sustainability is becoming increasingly important in the development of business strategies. Consequently, transport and logistics operations come under particular scrutiny due to their substantial impact on the environment. The aim of this paper is to illustrate two successful examples where logistics performance is optimized in tandem with a reduction in carbon emission. The selected case study provides documented examples, detailing how GHG reductions can be achieved while improving business efficiency. The following two initiatives of an US company of the paper and packaging producing sector will be presented:

Initiative I:

- The company works closely with their customers to promote rail transport.
- Goods are directly sent from production plants which operate their own railway connection to the customer that is also located along the railway.
- In 2011, the promotion of rail transport on 4 US routes saved 62–72% CO2 emission (1,500-2,300 tons of CO2) compared to trucking. These savings are equivalent to taking 300-450 cars off the road every year.

Initiative II:

- The company uses space-efficient pallets in selected railcars and thereby increases the number of shipped goods.
- Besides optimizing the spatial utilization of the cars, CO_2 can be saved by transporting more goods on the same railcar.
- 190 tons of CO2 were saved by using space-efficient pallets in 930 railcars in 2011. This equals the CO2 emission caused by 21,637 gallons of gasoline consumed by road vehicles.

The case study calculations illustrate, step-by-step, how the reductions were estimated, and provide a detailed “road map” for future participants to implement and properly estimate the GHG reductions. Additionally, we also aim to present ‘Carbon Footprinting’ as a useful method of environmental monitoring and reporting and discuss different methodological approaches.

Introduction

Sustainability has increasingly become a central focus of business in times where most societies are aware of the critical influence of industry on both the environment and human health. It is not only policy makers that demand pro-active performance from companies, but also various members within their supply chains who expect their business partners to reduce their negative impact on the environment and society. Furthermore, customers are becoming more and more conscious of environmentally-friendly and ethically-produced products and services. Companies, of course, are aware of this development and not only regard it as an opportunity for new markets and ways to distinguish themselves from the competition, but have also started to sense opportunities to improve their businesses' efficiency and effectiveness by means of sustainable measures.

Carbon Dioxide (CO_2) is the most serious producer of greenhouse gas emissions (IPCC, 2007). CO_2 from fossil fuel use (accounting for 56% - others are CO_2 emissions from deforestation, decay of biomass (17.3%) or CH4 from agriculture, waste and energy (14.3%)) is mainly responsible for greenhouse gas (GHG) emissions (IPCC, 2007; OECD, 2010). According to Eurostat, transport is responsible for 24% of the European CO_2 emissions, with Road Transport amounting to, on average, some 77% of all national inland transport in the EU-27 countries (Eurostat, 2011). In the US, transportation accounts for more than 30% of all CO_2 emissions from fuel combustion. Within the sector, 87% of those emissions come from road transportation (IEA, 2012). Transport is the fastest growing sector in terms of the consumption of energy and the production of greenhouse gases in the European Union (EEA, 2010; Eurostat, 2012).

As the transport sector involves numerous unsustainable industrial processes, it is necessary to bring the sector in line with sustainability criteria (Roth & Kaberger, 2002). To address this issue, many companies promote transportation alternatives that are environmentally-friendly, such as railway transport instead of the traditional over the road trucking. In addition to physically altering the mode of transportation, increasing efficiency of their shipping operations also helps to lower carbon emissions and often expenses.

There are documented opportunities to slow the growth of logistics-related emissions such as, among others, mode shifting, load consolidation, equipment maintenance or network re-design. Although these solutions have been widely described, are economically viable and technically feasible, it is still challenging for companies to develop a "road map" that prioritizes and implements the variety of available options. The lack of a management framework and coherent methodology to communicate both internally with other corporate stakeholders, and externally with customers is a significant barrier for the improvement of the GHG efficiency (also known as *carbon-efficiency*) of freight flows.

The aim of this paper is to illustrate two successful examples where logistics performance is optimized in tandem with a reduction in carbon emission. The selected case studies provide documented examples, detailing how GHG reductions can be achieved while improving business efficiency. The case studies illustrate, step-by-step, how the reductions were estimated, and provide a detailed "road map" for future participants to implement and properly estimate the GHG reductions. In addition, it aims at discussing different methods of environmental reporting.

The rest of this paper is organised as follows. Section 2 is a literature review of the research topic. Section 3 presents the methodological approach and data. In Section 4 we outline the case studies, including detailed calculations, and present findings. Finally, Section 5 discusses the findings and concluding remarks are given.

