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# Towards harmonization of Carbon Footprinting methodologies: a recipe for reporting in compliance with the GLEC Framework, Objectif $CO_2$ and SmartWay for the accounting tool BigMile™

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# Summary

Carbon Footprinting (CF) is an important tool for reduction of $CO_2$ and other Greenhouse Gas (GHG) emissions from freight transport and logistics. A properly implemented CF procedure provides for visibility of GHG emissions in supply and logistics chains, thus creating opportunities to understand emission reduction potentials and implement emission reduction measures. There are a number of carbon footprinting and carbon reporting tools and methodologies available, starting from the European standard EN 16258 and the EU FP7 COFRET project, which paved the ground for the calculation of carbon emissions in transport and logistics chains, to the mature programs and methodologies such as the GLEC Framework, SmartWay, Objectif $CO_2$ and accounting tools like BigMile™.

The essence of carbon footprinting is in getting insights into the carbon intensity and total GHG emissions of transport and logistics operations. For the carriers it is the amount of $CO_2$ emitted per unit of transport work, such as tonne-km or $m^3$-km transported; for the cargo owners, such as shippers and consignees, it is the amount of $CO_2$ emitted per cargo unit transported, often measured in tonnes or $m^3$. Other units of work are possible: it is important that improvement measures are used to continuously reduce the carbon intensity of the operations. Moreover, governments and investors are becoming increasingly interested in the GHG emissions and the emission intensity trends.

To be able to use carbon footprinting in decisions related to the organisation of transport chains and logistics, there is a strong need that all parties involved in the process use the same method for computation of the $CO_2$ emissions and allocation of the emissions to the activities that cause them. Without methodological harmonization, comparison of different supply chain design options and of the performance of service providers is not possible. However, each of the abovementioned methodologies and tools have a strong market position and user group, who may find it unnecessary or difficult to switch the methodology, or accept another method than the one that is promoted by other organizations. Therefore, there is a need for a smarter approach than picking up a winning methodology and prescribing everyone to use it. This report provides recipes on how to harmonize different methods and approaches at the level of data requirements, computation algorithms and output reports. The described harmonization is a one-way harmonisation as seen from the BigMile™ initiative perspective, equipping the BigMile™ tool with a capability to report in accordance to the GLEC Framework, SmartWay and Objectif $CO_2$.

The choice of the BigMile™ initiative as a starting point for one-way harmonization is due to its flexibility towards input and output data detail and aggregation level, due to its combination of methodology and software implementation and due to the initiative's explicit wish, in the form of commissioning this study, to harmonize with the three other approaches.

This report shows that it is possible to achieve a one-way harmonization of the BigMile™ tool with the GLEC Framework, SmartWay and Objectif $CO_2$ approaches once the necessary software developments are performed. This report provides instructions (recipes) on how to do that at two levels.

At the first level, instructions are provided on how to compute output according to the GLEC Framework, SmartWay and Objectif $CO_2$ solely based on the input of the BigMile™ accounting tool. As the computational principles differ between different approaches, so are the data requirements. This report shows that it is possible to report according to the other approaches, but not always achieving a zero discrepancy between the outputs to be generated by BigMile™ and the output generated by the considered approach. For this type of harmonization, this report provides in addition to computation instructions also estimations of the entailing discrepancies that stem from the fact that not all data are available. In those cases, some assumptions and approximations will be necessary to perform the computations.

At the second level, this report further shows what data needs to be additionally collected and classified properly in order to eliminate the discrepancies to compute emissions 100% in accordance to the other approaches. The report shows it in a uniform way foreach of the three other approaches, for the GLEC Framework, Objectif $CO_2$ and SmartWay.

Finally, this report makes recommendations to further expand the scope of carbon footprinting in future methodological development.

This report provides technical recommendations on how to generate carbon footprint reports in accordance to GLEC Framework v 1.0, Objectif $CO_2$ and SmartWay under different data requirements conditions and different levels of output discrepancy. This report does not facilitate discussion on standardization of the carbon footprint and carbon accountancy methods, nor does it provide a basis for assessment of the related frameworks and does not touch upon the issue of a universal methodological harmonization. This report underscores that considered tools, methodologies and frameworks may be positioned at different conceptual levels and are essentially diverse in the purpose, scope, application level and target user groups, but does not get involved into corresponding discussions and positioning considerations.

# Contents

**Appendices**

# 1 Introduction

## 1.1 A brief introduction into Carbon Footprinting

Carbon Footprinting (CF) is an important tool for reduction of $CO_2$ and other GHG emissions from Freight Transport and Logistics (Davydenko and Smokers, 2017). A properly implemented CF procedure provides for visibility of carbon emissions in supply and logistics chains, thus creating opportunities to understand reduction potentials and implement emission reduction measures, see Figure 1. Introduction of CF procedures almost always results in unexpected findings of reduction potential (McKinnon, 2018).

At the top level, emission reduction can be realized through:

1. Redesign of transport and logistics chains: For instance, the main questions that are being considered here is the location of logistics facilities, service and speed requirements, transport modes involved and routing of the material flow, frequency of delivery, batch sizes and so on. The design of the transport and logistics chains is a powerful tool for emission reduction, but requires the capability to estimate future emissions from the chain.

2. Selection of the most environmentally friendly services and energy providers: Once the design of the transport and logistics chains is firmed, the most environmentally friendly service provider, within the constraints of costs and quality, can be chosen. For the service provider selection, there is a need for performance indicators of the service providers.

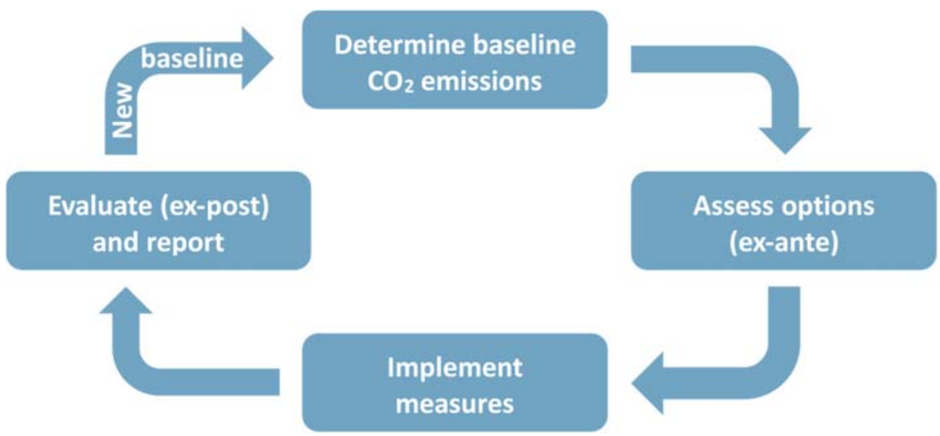


Figure 1: Positive decarbonisation loop through complete visibility of emissions.

In practice, a redesign of the transport chain may lead to a change of the contracted service providers, or to a change in performance of the existing service providers. Conversely, contracting a new service provider may shift the optimum of the transport chain and / or lead to a change in performance of the service provider. Therefore, the main practical question is to find a combination of these two types of actions which provides the largest emission reduction potential.

There are different tools and methodologies available to perform Carbon Footprinting and Carbon Reporting (see section 1.2 for disambiguation of the notions). Also, on the market several software packages exist for optimization of the transport and logistics chains. Due to historical reasons, preferences of the core user groups and regional conventions, the available methodologies have some differences in input, calculation method and output. As a result, the outcomes of computations based on the different methodologies are likely to differ, creating an environment where the outcomes are very difficult to compare. In all, this leads to a challenge of comparison and harmonization. This report takes further steps in bridging different CF methods to result in a more method-agnostic approach to emission computation and reporting in transport and logistics[1].

## 1.2 Disambiguation of definitions related to decarbonisation and carbon footprinting

The notions of Carbon Footprint, Carbon Reporting and Carbon Accountancy can be intuitively understood, however they differ in a rather subtle way. Although these terms are often used interchangeably, this report provides the definitions of the terms related to carbon footprinting in an unambiguous way. This is deemed necessary as the tools and methodologies considered in this report have their specific applications. The following provides definitions of the five core notions.

**Decarbonisation** is the process of reducing the carbon intensity[2] of transport and logistics activities.

**Carbon footprinting** is an analysis of GHG emissions and attribution of these emissions to the activities that cause them. Carbon footprinting feeds the decarbonization process with the data on actual emissions (ex-post) and expected emissions (ex-ante) related to the proposed improvements. Carbon footprinting provides insights into the impact of the activities on the GHG emissions and their intensities with the possibility of subsequent actions to reduce them. Carbon footprinting is the underlying method for carbon reporting and carbon accountancy. Carbon footprinting includes an analysis that computes or estimates $CO_2$-equivalent emissions and attributes those to the activities that cause them. Carbon footprinting can be performed at different levels, such as at macro (national or regional), meso (collaborative structures, ports, corridors), micro (company or department) and nano levels (specific activities, journeys, shipments). Carbon footprinting always includes decomposition of complex transport and logistics chains into transport chain elements or transport service categories, which can be further supplemented with in-depth analyses.

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[1] This report provides a guidance on how to report in accordance to the considered methodologies. It is not intended as a formal review or assessment of the carbon footprinting methodologies and tools, and does not provide a comparative assessment of the underlying methodologies.

[2] Note that *decarbonization* can be also understood as a complete removal of GHG emissions from transport and logistics activities. In this report, we treat the notion of decarbonization as the reduction of carbon intensity of operations; a complete removal of the GHG emissions from operations is thus a special case of decarbonization.

**Carbon Footprint** is the total greenhouse gas emission volume expressed in $CO_2$-equivalent weight. The emissions are related to a specific activity with a clearly defined scope.

