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Allocating greenhouse gas emissions to shipments in road freight transportation: Suggestions for a global carbon accounting standard

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HIGHLIGHTS

- Shipment inherent GHG emission drivers are discussed.
- The Shapley value is used to study the accurateness of different allocation rules.
- Suggestions for a global carbon accounting standard are presented.
- 'Distance' should be the only factor used to allocate transport GHG to shipments.

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ABSTRACT

The European Norm EN 16258 was published in 2012 to provide a common methodology for the calculation and declaration of energy consumption and greenhouse gas emissions related to any transport operation. The objective was to offer a pragmatic and scientifically-acceptable approach that allows a wide group of users to prepare standardized, accurate, credible, comparable, and verifiable energy consumption and emission declarations. However, in its current form, EN 16258 contains gaps and ambiguities, and leaves room for interpretation, which makes comparisons of supply chains difficult. This research aims to overcome the shortcomings in the domain of allocating emissions from road freight transport operations to single shipments. Based on a discussion of emission drivers and the results of numerical experiments comparing the allocation vectors created by the EN 16258 allocation rules with those generated by the Shapley value, which is claimed to be the benchmark, 'distance' is identified as the single most useful unit for bridging the trade-off between accuracy and simplicity better than the other recommended allocation schemes. Thus, this paper claims that future versions of EN 16258 should only allow the allocation unit 'distance.' This will promote the accurateness, simplicity, consistency, transparency, and comparability of emission declarations.

1. Introduction

1.1. Background

Greenhouse gas (GHG) emissions make a significant contribution to atmospheric changes and climate disruptions, both of which are harmful to natural and built environments and pose a threat to human health and welfare. McKinnon et al. (2015) cite a study undertaken by the World Economic Forum and Accenture that estimates that logistical activity accounts for about 5.5% of the global GHG emissions, with 90% of these emissions coming from freight transport and two-third of these transport GHG emissions being generated by trucks and vans.

Industry (shippers) and its customers (consignees), logistics companies (carriers), governments, and consumers share the common goal of reducing GHG emissions caused by freight transport operations (Cosimato and Troisi, 2015; McKinnon and Piecyk, 2009; Rigot-Muller et al., 2013; Wittenbrink, 2014; Wu and Dunn, 1995). Standards for the assessment of GHG emission that guarantee an accurate, transparent, and comparable quantification of GHG related to transport activities are needed in order to understand and compare the emission efficiency of different logistics strategies and processes, to identify GHG-cutting opportunities and best practices, and to promote ecological transparency across the supply chain (required in the framework of legal obligations, customer requests, corporate social responsibility, or industry-wide benchmarks).

Several organizations and initiatives have recently published guidelines on how to quantify transport-related GHG emissions (COFRET, 2011). Yet, despite some convergence towards a unified approach, there is at present no single globally recognized and

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accepted standard for the calculation of the product or corporate carbon footprint that covers the entire freight transport supply chain (Davydenko et al., 2014; McKinnon, 2010; Olson, 2010; Olsthoorn et al., 2001; Wick et al., 2011). As a result, the direct comparison of GHG assessments is often not possible, and the multiplicity of tools and methodologies has an impact upon the (perceived) accuracy of the calculations; moreover, there is often no confidence and clarity in the results obtained (Davydenko et al., 2014; McKinnon and Piecyk, 2009; Schmied and Knörr, 2012). The European Norm EN 16258 'Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passengers)' (CEN, 2012), which was published in 2012 by the European Committee for Standardization (CEN), is presently the only official international—though European—standard for emission calculation of transportation in supply chains (Davydenko et al., 2014; Schmied and Knörr, 2012). The national standardization bodies of 33 countries are obliged to adopt this norm.

1.2. Research objective

Similar to the research of COFRET (2015) and Davydenko et al. (2014), this study considers the EN 16258 as a starting point for a global standardization approach because it is not globally accepted but has the potential to be so. Furthermore, in its current form (EN 16258:2012), the EN 16258 contains gaps and ambiguities, and leaves room for interpretation, for instance, on the topic of GHG allocation to shipments. This makes the comparison of supply chains difficult (COFRET, 2011; Davydenko et al., 2014; Lewis et al., 2012). This research aims to overcome some of these shortcomings by suggesting how to overcome the gaps and ambiguities of the EN 16258 concerning the allocation of GHG emissions that result from road freight transport operations to the shipments that are moved by the vehicles (EN 16258:2012, Chapter 8).