Theoretical Approach

Sustainability

A widespread definition of sustainability was developed by the UN Brundtland Commission in 1987, which determined sustainable development as "[...] development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (United Nations, 1987). Starik and Rands specified the meaning further and reshaped the definition of sustainability to be "[…] the ability of one or more entities, either individually or collectively, to exist and flourish (either unchanged or in evolved terms) for lengthy timeframes, in such a manner that the existence and flourishing of other collectivities of entities is permitted at related levels and in related systems." (Starik & Rands, 1995). In recent years, business and management literature has focused increasingly on the integration of social, environmental and economic responsibilities as a definition of sustainability. This is broadly known as the triple-bottom-line approach and suggests a balanced interplay of the company's concerns. At their intersection, it is assumed that their activities not only positively affect the ecological or social environment but also result in economic benefits (Elkington, 1998, 2004).

Not long ago, sustainability and corporate social responsibility were viewed as a way to improve a company's reputation and distinguish it from the competition – a branding tool (de Boer, 2003; De Marchi, Di Maria, & Micelli, 2012; First & Khetriwal, 2010; Haddock-Fraser, 2012; McDonald & Oates, 2006; Nair & Menon, 2008; Peattie, 2001; Pedersen & Neergaard, 2006). Today, however, it goes beyond branding. Sustainable actions have become a value-adding tool for companies by improving efficiency and saving costs (MIT Sloan Management Review & The Boston Consulting Group, 2012; Semchi-Levi, 2010).

Environmental Management

The term "environmental management" (EM) refers to the environment-orientated management of a company (Müller-Christ, 2001). It involves all activities and decisions necessary to minimise the environmental pollution caused by the company (Baumann, Kössler, & Promberger, 2005). At first, environmental management was hardly more than complying with the relevant rules and regulations, although it was later suggested that win-win situations (for the company on one side and the environment on the other) were possible (Walley & Whitehead, 1994).

Carbon Footprinting

One of the most widely applied methods of measuring environmental sustainability is 'Carbon Footprinting'. It helps in emission management and evaluation of mitigation measures (Carbon Trust, 2012). Through quantifying emissions of certain measures, business units and other areas of reduction goals can be identified and processes can be measured. Besides intrinsic motivation of introducing environmental reporting, (external) legislative regulations on emissions have been initiated, which force organization to increasingly report their carbon footprint. Moreover, communication of carbon footprints to third parties and consumers becomes more and more popular (Pandey, Agrawal, & Pandey, 2011).

Carbon Footprinting has become a widespread method to calculate and report environmental impact at many different levels such as products, companies, households or individuals (Peters, 2010). Due to its use in the media, carbon footprint has become a synonym of the impact of companies, individuals or regions on the climate change (Wiedmann, 2009). Despite its wide use, the term is still unclear (Wiedmann & Minx, 2008). One definition was offered by Wiedman and Minx (2008) stating: "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 includes individuals, organizations, companies, governments etc. as well as products and services and refers to direct (on-site, internal) and indirect (off-site, external, embodied, upstream/downstream) emissions (Wiedmann & Minx, 2008). Throughout the last decade a number of different methodologies have been developed (Craig, 2012). They can generally be subdivided into three main categories (Baldo, Marino, Montani, & Ryding, 2009): (i) general guidelines that represent a normative standard to emission calculation, (ii) specific guidelines that contain ad hoc indication on emission calculation and (iii) monitoring and calculation tools that calculate emissions of specific activities.

Methodologically carbon footprinting can be approached in two main ways: bottom-up, based on Process Analysis or top-down, based on Environmental Input-Output Analysis (Craig, Blanco, & Sheffi, 2012). Bottom-up approaches were developed mainly to calculate the impact of single products from cradle to grave and mainly suffer from the problem of setting appropriate boundaries, in particular when it comes to calculations of larger systems. In contrast, top-down approaches are based on overall sector data including all economic activities (=system boundary) which are allocated accordingly. Due to the inclusion of complete economic systems its use on a micro level (products or processes) is limited. In the scientific discussion, a hybrid form, combining both approaches is increasingly recommended (Wiedmann & Minx, 2008).