**Carbon Reporting** is a means of carbon emission communication. Carbon reporting can be constructed as the sum of carbon footprints of specific activities that are within the reporting scope, as for instance, emissions related to all transport and logistics activities of the company. Carbon reporting allows setting communicable targets[3] to reduce emissions in the future.

**Carbon Accounting** is the processes undertaken to measure or estimate the amounts of carbon dioxide equivalents emitted by an entity. Carbon Accounting includes the processes related to data and metadata collection, data processing, including where appropriate data parsing, normalization, syntax analysis, as well as structured storage of data, processing and computation results.

**Carbon Accountancy** is a formal form of carbon reporting that can be validated and approved by an independent auditor.

## 1.3 Carbon footprinting standards, methods and tools

Many different carbon footprinting standards, methods and tools exist. This section provides a brief description of the most important ones.

### *1.3.1 EN 16258*

The first harmonized $CO_2$ footprinting methodology for transport and logistics is the European EN 16258 standard. EN 16258 has been the first serious step towards building a consensus about how carbon footprinting is to be done. EN 16258 has some issues with ambiguity of computation methods and fairness of emission allocation, which led to suggestions for methodological improvements as identified in the EU FP7 COFRET project (Davydenko et al., 2014).

### *1.3.2 Programmes and methodologies*

#### *1.3.2.1 GLEC*

Another derivative of the work done in the COFRET project is the Global Logistics Emission Council (GLEC) Framework (GLEC, 2015). The GLEC's approach is to build a comprehensive CF and CA method, which is based on consensus among the user group. In practice, the GLEC Framework follows the de facto industrial practices per mode and per type of transport and logistics activity. The GLEC Framework is partly based on the EN 16258 standard as well, in turn making certain harmonized choices, which add detail as well as override in some circumstances the EN 16258 prescriptions. The GLEC Framework can be seen as a way of helping large shippers and LSPs with computing their logistics-related emissions: where possible and preferably based on real-world data, or *primary* data, of carriers; where there are no such data by using detailed modelling or default consumption factors.

[3] This can be absolute volume of GHG emissions, as well as normalized intensity of GHG emissions.

#### 1.3.2.2 *Objectif $CO_2$*

By the application of Article L. 1431-3 of the French transport code (Art 228 French law 12 July 2010), all transport service providers (both goods and passengers; all modalities) and home moving services have to provide well-to-wheel (WTW) $CO_2$ information for every transport service. The French Objectif $CO_2$ methodology is to be used for computation of these emissions.

The legislation makes the Objectif $CO_2$ methodology an important one, as all transport services departing from and/or travelling to France have to provide emission data to the customers according to the method. The Objectif $CO_2$ methodology is flexible with respect to the exact computation method. This is due to the fact that the reporting companies can choose their own implementation as long as the implementation complies with the law with respect to the output requirements.

#### 1.3.2.3 *SmartWay*

The United States Environmental Protection Agency (US EPA) has established the SmartWay program to improve fuel efficiency and reduce GHG emissions and air pollution from the transportation and supply chain industry. The SmartWay program provides a collection of tools aimed at shippers, logistics service providers (LSPs) and carriers to compute their emissions. The SmartWay program provides output on $CO_2$, $NO_x$, PM and Black Carbon, thus being more broad in scope than only CF and CA functionalities. The SmartWay program is being developed and provided by a government agency; it is also a leading program for emission reduction from the transport and logistics sector in the United States.

#### 1.3.2.4 *BigMile™*

BigMile™ is a self-service platform that collects and combines data from the day-to-day operations of shippers, logistics services providers and carriers. BigMile™ consists of three modules: Carbon Footprint - for computation of a certified carbon footprint; Carbon Analytics - for creating insights into the emissions and evidence-based improvement plans; Profit Finder - for improvements in logistics performance. BigMile™ is aimed at both shippers and logistics services providers, covering all modalities and all possible fuels, including all important fossil fuels, different types of biofuels, electricity, synthetic fuels, etc. BigMile™ is a software implementation of a carbon footprinting methodology that is flexible with respect to input, allowing different types of data at different aggregation levels to be used, thus providing carbon footprinting implementation that is useful for different levels of data availability.

### 1.3.3 *Harmonization*

To be able to use carbon reporting and footprinting in decisions related to organisation of transport chains and logistics, there is a strong need that all parties involved in the process use the same method. Without methodological harmonization, comparison of different supply chain design options, and moreover, performance of the LSPs and carriers is not possible. On the other hand, each of the above-mentioned methodologies and tools have a strong market position and user group, who may find it unnecessary or difficult to switch the methodology, or accept another method, which is promoted by other organizations[4]. Therefore, there is a need for a smarter approach than picking up a winning methodology and prescribing everyone to use it.

## 1.4 Aim, scope and approach of this study

This study aims at designing a procedure for harmonization at the data input level: based on data input for the BigMile™ accounting tool, we construct recipes for computation and reporting according to the other three. In other words, this report facilitates coexistence and one-way harmonization of different methodologies, at the same time ensuring comparability of carbon footprinting computations between BigMile™ and GLEC (Framework v 1.0), SmartWay and Objectif $CO_2$.

This report describes how to achieve a one-way harmonization of computations from the BigMile™ point of view. In other words, it describes how BigMile™ may implement computing and reporting capabilities in accordance to GLEC, SmartWay and Objectif $CO_2$.

An analysis is provided on how BigMile™ can generate results that are in accordance with the prescriptions of the other methodologies under consideration. BigMile™ is both a methodology and an accounting software tool, which is flexible with respect to data detail and aggregation. This combination makes it uniquely suitable for a one-way harmonization with the other three approaches. The report provides a guidance on how BigMile™ can generate output based solely on the usual BigMile™ data inputs and what it means in terms of discrepancy between thus generated BigMile™ output and reporting according to the other studied methodologies. This report further provides information on what data should be collected additionally to the BigMile™ inputs in order to generate zero discrepancy outputs in accordance to the other methodologies.

## 1.5 BigMile™ harmonization with other methods

In this study, BigMile™ was taken as the reference method. The reasons for this choice are threefold.

1) BigMile™ is open with respect to the level of detail and precisions in input and output data allowing different levels of aggregation. The Objectif $CO_2$ is also open to the aggregation levels and the levels of detail in the input/output data, while the GLEC Framework and SmartWay provide specific aggregation conditions;
2) BigMile™ is both an underlying methodology and an accounting software tool that allows companies functionalities to analyse their data and carbon footprint, as well as functionality to help decarbonize operations. Of the other three considered approaches, only SmartWay has a software implementation;
3) BigMile™ is willing to harmonize its methodology with the other three approaches.

[4] A methodological framework can to a certain extent alleviate this problem, however, specific methodological differences would persist, leading to different computation outcomes for the same input datasets.

Thus, BigMile™ presents a combination of methodology and software implementation that can work with different levels of detail and data aggregation. This combination of factors makes it suitable for the purpose of one-way harmonization with the three other approaches. The report answers the following questions:

1. Using the BigMile™ data input, how can the output be computed in conformance with:
   a. the GLEC Methodology v1.0;
   b. SmartWay, and;
   c. Objectif $CO_2$?
2. Does the usage of only BigMile™ data input lead to good quality reporting conform the three abovementioned methodologies?
3. What minimum extra data requirements in addition to the BigMile™ data requirements are needed to report fully conform to the other methodologies?

This report provides a “recipe” on how the BigMile™ tool, using its standard data input, where necessary supplemented with other data, can be used to generate output conform GLEC, SmartWay and Objectif $CO_2$. This is a practical solution for a one-way harmonization across these four different carbon footprinting and carbon accountancy methodologies and tools.

## 1.6 Reader’s guide

This report is structured as follows. Chapter 2 describes the fundamental principles of carbon footprinting of transport and logistics operations; Chapter 3 analyses BigMile™ as the basis methodology, and Chapters 4 - 6 provide “recipes” for generation of GLEC, Objectif $CO_2$ and SmartWay compatible output on the basis of the BigMile™ methodology and tool. Chapters 4 - 6 are identically structured and describe the scope of the methodology under consideration, i.e. transport and fuel chains, whether infrastructure and vehicle construction emissions are in the scope of the methodology under consideration; the calculation method (units, levels of data, fuel and energy use, transport activity, quantification of $CO_2$ emissions); the methodology’s specific output; a ‘recipe’ on how to generate output in conformance with the methodology in question using only BigMile™ input data; and what level of discrepancy will result compared with output generated with all the data needed. Each chapter ends with a section on what extra data need to be collected by BigMile™ for a full compliance and how it should be processed. Chapter 7 presents the conclusions and gives directions on possible scope extensions of carbon footprinting methodologies.

# 2 Fundamental principles of carbon footprinting for transport and logistics operations

## 2.1 Carbon footprinting as a tool for sustainable logistics

Carbon footprinting provides insights into and visibility of GHG emissions related to transport and logistics activities (Smokers et al., 2019). There are different ways of measuring carbon footprint, but most of them can be reduced to two main parts: 1) determining of the weight of GHG emissions within a certain transport and logistics scope and 2) allocation of those emissions to the activities that cause them. *Determining the amount* of GHG emissions relates to the physical and chemical properties of the energy sources used and can be computed unambiguously based solely on these natural properties. *Allocating* the GHG emissions relates to the way they are divided among the activities carried out within the measurement scope. With respect to allocation there is always some degree of arbitrariness present in all methodologies, while the two most important aspects of any carbon footprinting methodology are directional correctness and fairness of allocation.

It is very important that carbon footprinting methods are understood by the people that apply them and use the computation outcomes. As practice shows, even relatively computationally simple methods like the GLEC Framework v1.0 face implementational challenges if the complexity of data gathering and data processing are not hidden in software implementation (LEARN D4.4, 2018). Therefore, this report looks into how to compute the most accepted quantitative indicators of carbon footprinting, while also noticing that other indicators might theoretically be more suitable in situations that justify the use of more advanced methods and indicators.