Although the allocation of GHG emissions to shipments is just one aspect outlined in EN 16258, it is important for four reasons (Davydenko et al., 2014; DSLV, 2013; Kellner and Otto, 2012; Schmied and Knörr, 2012; Wittenbrink, 2015; Zhu et al., 2014). First, with more and more shippers and consignees asking for emissions related to the transportation of individual products, emission calculation on the shipment-level is becoming more important. This implies a growing need for standardized, comparable, accurate, and fair GHG allocation schemes. Second, from a physical point of view, the emissions are produced by the vehicle while carrying out the transport operation. In order to allocate the GHG to any other logistic object (handling unit, loading device, product, customer), it must first be allocated from the vehicle to the shipment. Third, the calculation of shipment-level GHG is necessary when the emissions do not result from an organization's own transport activities but from operations carried out by third parties. Fourth, the quantification of emissions in door-to-door settings is possible by means of shipment-level GHG values. This allows shippers to select the preferred transport solution ex ante (e.g., for the CO_2 benchmarking and optimization of supply chains) and to evaluate de facto GHG ex post (e.g., for CO_2 labelling of products).

The article is organized as follows: Section 2 reviews the relevant literature and summarizes the allocation principles stated in EN 16258:2012 and alternative allocation methods suggested for the allocation of GHG emissions to shipments in road freight transportation. Section 3 makes a concrete suggestion for harmonizing the apportionment process by means of a single allocation principle. The reasoning is supported by concepts of the cooperative game theory. Section 4 summarizes the main findings.

2. Literature review

2.1. The EN 16258 guidelines for allocating GHG to shipments in road freight transportation

According to EN 16258 (CEN, 2012), the calculation of the transport-related GHG emissions on the shipment-level is done in two steps: (1) Compute the total volume of GHG of a transport operation, and (2) allocate this quantity to the single shipments.

2.1.1. Step 1: computing the volume of GHG for a transport operation

The total GHG emissions of a transport operation are calculated on the basis of the 'vehicle operating system (VOS).' The latter is defined as a consistent set of vehicle operations carried out to move the relevant shipment. EN 16258 identifies collection and delivery trips as instances of a VOS. An important aspect of the VOS concept is that the VOS shall, in all cases, include the empty trips related to the vehicle operations. Once the VOS has been specified, the fuel consumption of the transport operation (VOS) has to be determined. Finally, standard emission factors are used to convert the amount of combusted fuel into GHG.

At this point, it should be noted that EN 16258 provides energy conversion factors to translate fuel consumption into GHG emissions. However, it does not detail how fuel consumption shall be approximated when it cannot be measured directly—e.g., because the transport operation has been carried out by third parties, or when future/alternative transport scenarios are to be evaluated. For those cases, fuel consumption models have been developed that estimate fuel consumption of transport operations based on a variety of vehicle, environment, and traffic-related parameters (Demir et al., 2014). Organizations that have participated in the preparation of EN 16258 and other (national) institutions engaged in the field of environmental protection recommend the following formulaic approach to approximate GHG emission related to transport activities (ADEME, 2010; DECC, 2015; DSLV, 2013; ifeu, 2014; Kranke et al., 2011; Schmied and Knörr, 2012):

$$GHG=\frac{FC_e+\left(FC_f-FC_e\right)*\frac{to}{Cap}}{100\text{km}}*distance*EF \quad (1)$$

GHG emissions are estimated by multiplication of the total fuel consumption of the considered transport operation and an energy conversion factor *EF* (in kg CO_2e per liter fuel). The total fuel consumption (in liters) is derived from the fuel consumption per kilometer (first factor in Eq. (1)) multiplied with the *distance* (in kilometers) travelled (second factor in Eq. (1)). The fuel consumption per kilometer is approximated based upon the vehicle-specific consumption patterns and the weight-based load factor (to/Cap), where to is the tonnage transported and Cap is the maximum weight-based vehicle payload capacity. FC_e is the (average) fuel consumption in liters fuel per 100 km when the vehicle is unloaded (empty vehicle), and FC_f is the analog when completely loaded (full vehicle). FC_e and FC_f are vehicle specific consumption patterns capturing all factors influencing fuel consumption, except weight capacity utilization, such as vehicle design, driver behavior, average road gradients, congestion situations, share of urban/inter-urban tours, European emission standards, etc. The values used in this research are explained below. According to Eq. (1), the effect of vehicle loading on fuel consumption (and GHG emissions) is linear. This is in line with the ARTEMIS data (DECC, 2015). The energy conversion factor *EF* transforms combusted fuel into GHG emissions as CO_2 equivalents (CO_2e). EN 16258 specifies an energy conversion factor of 2.67 kg CO_2e for the combustion of one liter diesel.