Among many, two of the most important standards to estimate greenhouse gas emissions from freight transportation are the GHG Protocol standard and the NTM calculator (Craig et al., 2012). The GHG Protocol is the product of a cooperation between the World Resource Institute (WRI) and the World Business Council of Sustainable Development and bases its emission factors on two main sources: the UK Department for Environment, Food and Rural Affairs (DEFRA) and the US Environmental Protection Agency (EPA). The calculation of the emission factors by mode is based on a top-down methodology. EPA divides the total emissions (derived from official EPA data, the national greenhouse gas inventory) by the estimated ton-miles carried by the mode (using data from the Bureau of Transportation Statistics) (EPA, 2008, 2012). DEFRA's approach is similar but more comprehensive as they also take into account different equipment types for each mode (e.g. fuel efficiency and loading factors for trucking and total consumption of diesel and electricity of freight trains) (Defra, 2010). Throughout the last decade, the GHG Protocol standard became presumably *the* most important basis for almost all GHG standards worldwide (Craig et al., 2012). The Network for Transport and Environment (NTM) is a Swedish based NPO. Their methodology follows a bottom up approach making use of two default data bases: ARTEMIS for road transport and EcoTransit for rail transport. Emission calculation from road transport is mainly based on fuel consumption of a specific vehicle type and vehicle load and fuel scenarios (empty vs. full vehicles, load/load capacity) (NTM, 2010, 2012). Despite the different methodologies both approaches have in common that they require detailed knowledge about weight and specific routing of the shipments, which is not sufficiently documented in many companies to estimate reliable total emissions.

Methods and Data

A case-based approach using two field studies was performed to illustrate two successful examples where logistics performance is optimized in tandem with a reduction in carbon emission. Yin (2002) states that case studies can be exploratory, descriptive or explanatory. As there is little evidence of tangible environmental practices in the transport and logistics sector and their impact on business performance, this study is both exploratory and explanatory in its nature. Furthermore, the case study approach is the best to capture the richness of individual settings (here: environmental initiatives of a specific company).

The selected case studies provide documented examples, detailing how GHG reductions can be achieved while improving business efficiency. The case studies illustrate, step-by-step, how the reductions were estimated, and provide a detailed “road map” for future participants to implement and properly estimate the GHG reductions. Direct company data from 2011 was provided by the partner company that was analyzed according to renowned methodologies in carbon efficiency measuring.

Case Study: Measuring Carbon Emissions in the transport and logistics sector

The following analysis is based on historical data from 2011 of a large US company operating in the field of paper and packaging production. Operating in a highly competitive market, they seek optimal economic performance as it is the basis for the existence of any company in the long run. Yet, social and environmental responsibility continues to be a key issue. Besides projects related to air and water quality, fiber and energy resources and waste materials to minimize environmental pollution they put a major focus on managing emissions and fuel usage from logistics operations. They have recently launched new initiatives to optimize their logistics operations and further improve their environmental performance simultaneously. These initiatives include shifting transport movements completely from the road to railways and implementing new tools to increase operational efficiency.

The focus of this case study will be on the following two initiatives: (1) shifting shipments from road to rail, an initiative where customers are directly supplied via railway and (2) the use of space-efficient pallets that enable an optimal utilization of railcars.

Initiative I: shifting shipments from road to rail

In course of this initiative selected customers are supplied with ordered goods solely via railway. Goods are sent directly from production plants which operate their own railway connection to the Distribution Center (DC) of the customer which is also located along the railway.

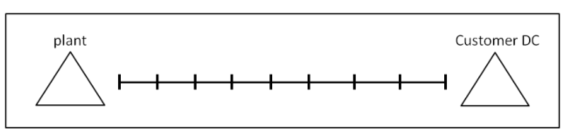

Figure 2. Railway transport operation

The company works closely with its customers to find solutions to increase the amount of loads that are sent solely via railway and consequently improve the environmental performance of its supply chains. However, there are restraints from the customer’s perspective that limit the realization of those transports. On the one hand, a certain equipment and infrastructure have to be provided; particularly a DC which is located directly at or close to the rail network. On the other hand, it impacts on the customer’s inventory as the size of single deliveries increases and might result in higher inventory costs. Decisions will therefore strongly be influenced by the type of product and product value.

Data

We were provided with shipping data of four specific U.S. routes from 2011. On each of those routes, goods were shipped from production plants directly to the DC of their customer. The data contained information about the origin and destination city of the rail haulage, distances, shipping dates and shipped tons. Table 1 summarizes the routes.