The insights of carbon footprinting determine the performance of logistics organizations, pinpointing less-optimal sections of logistics chains and, in doing so, provide a sound and objective basis for optimization and the design of decarbonisation measures.

## 2.2 Carbon footprinting for different actors

The commonly accepted carbon footprinting indicators can be split into two broad categories. For carriers and LSPs (1), the main carbon footprint key performance indicator (KPI) is defined as relative performance of the network, namely gram of $CO_2$ emitted per tonne-kilometre carried. $CO_2$ per tonne-kilometre is a measure for the efficiency of the network of the carrier with respect to carbon emissions: the smaller the amount of $CO_2$ emitted per tonne-kilometre, the better the operator performs within the scope of the network. Note that the performance of the network itself strongly depends on its structure. For shippers and freight forwarders (2), the total amount of emissions related to transport of a unit of goods, such as one tonne, defines the environmental performance of the company, including the choices for a network and the contracted carriers.

Therefore, the KPI from the shipper's perspective is gram of $CO_2$ per tonne transported[5]. In an ideal situation, the service provider computes the shipper's KPI and shares it with the shipper. Alternatively, the shipper's KPI can be computed by the shipper itself if the KPI of its carrier(s) is (are) known. Weight is the most used common allocation variable.
In practice, however, volume, pallets and other measurements are also used as an allocation variable, as section 2.5 further substantiates.

The carriers and LSPs can improve their environmental performance by minimizing the amount of $CO_2$ emitted per tonne-kilometre transported. This can be realized by a number of measures, for example, by using electric trucks, ensuring better utilization rates of the vehicles and optimizing networks. Shippers can improve their environmental performance by reducing distances between production and consumption locations, using less carbon-intensive modes, using larger shipment batches and less frequent deliveries, by choosing best in class carriers, etc. Furthermore, shippers and carriers or LSPs can collaborate to improve their environmental performances. By getting insight in the impact of their own and each other's choices they can maximize their common emission reduction potential.

## 2.3 Logistics chains

The logistics chain is a path of goods from the production to the consumption location. A logistics chain can consist of a single transport operation (transport leg), where goods are loaded at production and unloaded at consumption, as well as a number of sequential transport legs, possibly connected at logistics nodes, such as ports, terminals, distribution centres and warehouses or cross docks.

Shipment-level emission computation at the logistics chain level involves summing up shipment-related emissions from each part of the logistics chain transport.
The carbon footprinting methods are applicable at the level of individual legs and operations. Therefore, logistics chain emission computation requires emission data or estimation thereof on each individual leg and, if included into the scope, logistics node operations.

At this moment not all emissions are included in carbon footprinting methodologies. For instance, vehicle and infrastructure construction emissions are excluded from the scope. Transhipment-related emissions start to be included into the scope (Dobers, Ehrler, Davydenko, 2019). IT and connectivity infrastructure emissions are implicitly out of scope (they might be partly be in scope if transhipment points' emissions are within in the scope). IT and connectivity emissions are becoming important as logistics organisations rely more and more on computing and remote sensing. The IT emissions need to be considered in the following iterations of carbon footprinting methodologies.

[5] There are shippers who are interested in other indicators too, such as $CO_2$ per tonne-kilometre transported, for their analytics.

## 2.4 Modalities and Transport Service Categories

Typically, the following transport modalities are distinguished:

1. Road
2. Rail
3. Inland water navigation
4. Sea (deep sea and short sea)
5. Air

A further segmentation of markets and / or operations within transport modes is desirable. For instance, the carbon footprint of parcel networks and that of long-haul transport of bulk products are completely different per tonne-kilometre transported, as well as per tonne shipped. Therefore, it is reasonable to divide operations further into Transport Service Categories (TSCs), which are groups of similar journeys that represent the way freight transport services are procured and provided.

## 2.5 Transport activity and emission allocation methods

In the allocation part of carbon footprinting methods, the GHG emissions from the carbon footprinting scope are allocated to the activities that cause them. The share of emissions that is allocated to the activity under consideration is proportional to the activity's share of the total transport activity.

Transport activity is measured per transport leg within a transport service category. The most common measure of transport activity is tonne-kilometre, which is obtained by multiplying the quantity of goods by the distance over which the goods are displaced. Some methodologies allow using $m^3$ and other measures for the quantity of goods; the distance unit (kilometres) can be measured as great circle distance (GCD), actually driven distance, planned distance, shortest feasible distance and fastest distance (see section 2.6). Independently of the specific units chosen, transport activity is measured as a multiplication of shipment size dimension (weight, volume, other) by the distance over which the shipment is displaced, thus the simplest and most commonly used form of transport activity measure is tonne-kilometres.

The scale of the measurements varies from the simplest allocation proportionally to tonne-kilometres, through multidimensional capacity allocation methods (Davydenko et al., 2014) and revenue driven allocation, to the game theoretical allocation approaches (Naber et al., 2015). These approaches vary with respect to complexity and data requirements, as well as with respect to their capacity to drive transport systems into the desired direction of decarbonization.

It should be noted that allocation of emissions purely on the basis of mass appears to be insufficient in cases where other characteristics limit the amount of goods that can be transported or where different types of cargos are mixed. A broader definition of vehicle capacity utilization would be a fairer form for allocation.
The shipment's claim on a vehicle's capacity is a better indication of the need for transport to take place, which is what results in the emission of $CO_2$. The vehicle capacity has several dimensions, such as weight, volume, floor space, number of passengers (if applicable), number of pallet places and other possible dimensions. Davydenko et al. (2014) specify a quantitative indicator that combines different

vehicle capacity dimensions and their utilization by the shipment into one synthetic indicator (called by the authors “allocation weight”). The allocation weight takes into account different dimensions of capacity utilization and makes allocation of $CO_2$ to the shipments more fair (and thus more suitable for the purpose of decarbonisation) than weight-only-based indicators.

Proper allocation is particularly important when the outcome of the CF activities is used as an input into the decisions on logistics organization and decarbonisation. At the same time, not all allocation is straightforward to do properly.

In case of combined freight-passenger operations allocation proportionally to the weight can lead to undesirable results. For instance, in case of ferries that carry passengers and freight lorries, weight-based allocation would result in almost all GHG emissions allocated to the lorries, due to the sheer difference of weight between people and heavy goods vehicles. A more subtle case in point is aviation operations, where passenger aircraft and dedicated freighters have different weight capacities, leading to higher emission allocation to freight travelling in the bellies of passenger aircraft than to the freight travelling on dedicated freighters. Given the fact that passenger aircraft movements are mostly determined by the passenger demand, a preference for dedicated freighters may result in unnecessary aircraft movements and extra real-world emissions, while belly freight capacity may be still underutilized.

## 2.6 Distance measures

Computation of transport activity requires determination of distance over which the shipments are displaced. Different distance measures are used in carbon footprinting methodologies. Each of these measures has its own advantages.

The following considers the five most important distance measure definitions:

1. **Great Circle Distance (GCD).** The great circle distance is the shortest distance between two points on the surface of the Earth, measured along the surface of the Earth. It is also known as the “as the crow flies” distance: this distance does not consider any infrastructure, so two points are connected directly, as if there is a straight road between them. The GCD is the most suitable measure for distance for the purpose of carbon footprinting as it looks at the net transport work independent of the chosen modality, infrastructure density and routing of the goods flow. It is the only measure that leads to a correct calculation of the impact of changes in routing or modalities on the carbon footprint. It is also the “easiest” distance measure from an administration and data requirements point of view, as there is no need to keep track of the routes that the vehicles travelled.
2. **Actual Driven Distance (ADD).** The actually driven distance is the distance travelled by the vehicle. This distance can be measured by the vehicle’s odometer. The ADD is the most intuitively understandable distance: for this reason it has deep usage roots. For instance, transport statistics is expressed in tonne-kilometres actually driven and the companies are used to reporting to the statistics bureaus in this manner. Also, some transport companies charge their clients based on travelled distances.

3. **Planned Distance (PD).** The planned distance is the distance that a shipment will be following in a vehicle as the route of the vehicle is optimized by the planning software. The software optimizes the vehicle route, for instance, minimizing total kilometres driven and / or making sure that time-related constraints are satisfied. The PD is therefore not the shortest distance for a shipment, but a distance that the shipment is planned to travel. The advantage of the PD is that it is an ex-ante estimation of distance to be travelled, it can be computed and stored in a database. The PD can be later revoked from the database.
4. **Shortest Feasible Distance (SFD).** The shortest feasible distance is the shortest distance between two places on a mode-specific network. The SFD may not be the best route as it may include slow moving streets, or toll roads. The advantage of the SFD is that it is easily understood and is the same for all users that use the same software to compute it. In case of unimodal operations, the SFD is conceptually not different from the GCD measure of distance in its quality for the purpose of carbon footprinting.
5. **Fastest Distance (FD).** The fastest distance is the distance of the route that allows travelling from the departure point to the arrival point. The advantage of the FD is that for a given pair of departure and arrivals points it is the likeliest to be used.

## 2.7 $CO_2$-equivalent emissions

A carbon dioxide equivalent or $CO_2$ equivalent, abbreviated as $CO_2$-eq or $CO_{2e}$, is a metric measure used to compare and add the emissions from various greenhouse gases on the basis of their global-warming potential (GWP), by converting amounts of other gases to the equivalent amount of carbon dioxide with the same global warming potential[6]. The carbon dioxide equivalent allows taking into account greenhouse gasses other than $CO_2$ without the need for explicit reference to them. All relevant emissions are aggregated into one quantitative indicator. In this report for the purpose of simplicity and if it is not otherwise specified, $CO_2$-equivalent emissions are understood under $CO_2$ emissions.

## 2.8 Type of $CO_2$ emissions: well-to-wheel and tank-to-wheel

There are three types of $CO_2$ emissions distinguished. Each measure is normalized per litre or kg of fuels used.

The three types are as follows.