Origin	**Destination**	**Distance (miles)**	**Total # of cars**	**Total # of tons**
A	B	604	43	3,176
A	C	1,614	22	1,672
D	E	1,932	165	14,744
D	F	1,027	25	2,233

Table 1: shipping information of initiative I

Approach to calculate CO_2 savings

In order to compute the CO_2 emission savings, we needed to compare the total CO_2 emissions of railway shipments versus trucking. As a first step, we calculated the amount of CO_2 that was emitted by performing rail transport for all four routes. We define the carbon footprint of each railway shipment using the following formula:

$$CF_{CD} = w * d_r * c_r$$

where,
w =shipment weight (short tons)
d_r =distance of rail haul (miles)
c_r =carbon efficiency of rail transport (Kg CO_2/short ton-mile).

We used information on the carbon efficiency of rail transport from the WRI Greenhouse Gas Protocol (WRI, 2012). WRI's emission factors for freight transport on US railways are based on default data from US EPA Climate Leaders (EPA, 2008) .

In order to compute the GHG emission savings we needed to compare the total carbon emissions of railway transport to trucking, assuming that the goods would have been shipped on the road from the same origin to the same destination on full-loaded trucks if the railway transport had not been conducted.

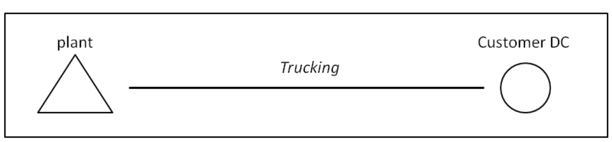

Figure 3. Trucking operation

Information from *Google maps* (Google, 2012) was used to compute the road distances between production plant and the customer DC.

Due to a broad range of ways to estimate carbon emissions of truckload transportation, an important step was to select the appropriate methodological approach. After evaluating various approaches we found the methodologies of WRI Greenhouse Gas Protocol (WRI, 2012) and NTM (NTM, 2012) to be the most suitable. Both are based on official default data and are commonly used for carbon emission calculation of transportation (Craig et al., 2012).

The following formula estimates the carbon emissions for a truckload movement according to the methodology of the WRI Greenhouse Gas Protocol (Vehicle distance):

$$CF_{TL} = d_{otr} * c_{tl}$$

d_{otr} = over the road distance (miles)
c_{tl} = carbon efficiency of truckload transportation (kg CO_2/mile).

Carbon efficiency of truckload transportation of WRI Greenhouse Gas Protocol (Vehicle Distance) is based on default data from US EPA Climate Leaders (EPA, 2008).

We assumed the truckload to be 20 short tons and the following vehicle type to be used: *Heavy Duty Vehicle - Articulated – Diesel – 5.9 mpG - Year 1960-present, US*.

Following the methodology of NTM the carbon emission for a truckload movement was estimated using the following formula:

$$CF_{TL} = fc_{xy} * d_{otr} * c_{tl}\text{, with}$$

$$fc_{xy} = fc_e + (fc_f - fc_e) * \text{load/load capacity}$$

fc_{xy} = fuel consumption for driving on road x with vehicle y (l/mile)
d_{otr} = over the road distance (miles)
c_{tl} = carbon efficiency of truckload transportation (CO_2/mile).
Fce = fuel consumption of empty vehicle (l/km)
Fcf = fuel consumption of full vehicle (l/km)
Load = weight of loaded goods on vehicle (short tons)
Load capacity = permitted weight capacity of vehicle (short tons)

According to NTM the carbon emission calculation of truckload transportation is related to information on the vehicle type including fuel type, load capacity and road types. Based on that information, average fuel consumption is determined. NTM provides a default data base if no situation-specific data is available.

We assumed the load of each truck to be 20 short tons and the following vehicle type to be used on the motorway: *Tractor + semitrailor, Diesel, Euro 4, 28 metric tons (31 short tons)*. Fuel consumption for empty vehicles was determined to be 0.226 liter/km while 0.36 liter/km applied for full vehicles.

Finally, savings from railway transport were evaluated by comparing actual emissions of the rail haulage to emissions from (hypothetical) trucking.

Table 2 shows the emissions factors used.

Vehicle type	**methodology**	**emission factor**	**unit**
Rail	WRI GHG protocol	0.0252	Kg CO_2 per mile
Road vehicles	WRI GHG protocol	1.717118644	Kg CO_2 per mile
Road vehicles	NTM	1.245660336	Kg CO_2 per mile

Table 2. Emission factors for transporting on road and rail

Results

Table 3 summarizes the final results of the carbon emission calculation for all analyzed routes.

Railway Transport		
Source emission factor rail	GHG protocol	
total CO_2 emissions (kg)	891,846	
average CO_2/ton mile*	0.029	
Trucking		
Source emission factor road	GHG protocol	NTM
CO_2 emission (kg)	3,237,955	2,348,930
average CO_2/ton mile*	0.102	0.074
Total		
savings (kg CO_2)	2,346,109	1,457,084
Percentage	72%	62%

Table 3. Emission savings from Railway transport

* great circle distance

Based on our analysis, the company saved total carbon emissions of 62-72% by promoting railway transport (depending on which methodology for the carbon emission of trucking was used). This is equivalent to 1,500-2,300 tons of CO_2, which equals the consumption of 168,000-258,000 gallons of gasoline or annual GHG emissions from 294 – 451 passenger vehicles (EPA, 2012). While the average CO_2 emission per short ton-mile is 0.029 kilograms for rail transport, it rises to 0.074 kilograms (NTM) or 0.102 kilograms (WRI) for trucking. Consequently, the longer the distance between origin and destination the higher were the CO_2 savings.

Initiative II: Car Load optimization using space-efficient pallets

The company equips rail cars with so called space-efficient loaded pallets on selected routes and shipments. Those space-efficient pallets enable them to increase the total number of shipped goods. This initiative evolved in the course of the following considerations: by looking closely at carloads, the company determined that there was an opportunity to increase the volume of products in each rail shipment. They realized that when leaving the factory pallets did not reach from floor to ceiling, and a small space was not utilized on the rail cars. Since the space was not large enough for a traditional pallet to be added, the company tried to place a half size pallet on top of the existing pallets. After a few operational trials they realized that the half size pallets were best positioned in the middle layer of the stack in a 'step-down' configuration starting with the highest and heaviest at the far end of the rail car. Cardboard sleeves were added around the top layer units in order to further increase protection and reduce risk of damage. This configuration had a potential to significantly increase rail car utilization.

Once the operational configuration was solved, the company needed to work with its customers to be able to obtain orders that would fit space-efficient pallet shipment: to ship a half pallet in a rail car, there needed to be an order for a half pallet of product. Customers needed to create new SKUs and modify ordering and receiving systems to allow for the new half-pallet product configuration. It turned out that a half pallet was a perfect solution for seasonal or lower-demand specialty items. As these items did not move as quickly they often sat in customer's warehouses. The half pallet allowed the customer greater flexibility in their ordering creating a win-win situation for both the company and its customers.

The configuration was finally added as an optional configuration for customers in 2011.

Data and CO_2 savings calculation

The company provided data of 5,553 railway shipments within the US in 2011. Out of those, 928 cars were partly equipped with space-efficient pallets. The data set included information about origin and destination of the cars, shipping date, car type, number of pallets, total weight, number of space-efficient pallets used, and weight of loaded space-efficient pallets.

As a first step, we calculated the extra utilization resulting from the use of space-efficient pallets. We differentiated between cars with and without space-efficient pallets and computed the average shipped tons per car for each car type (50' low, 50' high, 60' low and 60' high). Table 4 summarizes the results of the extra utilization calculation per car type.

Car type	**Regular cars**	**Cars with space-efficient pallets**	**Extra utilization %**
	Average tons/car	**Averages tons/cars**	
50' high	75.9	83.2	9.6%
50' low	74.5	75.6	1.5%
60' high	89.1	95.1	6.7%
60' low	89.9	92.4	2.8%
total	84.2	91.1	8.2%

Table 4. Extra utilization from space-efficient pallet use

Looking at the car type in detail, we found a significant utilization increase for 50' and 60' high cars, in particular.

As a next step, we calculated the amount of CO_2 emission that was saved by using space-efficient pallets. There are two approaches to try to estimate the CO_2 savings. One approach is to assume that, to be able to provide the same level of service, the company will need to ship those space-efficient pallets in a different mode (e.g. in a truckload). This approach will follow the same lines of analysis we used for initiative 1. However, this will not be a realistic estimate since customers will most likely not be willing to pay more for a half-pallet being shipped in a more expensive mode. This will also significantly overestimate the CO_2 reductions since truck emissions are much higher than rail emissions.