1. Tank-To-Wheel (TTW). The tank-to-wheel emissions are emissions of the GHGs that are a direct consequence of burning fuel. The carbon content of fuel is transformed into $CO_2$ in the process of burning.
2. Well-To-Tank (WTT). The well-to-tank emissions are the emissions of GHGs that result from production of the fuels and include emissions from fossil oil and gas extraction, transport of raw materials, refining, storage and distribution. The WTT emissions are the emissions emitted by the fuel production and distribution chain.

[6] https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Carbon_dioxide_equivalent

3. Well-To-Wheel (WTW). The well-to-wheel emissions are the sum of TTW and WTT emissions. The WTW emissions are the total amount of direct and indirect $CO_2$-equivalent emissions emitted as a result of transport activity.

## 2.9 Key performance indicators (KPIs)

The carbon footprint can be measured based on different capacity units, like tonnes, cubic metres or pallets. In general, all carbon footprint KPIs can be divided into two levels:

1) Carbon efficiency of a carrier or an LSP. This is measured as kg $CO_2$-equivalent emissions resulting from a unit of transport activity, which is typically defined as a unit of goods carried over a unit of distance.
The most common measurement of transport activity is one tonne-kilometre (tkm) and in that case, the carbon efficiency of a carrier is kg of $CO_2$-equivalent per tonne-kilometre transported. Another common measure of transport activity in for example package distribution is $m^3$-kilometre, since these vehicles are more often capacity-limited by volume as opposed to weight.
2) Carbon efficiency of a supply chain of a shipper or consignee. This is measured as kg $CO_2$-equivalent emissions resulting from one tonne (or other capacity unit like $m^3$) shipped. Note that a shipper's KPI does not include distance[7]. Although the most preferred way of shipper KPI computation is when it is computed and reported by the service provider, the shipper's KPI can be computed by multiplying carrier's KPI by the distance. The latter way of computation is used when the carrier does not provide such a service, or when the shipper considers its own computations to be more reliable than those of the service provider.

## 2.10 Fuel and energy use

To carry out a transport activity, vehicles[8] use energy: fuel or electricity. The measured quantity of fuel or electricity should correspond exactly to the transport activity, including all auxiliary vehicle moves, such as empty trips, transport of empty load carriers and movement to and from client locations. The quantity of fuel and electricity is converted into $CO_2$-equivalent emissions using emission factors. Both $CO_2$-equivalent emissions and the total amount of energy (fuel or electricity) are proxies to measure energy efficiency of transport and logistics operations. The total amount of energy will become more relevant compared to $CO_2$, particularly when zero emission electricity is being used.

## 2.11 Levels of data resolution

Different levels of data resolution are possible, however, they can broadly be grouped into the following four categories[9]:

[7] Some shippers are interested in the GHG emission intensity of their LSPs, thus may request their normalized indicators, such as kg $CO_2$-equivalent emissions per unit of transport activity.
[8] The term 'vehicles' is used to refer to all means of transport in all transport modalities.
[9] It should be noted that this categorization does not account for data quality, as in practice data quality can be "patchy" and thus push the users of the methodology to use a more aggregated level even if data exists at a more detailed resolution level.

1. Individual journeys where both transport activity and fuel (energy) use are known;
2. A collection of journeys by a single or a number of vehicles over a certain period (week, month, year), where both transport activity and fuel (energy) use are known;
3. A journey or a collection of journeys by a single or a number of vehicles over a certain period, where transport activity is known, but fuel (energy) use is not known;
4. A journey or a collection of journeys by a single or a number of vehicles over a certain period, where transport activity can only be estimated, and fuel (energy) use is not known[10].

Some intermediary levels of data resolution are possible, e.g. when fuel use is partly known, or transport activity is estimated.

[10] For the cases when transport activity and / or fuel used are not known, the actually driven distance or planned distance can be used for estimation of transport activity, and for estimation of fuel use if the type of vehicle is known. Note that this will result in a lower level of the accuracy.

# 3 BigMile™: the Reference Method

## 3.1 Logistics chain (scope)

The BigMile™ tool[11] broadly follows the COFRET methodology for calculation of its output. The transport chain is constructed as a number of sequential transport legs, possibly connected via nodes (logistics facilities). At the shipment level, the shipment emissions are computed as the sum of emissions related to the shipment under consideration in each transport leg. The BigMile™ tool takes emissions of transport legs and nodes (transhipment and storage) into account.

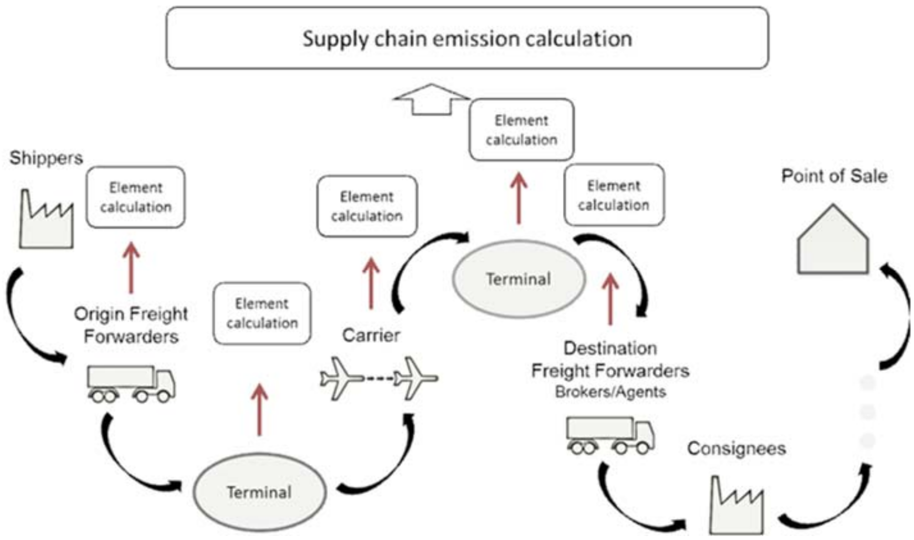


Figure 2: Example of logistics chain consisting of a number of individual legs. (Source: COFRET project.)

## 3.2 Calculation method

The BigMile™ method computes the following KPIs:
- $CO_2$/tonne
- $CO_2$/tonne.km*Shortest Feasible Distance*
- $CO_2$/tonne.km*Great Circle Distance*
- $CO_2$/unit
- $CO_2$/unit.km*Shortest Feasible Distance*
- $CO_2$/unit.km*Great Circle Distance*

[11] This analysis of the BigMile™ tool and methodology is based on the confidential document “THE BIGMILE ALGORITHM, Definitions and calculations” version 1.31 dated 07 October 2018. This document was shared with TNO per email on 8 October 2018 for the purpose of this report only. The parts of the method not covered by this document have been treated in accordance to the COFRET methodology, Davydenko et al. (2014). Public documentation on the BigMile™ tool and methodology is provided in [Connekt, 2019]. During the writing of this report, the developer decided to follow most of the recommendations that were done with respect to harmonizing the BigMile™ tool with other methods. Appendix A shows an overview of the BigMile™ developments that are scheduled.

Note that the users can specify their input unit (e.g. pallet or $m^3$), which is converted into tonnes using a user definable conversion table. In the remainder of this chapter only tonne and tonne-kilometre are mentioned for simplicity, but in all cases these terms refer to the user specified input unit.

These KPIs fall into two broad categories: first, performance of the shipper ($CO_2$/tonne), which shows the amount of $CO_2$ emitted per unit of shipment between origin and destination. Second, performance of the LSP or carrier ($CO_2$/tonne.km*Distance Unit*). The second KPI shows the carbon efficiency of the network or operations of the LSP('s).

Although other measures of distance are possible (e.g. shortest feasible distance), the methodology works with the Great Circle Distance (GCD) measurement of distance, and hence the BigMile™ method uses the GCD as primary measurement of distance.

Transport activity and fuel use (energy use) are the primary inputs for calculation of the KPIs. Within a certain calculation scope, the amount of transport work is computed in the form of tonne-kilometer shipped. The total amount of $CO_2$ emitted should strictly[12] correspond to that transport activity within the same calculation scope.

### *3.2.1 Transport activity*

Within the calculation scope of a transport leg, transport activity is computed as the sum of transport activities of constituting shipments. The shipment transport activity values are computed as the weight of a shipment multiplied by the distance between loading and unloading locations. The use of distance measure (e.g. GCD (preferred), shortest feasible, actually driven, etc.) must be consistent (i.e. the same) to avoid systematic error within the calculation scope.

### *3.2.2 Fuel and energy use*

$CO_2$ emissions are computed as the amount of fuel used (or the amount of electricity used) times the relevant emission factor. Standard emission factors are used, as defined on www.co2emissiefactoren.nl or other (regional) equivalent data sources. The main underlying requirement is that emission factors are Well-To-Wheel (WTW).

## 3.3 Levels of data resolution

BigMile™ distinguishes several data quality levels:

- (B) Bronze: estimations based on default values and key figures.
- (S) Silver: measured values, aggregated per period (year or month) or per license plate or location.
- (G) Gold: measured values per license plate or location per period (month, week, trip or stop).

The data quality level is assigned to subsets of the input data and is stored together with transport and fuel data. This allows data segmentation according to its quality: generating output as a mix of data quality levels (x% Gold, y% Silver, z% Bronze).

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[12] The sum of allocated GHG emissions to the shipments (clients) must equal to the amount GHG emissions emitted within the scope.

In other words, the system can find ‘islands’ of higher resolution data in a data set that is qualified to be a lower quality. For the purpose of this report, the levels Silver and higher are considered. Table 1 and Table 2 provide an overview of the different fuel/energy and cargo data aggregation levels and its corresponding BigMile™ data quality level (S, G). The subscripts in these tables refer to the aggregation period: year (y), month (m), week (w), trip (t) or stop (s).