A second approach will be to assume that the marginal CO_2 contribution of placing half-pallets in an existing railcar is negligible. We can then estimate the savings of the space-efficient pallet by assuming that the weight of the space-efficient pallets would have been shipped in additional railcars that will generate new CO_2 emissions. Thus, to estimate the CO_2 savings, we subtracted the average weight of a 'regular' car (i.e. those that did not carry space-efficient pallets) from cars that carried space-efficient pallets, taking into account the different car types. We then multiply this extra weight by the rail distance and the rail emission factor. This number was used as a proxy estimate of CO_2 savings due to higher rail car utilization.

Following the methodology of WRI Greenhouse Gas Protocol (WRI, 2012) we calculate the carbon footprint of an extra shipment using the following formula:

CF3T =w * dr * cr

where,
w = shipment weight
dr = distance of rail haul
cr = carbon efficiency of rail.

Again we used information on the carbon efficiency of rail transport from the WRI Greenhouse Gas Protocol (WRI, 2012). An emission factor of 0.0252 CO_2 per short ton-mile (rail, U.S.) was used.

Table 5 summarizes the results of the calculations of CO_2 savings from using space-efficient pallets.

Car type	saved tons	CO_2 savings (kg)	%
50' high	2,248.11	65,212.42	8.60%
50' low	6.21	158.98	1.64%
60' high	3,648.62	124,538.03	6.30%
60' low	72.65	2,666.94	2.90%
total	5,975.60	192,576.37	6.79%

Table 5. Carbon savings from using space-efficient pallets

Based on our calculations, the company saved approximately 193 tons of CO_2 (6.8%) by using space-efficient pallets. This is equal to CO_2 emissions from 21,637 gallons of gasoline consumed or annual GHG emissions from 38 passenger vehicles. The results show that the highest savings could be achieved by using space-efficient pallets in 50'high (8.6 % savings) and 60'high cars (6.3 % savings).

Notice that the weight of the product placed in a space-efficient pallet will still travel the same distance to the client location. Thus, if we use the rail emissions formula above, space-efficient configured railcars generate the same CO_2 emissions as regularly configured railcars. Thus, we could conclude that the extra rail car utilization does not save any CO_2 emissions. This is indeed a limitation of the approach used for rail emission calculations: the rail emission factor already takes into account the average network railcar utilization and does not provide any parameters to capture any extra CO_2 savings due to the new pallets in the railcar. In other words, the ton-mile rail emission factor used in the formula above does not take into account marginal changes in railcar utilization levels. More information will be needed about the marginal fuel consumption of the rail locomotive due to the space-efficient pallet configuration.

Conclusion

Both initiatives are good examples of improving logistics operations in terms of both environmental and efficiency issues. Railway transport is a perfect example of building long-term customer loyalty to optimize business and environmental performance through improved logistics performance. Compared to trucking, rail haulage is able to save large amounts of carbon emission for long-distance transport movements. The use of space-efficient pallets illustrates how rail transportation can be further optimized in terms of space utilization and carbon efficiency. Sellers of slow-moving goods, in particular, can benefit from optimizing their inventory. The overall results show that space-efficient pallets are particularly appropriate to be transported in high cars.

We performed carbon footprint calculations to monitor the environmental impacts of both initiatives. CO_2 emissions for trucking were calculated using two methodological approaches in order to validate results, increase precision and illustrate general differences of the two different approaches: WRI's GHG protocol methodology (WRI, 2012) and the NTM methodology (NTM, 2010, 2012). Any variances in the calculation of carbon emissions for trucking between both approaches are due to their different underlying methodologies. WRI uses a top-down approach to compute the emission factors by dividing total emission (source: EPA National Greenhouse Gas Inventory (EPA, 2008) by estimated average mileage of the specific transport mode (source: Federal Bureau of Transport Statistics). NTM takes a bottom-up approach. Estimations on fuel consumptions are based on vehicle type and load capacity using information from the ARTEMIS emissions modeling software. In general, literature favors bottom-up methodologies for single products or processes as they prevail in detail and accuracy (Wiedmann & Minx, 2008).

In order to benefit from advantages of both approaches a hybrid method is increasingly suggested. Consequently, the detail and accuracy of bottom-up approaches can be preserved while 'higher order requirements' can be met by the top down approaches (Wiedmann & Minx, 2008).

In general, the method of carbon footprint proved to be accurate to monitor the environmental performance of companies and evaluate specific initiatives. Since today, environmental behavior is associated with economic actions in form of taxes, carbon offsets or positive as well as negative costumer behavior (Pandey et al., 2011), consistent carbon footprinting can be described as an essential corporate key criterion.

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