Table 1: Data quality levels for fuel/energy data.

| **Period** | **Total fuel/energy** | **Fuel/energy per license plate or location** |
|---|---|---|
| Year | $S_y$ | $S_y$ |
| Month | $S_m$ | $G_m$ |
| Week | N/A | $G_w$ |
| Trip | N/A | $G_t$ |
| Stop | N/A | $G_s$ |

Table 2: Data quality levels for cargo data.

| **Period** | **Aggregated** | **Bill of lading** |
|---|---|---|
| Year | $S_y$ | N/A |
| Month | $S_m$ | N/A |
| Week | $S_w$ | N/A |
| Trip | N/A | $G_t$ |
| Stop | N/A | $G_s$ |

As the Silver and higher levels are the only levels considered in this report, this specifically means that the transport activity (cargo data) is known on the basis of loading and unloading locations; corresponding fuel/energy use is also known and aggregated for no longer than one year. The higher resolution levels are one-way compatible with the minimum required Silver level (e.g. Gold level, where information is known at the level of trips) and can be aggregated to the Silver level under the condition of available data for the aggregation period (in other words, higher quality levels such as Gold can be aggregated to the Silver level).

## 3.4 BigMile™ carbon footprint reporting output

See section 3.2 where the BigMile™ KPIs are discussed. These KPIs are the carbon footprint reporting output. Note that the Carbon Footprinting and decarbonisation functionalities for the BigMile™ tool go beyond carbon footprint reporting.

# 4 GLEC Framework Reporting

## 4.1 Introduction

The goal of GLEC is to help companies calculate transport emission inventories for their transport services, and to use this information to reduce product or company emissions. To this end, existing (single or multiple modality-) methodologies are harmonized within a single framework.
The base methodologies are listed in Table 3.

Table 3: Base methodologies GLEC is built on.

| Modality | Base methodology |
|---|---|
| Air | IATA 2014 recommended practice 1678<br>EN 16258 if application is specified |
| Inland waterways | IMO 2009, Guidelines for voluntary use of the ship energy efficiency operation indicator |
| Sea | IMO 2009, Guidelines for voluntary use of the ship energy efficiency operation indicator.<br>Container ships: clean cargo working group 2015 |
| Rail | IFEU Heidelberg, Infras & IVE 2014. EcoTransIT World – ecological transport information tool for worldwide transports |
| Road | United states EPA smartway transport partnership 2015. Truck carrier partner 2.0.15 tool<br>EN 16258 |
| Transhipment | Container terminals: green efforts 2014<br>All transhipment centers: Fraunhofer MFL 2014. Green logistics method |

Version 1 of the GLEC Framework uses existing methodologies as the basis to provide guidance on how to calculate and report logistics emissions. There is flexibility and application freedom, within certain boundaries, to decide what suits your situation best, taking into account the input data available and the purpose of the calculation. The GLEC Framework made a step beyond EN16258 towards harmonization of mostly industry-led approaches. As such it provides a mechanism with which calculation tools and green freight programs can work collectively towards further harmonization.

The target audience is logistics service providers and carriers but most importantly shippers. By proposing a consistent approach, GLEC facilitates companies to exchange carbon footprint information with their business partners, and use it as input for their own footprint calculation.

In general, three ways of calculating can be employed within GLEC:

- Based on primary (real-world) data, if these are available;
- Based on calculation tools that follow the basic principles (i.e. based on algorithmically estimated primary data);
- Based on default consumption factors, when primary data are not available.

## 4.2 Scope

### *4.2.1 Transport chain*

The GLEC Framework describes the boundaries of a transport chain as follows: “a freight movement begins with the hand-over of the consignment to the party transporting the shipment and ends with the hand-over of the shipment to the consignee”.
All intermediate elements of the chain are included: transport and handling and storage in transhipment centres. A few examples are included in Figure 3.


Figure 3: Examples of transport chains [GLEC Framework].

Emissions accounted for according to GLEC take into account two broad categories:

1) Emissions by transport activities and auxiliary services, such as cooling and handling of goods in the vehicle;
2) Emissions from handling, and storage of goods (ambient and temperature controlled) at storage and transhipment points.

### *4.2.2 Fuel chain*

The GLEC Framework covers the WTW emissions of the entire energy chain.

### *4.2.3 Infrastructure / vehicle chain*

The emissions from the production of vehicles, buildings and machinery are not considered in GLEC.

## 4.3 Calculation method

### *4.3.1 Unit*

The carbon footprint is always expressed in g or kg $CO_{2e}$ per tonne-kilometre transported goods.

### *4.3.2 Levels of data resolution*

The required time resolution is one year, meaning that fuel use and transport activity have to be established as annual totals.

The transport activity does not have to be further broken down, but it is recommended to define so-called Transport Service Categories (TSCs), especially for larger companies with clearly defined separate activities.

TSCs can be defined along the lines of, for instance, cargo type, journey type, contract type, network, or condition of transport. This way, e.g. parcel distribution and bulk transport can be described using separate fuel consumption factors per unit.

### 4.3.3 *Fuel and energy use*

The fuel consumption and electricity consumption is collected for an entire year on the level of a company or on the level of a Transport Service Category. The amounts are summed for each fuel, and converted to kilograms of $CO_2$-equivalent. If necessary, default fuel consumption factors can be used, expressed in gram of fuel per tonne-kilometre transport activity.

### 4.3.4 *Transport activity*

Next, the transport activities are quantified, expressed in tonne-kilometre (tkm). This is done on the level of a company or on the level of a Transport Service Category. The time frame is one year.

For the distance measure, GLEC states that the planned distance is the preferred distance measure for most cases, although it is not forbidden to use other measures such as great circle distance, shortest feasible distance, planned or actual driven distance. However, the output of the methodology is at the level of the planned distance. Therefore, all distances need to be converted to planned distances[13], by possibly using correction factors. Specific factors are included in the base methodologies for each modality.

The transported weight is the net weight of the goods plus packaging material of the shipper. Packaging applied by the carrier or LSP should be excluded. For transport over water, cargo can be expressed in 20-foot containers, which are considered to be equivalent to 10 tonnes of net weight as a default value in the GLEC framework. The GLEC Framework allows use of actual weight if it is known and documented. The use of actual weight is expected to become more common with new maritime regulations.

For air freight in combination with passenger transportation, the cargo emissions are allocated proportionally to the cargo weight and the weight of passengers, which is 150 kg per pax (50 kg/chair and other passenger-related items like catering plus 100 kg for passenger together with their bags).

Dividing the kilograms of fuel by the tonne-kilometres yields the consumption factor (kg/tkm) for a particular year.

Consumption factors calculated by carriers can be communicated with shippers[14].

### 4.3.5 *$CO_2$ emissions*

The $CO_2$-equivalent emissions are calculated by multiplying the consumption factor (kg fuel/tkm) by a $CO_2$-equivalent emission factor for each particular fuel.

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[13] Carriers often only have actual distance driven, therefore the GLEC Framework includes an approximation to allow them to convert (scale) from actual driven to planned distance.

[14] In February 2019, Smart Freight Centre published the GLEC declaration, further specifying what emission-related information should be communicated in B2B relations, as well as a public declaration intended for open publication.

A carrier can compute it for its activities, and a shipper can multiply their transport activity in tkm with the consumption factor obtained from carrier(s), resulting in the fuel consumption for the transportation of their goods.

The GLEC Framework prescribes using WTW emission factors. Some emission factors of the combustion of fuels are provided, but it is allowed to use own factors if they reflect the carbon content of the fuels more precisely and can be fully documented. Alternatively, the greenhouse gas emissions from the production of the fuel can be accounted for by using a multiplication factor[15], to be applied to the TTW combustion emission factor.

For electricity, one can apply an average emission factor for the country in which the electricity is used. One may include or exclude renewable energy certificates in this average emission factor.

## 4.4 GLEC carbon footprint output

The carbon footprint of a carrier is expressed as grams of $CO_2$-equivalents per tkm. Included in these equivalent values are the greenhouse gases $CO_2$, methane, $N_2O$, hydrofluorocarbons, perfluorinated compounds, $SF_6$, and $NF_3$.

The $CO_2$-equivalents per tkm are calculated by dividing the total annual $CO_2$ emission by the total annual amount of tonne-kilometres, if desired per TSC.
A shipper computes its carbon footprint by multiplying its transport activity in tonne.km by the consumption factor (of the carrier or a relevant default consumption factor) and then by multiplying it by the emission factor.

## 4.5 GLEC report generation by BigMile™

### *4.5.1 Based solely on BigMile™ data*

It is possible to generate a carbon footprint that is compliant with GLEC, based on BigMile™ input data. A number of specific differences have to be dealt with, however.

### *4.5.2 Calculational recipe*

Both indicators, $CO_2$/ tkm and $CO_2$/tonne can be computed according to the GLEC Framework using BigMile™ (silver or higher) input.

The implementation should take into account the conceptual differences with the BigMile™ methodology, specifically that the GLEC Framework 1.0:

1) Prescribes using the planned distance measure to compute transport activity;
2) Uses emission factors that may differ from those of the $CO_2$emissiefactoren.nl database that is used by BigMile™;
3) Generally prescribes data aggregation over a period of one year to allow for seasonal fluctuations in transport demand and changes in weather conditions;

[15] The scaling factor is introduced to accommodate base methods such as SmartWay or CleanCargo that still report TTW only. For these methods the easiest way to add in the WTT element is to scale up by a prescribed factor.

4) Prescribes using weight for the measure of the quantity of transported goods (BigMile™ allows other input than weight, e.g. $m^3$);
5) Suggests segmentation of transport activities within transport modes into the so-called transport service categories.

Condition 1) of the GLEC Framework requires consistency in distance computation on the part of the reporter (carrier) and the receiver of information (shipper). The choice of planned distance (or actually driven distance – less preferred option) requires both sides to use the same value for the distance between origin and destination of the transport leg. If BigMile™ does not receive in its input the planned or actually driven distance between loading and unloading locations, a relevant network distance between these locations can be used. It is suggested to use the fastest network distance for trucks; for trains[16] and ships to use the shortest feasible distance and for the air mode the Great Circle Distance plus 95 km between the airports.

For condition 2) the GLEC Framework's default emission factors should be used. This can most easily be done by replacing default values of the CO2emissiefactoren database with those published by GLEC.

For condition 3) some extra data storage will be required to aggregate the data to the desired level of one year. It is allowable to use shorter aggregation periods in case data are not available or are still being collected. The use of aggregation periods shorter than 12 months is discouraged: if a shorter aggregation period is used, it should be specified in the output.

For condition 4) in case BigMile™ input is provided in other cargo quantity units than weight, a conversion would be required. BigMile™ provides default conversion factors, but it is also possible to use user-specific conversion factors. Note that it is always preferred to have measured input data (e.g. tonnes). In case this is not available the user has to describe which conversion factors are used. Preferably the user provides measured values of a different unit (e.g. pallets) and adds the conversion factor (e.g. from pallets to tonnes).

For the condition 5) the computation of KPIs should be segmented per mode and per transport service category within the model. The GLEC Framework presents a logical segmentation along the lines of cargo type, journey type, contract or service type.

The computation of KPIs can follow the general rules of BigMile™ through computing transport activity expressed in tonne-kilometres and computing $CO_2$ emissions related to realization of the transport activity.

[16] The GLEC Framework prescribes using planned distance to determine the volume of transport activity tkm. However, the planned distance is only known to the operator. The Framework does not specify unambiguously how the distance can be computed by parties other than the operator. The GLEC Framework further defines distance as “Distance refers to the planned distance reflecting the actual rail network infrastructure”; and Rail Network is referred to as “This descriptor refers to the distance travelled: rail journeys can either go directly from A to B, or take a detour through a rail hub. This extends the distance travelled and thus should be accounted for.”

#### 4.5.2.1 *Description of discrepancy*

Section 4.5.2 presents five main differences between the BigMile™ methodology and the GLEC methodology with respect to computing carbon footprinting KPIs. Here we briefly estimate the level of discrepancy introduced by the use of BigMile™ input data for the computation of the GLEC KPIs solely using BigMile™ input.

1) GLEC's prescription of the use of planned (or actually driven) distances to compute transport activity can only be satisfied by the carrier accurately logging and reporting it. BigMile™ does not collect it by default. The planned distance can be approximated by the use of fastest distance for road transport and shortest feasible distance for rail and waterborne transport. The discrepancy stems from the fact that in many instances the carrier optimizes its network and some shipments make 'extra' kilometres than the shortest distance for those shipments would suggest. This happens due to other shipments' requirements to visit certain locations, which are not situated directly on the fastest or shortest routes (e.g. pallets get loaded/unloaded at various locations, deep sea vessels call at different ports that are not situated on the shortest path between cargo's origin and destination). This all leads to the fact that cargo makes more tonne-kilometres than the fastest or shortest distance would suggest. For deep sea cargo, actually travelled kilometres can be more than the shortest distance by some 10-20%, in some instances the figure can be higher (i.e. Singapore to Rotterdam via Suez or via Horn of Africa). For the linehaul services the error would be generally smaller than for the combined network. The largest error will occur in case of distribution journeys.

   The exception is air freight, where GLEC suggests using the Great Circle Distance (GCD) + 95 km. The air freight transport activity is estimated 100% correctly solely using BigMile™ input.

2) The use of GLEC's emission factors instead of $CO_2$emissiefactoren database should lead to a 100% correctness of reporting according to the GLEC methodology. Attention should be paid to the use of proper emission factors and to the use of proper units (i.e. weight (kg) of fuel vs volume (litres)).

3) Aggregation of the data over a longer period (i.e. one year) does not entail extra discrepancies.

4) Conversion of the volume of goods into weight can entail a substantial error margin, as volume-weight density of goods varies a lot for different commodities, as well as within the same commodity group. However, a consistent application of volume-weight conversion factors should alleviate the problem due to aggregate cancelling of errors (e.g. overestimation of weight for certain goods will be compensated by the underestimation of weight for other goods).

5) The GLEC Framework provides relatively broad transport service categories that should be followed. Grouping transport operations differently may result in a bigger discrepancy in the output.

#### 4.5.3 *Full GLEC conformity*

For full GLEC conformity, additionally to the BigMile™ data input, some GLEC-specific data must be collected. These data may already be collected by BigMile™, such as route information. However, we now specify what data needs to be collected to completely eliminate the error margins discussed in section 4.5.2.1.

##### 4.5.3.1 *Additional data to be collected for full GLEC conformity*

Corresponding to the items of the list of differences presented in section 4.5.2, the following data have to be collected in addition to the minimum BigMile™ data input:

1) Data on planned or actually driven routes. This is necessary to determine the distance planned or actually driven for each shipment. Essentially, for each shipment, the weight of the shipment and the number of kilometres planned or actually travelled should be known to determine the related transport activity, which is expressed in tonne.kilometers;
2) For conversion of the fuel quantity or energy use into $CO_{2eq}$ emissions, the GLEC default emission factors should be used. These are provided in the GLEC Framework 1.0 freely accessible (source);
3) Data for a one-year period;
4) Data on the weight of goods transported in case the weight data is not included by default in the BigMile™ input;
5) Mode-specific segmentation of transport market into transport service categories provided by GLEC. This means that transport operations for, for instance, bulk transport, dedicated transport and combined transport need to be aggregated separately, resulting in separately computed KPIs.

##### 4.5.3.2 *Calculational recipe for full GLEC conformity*

Both indicators, $CO_{2eq}$/tkm and $CO_{2eq}$/tonne, should be computed according to the GLEC Framework using the BigMile™'s input, extended with data described in section 4.5.3.1. Specifically, $CO_{2eq}$ is determined as the amount of fuel used (or the number of kWh used) multiplied by the relevant GLEC emission factor.

The tonne.kilometre value is determined as the sum of all shipment-related tonne.kilometres within the scope. The shipment-level tonne.kilometre value is determined as the distance multiplied by the weight of the shipment. Once the quantities of $CO_{2eq}$ and transport activity in tonne.kilometer are determined, the $CO_{2eq}$/tkm is computed by dividing $CO_{2eq}$ by tonne.kilometer transport activity. $CO_{2eq}$/tonne is determined by multiplying $CO_{2eq}$/tkm and the relevant shipment's distance.

# 5 Objectif $CO_2$ Reporting

## 5.1 Introduction

By the application of Article L. 1431-3 of the French transport code (Art 228 French law 12 July 2010), all transport service providers (both goods and passengers; all modalities) and home moving services have to provide well-to-wheel (WTW) $CO_2$ information for every transport service departing from and/or ending in France. The goal of the French Objectif $CO_2$ guide is to help stakeholders calculate and provide $CO_2$ emissions for a specific transport service. Companies are allowed to choose their own calculation method, as long as it complies with the law.

To help stakeholders calculate $CO_2$ information for transport services Objectif $CO_2$ provides 34 profession-specific factsheets with concrete examples. Table 4 provides an overview of categories in which these factsheets are divided.

Table 4: Overview of profession-specific factsheets.

<table>
<tr><td rowspan="6">Shipment of goods by</td><td>Air</td><td>1. Combined and cargo</td></tr>
<tr><td>Rail</td><td>2. Freight by rail</td></tr>
<tr><td>River</td><td>3. Full load consignments<br>4. Partial load consignments<br>5. Containers</td></tr>
<tr><td>Sea</td><td>6. Container ship<br>7. Motorway of the sea service<br>8. Bulk freight<br>9. Combined passengers and freight – to and from islands</td></tr>
<tr><td>Road</td><td>10. Full load consignments<br>11. Partial load consignments<br>12. Parcel delivery<br>13. Temperature-controlled parcel delivery service<br>14. Courier service</td></tr>
<tr><td>Multimodal transport</td><td>15. Freight forwarders<br>16. Express<br>17. Unaccompanied combined rail-road freight<br>18. Rolling highway<br>19. Home moving</td></tr>
<tr><td rowspan="5">Transport of passengers by</td><td>Air</td><td>20. Passengers by air</td></tr>
<tr><td>Rail</td><td>21. Passengers by rail</td></tr>
<tr><td>River</td><td>22. Cruises</td></tr>
<tr><td>Sea</td><td>23. Combined sea transport<br>24. To and from islands</td></tr>
<tr><td>Road (individual transport)</td><td>25. Taxi drivers<br>26. Taxi companies<br>27. Commercial chauffeur-driven car hire (VTC)<br>28. Private chauffeur-driven car hire</td></tr>
</table>

| | | |
|---|---|---|
| | | 29. Two or three-wheeled motor vehicles |
| | Road (public transport) | 30. Combustion engine-powered<br>31. School transport services |
| | Public, guided transport | 32. Electricity-powered<br>33. Cable cars |
| | Travel agency and tour operator activities | 34. Travel agency and tour operator activities |

In general, Objectif $CO_2$ lets the user decide which implementation of the methodology and which level of data input to choose. The 34 factsheets guide users and provide them with concrete examples.

The target audience is described by article 2 of the French decree No. 2011-1336 as *"any public or private persons organising or selling transport services for passengers, goods or moving purposes, carried out using one or several means of transport, departing from or travelling to a location in France, with the exception of transport services organised by public or private persons for their own behalf".* Objectif $CO_2$ helps these stakeholders to calculate and provide information on $CO_2$ emissions.

## 5.2 Scope

### *5.2.1 Transport chain*

Objectif $CO_2$ only applies to transport services for both goods and passengers. Handling and storage in transhipment centres is excluded from Objectif $CO_2$. Only the carbon dioxide emissions are taken into account and other greenhouse gas emissions are excluded. In case multileg transport is used, the methodology provides for breaking down the transport service into segments.

### *5.2.2 Fuel chain*

Objectif $CO_2$ takes both the operating phase and the upstream phase into account. This is in general known as “well-to-wheel” (WTW) emissions.

Objectif $CO_2$ provides for conversion factors for the computation of WTW $CO_2$ emissions related to the use of different types of fuels and electricity. The $CO_2$ intensity of electricity is further specified for France, its overseas territories and other European countries.

### *5.2.3 Infrastructure / vehicle chain*

The emissions in relation to the construction and maintenance of production equipment for sources of energy are not taken into consideration. The emissions related to the construction and maintenance of means of transport, and the construction and maintenance of infrastructures are not included.

## 5.3 Calculation method

### *5.3.1 Unit*

The carbon footprint is always expressed in g or kg or tonnes $CO_2$ for a specific transport service.

### 5.3.2 *Levels of data resolution*

The regulatory texts require transport service providers to provide $CO_2$ emission information for every single transport service. To do this, the service provider has to identify different segments, determine the $CO_2$ emissions for every segment and calculate the total quantity of $CO_2$ emissions.
To obtain this high resolution of data, four different data quality levels can be used.

<u>Level 1 values</u> – default values provided for each mode of transport per type of activity or means of transport.
<u>Level 2 values</u> – average figures calculated by the service provider for all of its activities.
<u>Level 3 values</u> – mean values calculated by the service provider based on a complete breakdown of its activity. This is similar to the so-called Transport Service Categories (TSCs) that are used in the GLEC framework.
<u>Level 4 values</u> – calculated based on real data for the transport service (ex-post).

Service providers with less than 50 employees are allowed to use level 1 (default) values for the calculation. This simplifies the implementation of this methodology for small organisations.

The mean values in level 2 and level 3 must be calculated over a period of at most three years. Note that level 4 values can only be used after performing the transport service, since these values are based on real world data for that specific transport service. This also requires allocating empty journeys to specific services, since they are not uniformly allocated to all services via mean values (as in level 2 and level 3). For instance, if at level 4 only transport of goods from origin to destination is included, the scope should be extended to the part of the journey that includes positioning of the vehicle and/or empty return trips to the depot.

These four levels of data accuracy are used for two data items in de calculation:

- Fuel and energy use;
- Transport activity.

These data items are discussed in the following two paragraphs.

### 5.3.3 *Fuel and energy use*

In case the energy source consumption is not directly known for a segment of a transport service, the energy source consumption rate (l/km) is multiplied by the distance of the segment (km) to obtain the energy source consumption (l).

The energy source consumption rate can be provided on four different data levels. In case of level 1 values, a default consumption rate of the energy source by the means of transport is given. For example 0.240 l/km for a straight truck with a GVW of 12 tonnes – Miscellaneous goods – Road diesel fuel. In case of level 2 or level 3 values, the consumption rate is based on the organisation’s own figures for all services (level 2) or a complete breakdown of its activity (level 3). For level 4 values, the actual amount of energy consumed for a specific transport service has to be registered.

### 5.3.4 *Transport activity*

The second data item is transport activity, which is expressed as:

$$\frac{number\ of\ units\ transported\ for\ the\ customer\ by\ the\ service}{total\ number\ of\ units\ in\ the\ means\ of\ transport}$$

Again, this data item can be provided on four different data levels.

Objectif $CO_2$ leaves the freedom to use any type of unit to determine the share of transport activity of a specific transport service in the total transport activity of this means of transport. The following options for the units transported are suggested by the regulatory texts:

- For transport of passengers: passengers (or passenger.distance).
- For transport of goods: mass (or mass.distance), volume (or volume.distance), surface area (or surface area.distance), linear metres (or linear metres.distance), packages (or packages.distance).

A service provider is also allowed to select another option for the units transported if this better reflects its own operations, as long as the beneficiary is informed about this.

In case distance is included in the units transported, the service provider can choose which type of distance is used, as long as this choice is applied consistently. Examples of different distance types are Great Circle Distance (GCD), direct distance travelled or shortest possible distance travelled.

### 5.3.5 *$CO_2$ emissions*

The $CO_2$ emission calculation consists of the following steps:

1. Break the transport service down into segments.
2. Quantify the source of energy consumed per segment.
3. Allocate the appropriate part to the beneficiary[17].
4. Multiply by the emission factor of this energy source (well-to-wheel).
5. Sum the quantities of $CO_2$ emitted in the different segments.

The result of the computations must be given in kilograms (kg), grams (g) or tonnes (t) of $CO_2$. The unit chosen must appear on the document issued or made available to the beneficiary (i.e. the user of the transport services). The value given by the service provider must correspond to the service performed. This is therefore an absolute result.

## 5.4 Objectif $CO_2$ carbon footprint output

The result of the computation is the amount of WTW $CO_2$ emissions related to the performed transport service. Therefore, Objectif $CO_2$ only provides a shipper (i.e. the user of transport services) related KPI. This KPI is the absolute amount of $CO_2$ emissions, expressed in weight units, related to the performed transport service.

[17] Objectif $CO_2$ allows different allocation methods, which may be applied according to the transport operations and varying contexts. Nonetheless, empty journeys must be taken into account in the allocation method.

## 5.5 Objectif $CO_2$ report generation by BigMile™

It is possible to generate a carbon footprint that is compliant with Objectif $CO_2$, based on BigMile™ input data.

### *5.5.1 Based solely on BigMile™ data*

The general computation principle of Objectif $CO_2$ follows the rule of the collection of two data sets: the transport activity data and corresponding fuel use (energy use). Both datasets are collected by BigMile™. Objectif $CO_2$ prescribes determining relevant fuel (energy) use and translation of it into $CO_2$ values using emission factors. The determination of transport activity data is solely at the discretion of the user of the methodology under condition that it is logical and applied consistently.

#### *5.5.1.1 Calculational recipe*

As a rule, the output of BigMile™ as described in chapter 3 is in conformity with the requirements of Objectif $CO_2$. Nonetheless, special attention has to be paid to the following aspects:

1. For data level 3 and higher, transport is advised to be segmented according to Table 4 on transport categories[18]. For example, road transport partial loads should not be grouped with road transport full load and parcel networks. These should be treated as different transport service categories that are reported separately.
2. It is advised to use specific Objectif $CO_2$ emission factors, as specified in the Objectif $CO_2$ Methodological guide on page 14 in Table 1: energy source emission factors of the French Order of 10 April 2012 (Objectif $CO_2$, 2012). Apparently, these constants are mandated by an Order (i.e. law).
3. Determination of transport activity data can be done in many different ways and is at the discretion of the party implementing the methodology (section 5.3.4). The ways that are used by BigMile™ are amongst those that are allowed. The computations, however, should be applied consistently for all computations involving the service provider and its clients.

#### *5.5.1.2 Description of discrepancy*

The output generated taking into account the considerations of the section 5.5.1.1 on the calculation recipe will generate fully accurate reports conform Objectif $CO_2$.

### *5.5.2 Full Objectif $CO_2$ conformity*

Computations based solely on the BigMile™ would generate output that is fully conform Objectif $CO_2$ methodology, therefore, no extra data has to be collected.

[18] Objectif $CO_2$ suggests a segmentation of transport activities as presented in Table 4, but does not make it mandatory, allowing companies to use their own segmentation in case that is more appropriate.

# 6 SmartWay

## 6.1 Introduction

SmartWay is a US EPA (United States Environmental Protection Agency) program, run by the government agency. The SmartWay program helps companies advance supply chain sustainability by measuring, benchmarking, and improving freight transportation efficiency. To address the trends of growing freight transport activity and the challenges related to emissions and negative externalities of freight transport activities, the EPA launched the SmartWay program in 2004. The program provides a system for tracking, documenting and sharing information about fuel use and freight emissions across supply chains. SmartWay helps companies identify and select more efficient freight carriers, transport modes, equipment, and operational strategies to improve supply chain sustainability and lower costs from goods movement. The program aims to accelerate the use of advanced fuel-saving technologies. SmartWay is supported by transportation industry associations, environmental groups, state and local governments, international agencies, and the corporate community.

The program is structured around three core elements:

1) The SmartWay Transport Partnership: The SmartWay Transport Partnership helps companies and organizations to achieve their freight supply chain sustainability goals by providing credible tools, data, and standards – at no cost – for measuring, benchmarking, and improving environmental performance. There are three types of SmartWay partners: Shippers, Carriers and Logistics Companies. For each type of SmartWay partner, the program provides a quantitative tool that can be used to determine environmental performance of company operations.

2) The SmartWay Brand: Companies and organizations that work with SmartWay can use the SmartWay brand to show their commitment to building a more sustainable freight supply chain and reducing the impact of freight transportation on climate change.

3) The SmartWay Global Collaboration: EPA works with counterparts in Canada and Mexico to implement the SmartWay program. The agency also provides a comprehensive guide on setting up a Green Freight Program in different languages. SmartWay refers to the Lean and Green program, among other international programs and initiatives, as a platform addressing the impacts of freight transportation.

Figure 4 provides an overview of the SmartWay structure and its three core elements.

**1. SmartWay Transport Partnership**

SmartWay Shippers

SmartWay Carriers
- Truck Carrier
- Rail Carrier
- Barge Carrier
- Air Carrier
- Multimodal Carrier

SmartWay Logistics Company

Per target group:
- SmartWay Tool
- User guide
- Technical documentation
- Efficiency strategies to improve performance

**2. SmartWay Brand**


**3. SmartWay Global Collaboration**

Related Programs
- GLEC
- BSR Clean Cargo
- FRET21
- Green Freight Asia
- Green Freight China
- Lean and Green
- Objectif $CO_2$

Figure 4: SmartWay structure.

For the purpose of this report, this chapter focusses on the SmartWay Transport Partnership. The SmartWay tools assess freight operations, calculate fuel consumption and carbon footprint, and track fuel efficiency and emission reductions. The tools help to improve efficiency, to demonstrate efficiency to customers and stakeholders, and to evaluate and compare carrier performance. The tools provide input into the process of awarding SmartWay Excellence Awards. The program requires that the tools are submitted at least once a year with data on that year (exception is the first year, where the minimum data requirement is 3 months of operational data). This chapter further looks into the SmartWay Transport Partnership tools and explains the underlying methodology.

## 6.2 Scope

The philosophy of SmartWay is centered around the use of tools, which are made for specific types of companies and mode-specific operations. The computations are hidden from the user; the underlying methodology is provided in the documents related to the tools.

### *6.2.1 Transport chain*

The SmartWay tools are oriented at carriers, shippers and logistics companies as different types of users. For the carriers, the following mode-specific tools are available: truck carrier, rail carrier, barge carrier, air carrier and multimodal carrier. Note that deep sea shipping is not included into the scope at this moment, however SmartWay has a memorandum of understanding (MoU) with the Clean Cargo Working Group to include their ocean going freight trade lane emission factors into SmartWay, and SmartWay is initiating the coding changes in the tools and database to execute on this.

SmartWay provides one tool per user group, together with guidance and improvement strategy documents.

Emissions from transhipment points (e.g. ports, hubs, DCs) are not included into the scope at the moment. However, SmartWay is exploring the potential to include emissions from distribution hubs. Another EPA program called Ports Initiative (https://www.epa.gov/ports-initiative) provides guidance on how to assess emissions from port-related activities.

### *6.2.2 Fuel chain*

The specifics of the SmartWay methodology is that it produces not only $CO_2$ emission output, but also computes the emissions of other pollutants ($NO_x$, $PM_{2.5}$, $PM_{10}$ and black carbon).

SmartWay provides a conversion table for the quantity of fuel expressed in gallons to be converted into grams of $CO_2$.[19] The table implies that the use of 1 litre of diesel fuel results in 2.69 kg of $CO_2$ emissions, which is a Tank-To-Wheel (TTW) conversion factor. Therefore, it should be concluded that SmartWay uses TTW emission factors. SmartWay provides specific emission factors for electricity, depending on the source, as well as a general electricity emission factor for a total US electricity generation mix, which implies that for electricity WTW emission factors are used.

Emissions related to cooling (e.g. reefer) are included into the scope. Reefer fuel consumption is explicitly included: if it is diesel fuel from the truck's fuel tank, then it can be added to the diesel fuel consumption by the vehicle, if not, the emissions should be computed separately and added to the total relevant emissions.

### *6.2.3 Infrastructure / vehicle chain*

The SmartWay description does not include any guidance on emissions related to infrastructure and vehicle chain. Therefore, it can be concluded that these emissions fall outside of the SmartWay's scope.

[19] 2018 SmartWay Truck Carrier Partner Tool: Technical Documentation, Table 1.

Furthermore, SmartWay specifically prescribes that fuel/energy used in heating buildings, forklifts or other non-transportation sources are excluded.

## 6.3 Calculation method

On a high level, the general approach of SmartWay is similar to the approach of the other carbon footprint methodologies described in this report. Fuel and energy use are converted to emissions ($CO_2$, $NO_x$, $PM_{2.5}$, $PM_{10}$ and black carbon), which are divided by the transport activity to calculate the performance metrics. Both fuel/energy use and transport activity are input per year and disaggregated by the dimensions as specified in Table 6 in section 6.4.

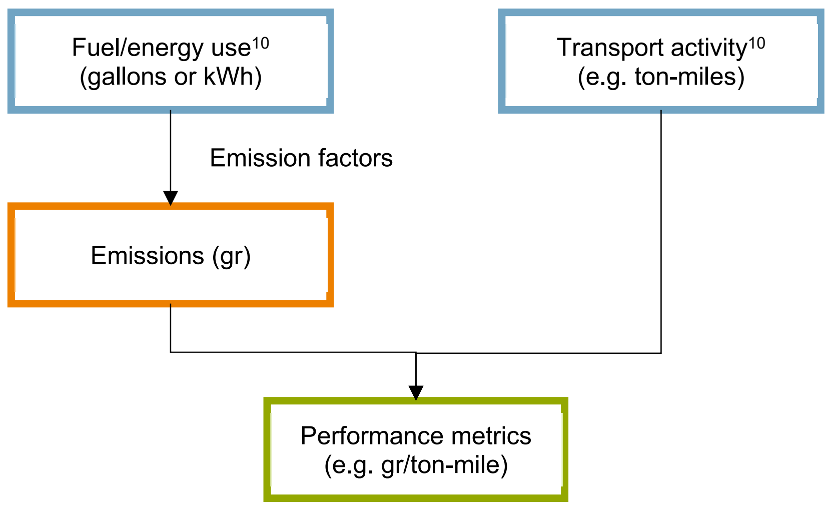


Figure 5: Schematic overview of the SmartWay calculation method.

### 6.3.1 *Unit*

The output is expressed in grams per unit measurement (e.g. mile, average payload tonne-mile, barge-mile) for the following pollutants: $CO_2$, $NO_x$, $PM_{10}$, $PM_{2.5}$ and black carbon. Note the diversity in the tools' output, as for instance, the black carbon emissions are only reported by the truck carrier tool and that the air carrier tool reports general PM emissions instead of $PM_{2.5}$ and $PM_{10}$. It depends on the user type which measurement units are included in the tool. Table 5 in section 6.4 shows more details.

### 6.3.2 *Levels of data resolution*

The users of the SmartWay tools can select the level of aggregation (detail) (e.g. per vehicle, per fleet or per fuel type) to be displayed in the output files. These aggregation levels correspond to the fixed dimensions along which the input data has to be provided. An overview of the disaggregation levels per user type can be found in Table 6 in section 6.4 *SmartWay carbon footprint output*. For example, in the truck carrier tool both input and output data are disaggregated per carrier mode (truck in this case), per fleet, per fuel type and per truck class. This implies that data on fuel/energy use and data on transport activity is entered by the user per carrier mode, per fleet, per fuel type and per truck class.

The fleets have to be composed by using some specific characteristics (e.g. geographic areas, types of services provided, types of networks, etc). This enables users to compare the emission output of similar fleets. Furthermore, these characteristics are used as the input for the computation of the $NO_x$, PM and BC emissions.

All SmartWay tools report over a period of one year. For the initial period, a minimum of three months of data are allowed.

### 6.3.3 *Fuel and energy use*

The fuel and energy use is always provided in amounts per year in accordance to the fixed disaggregation levels per tool (see Table 6 in section 6.4 *SmartWay carbon footprint output*). For example in the truck carrier tool, the fuel is entered per fleet per fuel type per truck class. All fuel and energy used by the different fleets has to be reported, including refrigeration, bunk heaters, yard moves, or any other fuel/energy directly attributable to transportation.

In case the user is not able to split the fuel/energy data along the fixed disaggregation levels, the truck tool is the only tool offering an alternative in the form of fuel use estimation on secondary data such as miles driven and the average fuel consumption in miles per gallon (MPG).

The tools for shippers and logistics companies do not require the user to enter fuel/energy data. In these tools the user specifies two out of three of the following values per carrier per year: ton[20]-miles, total miles and/or average payload. The third of these values is calculated using the following equation:

$$ton.miles = total\ miles * average\ payload$$

Total emissions per truck carrier are calculated by multiplying shipper-specific data on transport activity (or on miles driven for dedicated transport) by the standard carbon footprint values per SmartWay Category, which are $CO_2$ per tonne-mile or $CO_2$ per mile, depending on the shippers' input. The SmartWay Categories are only defined for truck carriers and an overview can be found in Figure 6. Section 6.4.1 explains how total emissions are calculated for the different modalities.

| TRUCK | Dry Van & Chassis | Reefer | Flatbed | Tanker | Heavy & Bulk | Auto Carrier | Moving | Specialized & Utility | Mixed |
|---|---|---|---|---|---|---|---|---|---|
| Dray | Dray 5 Performance Levels | | | | | | | | |
| Truckload | Truckload DryVan 5 Performance Levels | Reefer 5 Performance Levels | Flatbed 5 Performance Levels | Tanker 5 Performance Levels | Heavy & Bulk 5 Performance Levels | Auto Carrier 5 Performance Levels | Moving 5 Performance Levels | Specialized & Utility 5 Performance Levels | Mixed 5 Performance Levels Less than 75% in any category |
| Expedited | Expedited 5 Performance Levels | | | | | | | | |
| LTL | LTL 5 Performance Levels | | | | | | | | |
| Package | Package Delivery 5 Performance Levels | | | | | | | | |
| Mixed | Mixed | | | | | | | | |

Figure 6: SmartWay Categories for Truck Carriers 2018 calendar year.

[20] A caution in units is warranted: ton and tonne are not interchangeable without conversion. Smartway's default is the US ton (also known as short ton), which is 907kg, so a conversion is required into the metric ton (tonne) of 1000kg.

Note that shippers do not get direct information on the $CO_2$ emissions of the carrier, but instead they get averaged $CO_2$ emissions of the category of carriers to which the carrier in question belongs. This is only done for the road modality; for other modalities the shippers get direct emission indicators of the carrier.

#### 6.3.4 *Transport activity*

The transport activity is, just like the fuel and energy use, always provided in amounts per year in accordance to the fixed disaggregation levels per tool (see Table 6 in section 6.4 *SmartWay carbon footprint output*). For example in the truck carrier tool, the transport activity is entered per fleet per fuel type per truck class. All tools require users to provide data from which the transport activity can be computed by specifying actual tonne-miles or miles (railcar miles for trains) and average payload.

Note that transport activity for trucks must be provided in both weight *and* volume terms. Specification of only one freight measurement, weight or volume, will not be sufficient as the tool would not allow submission of this partial information. In the other SmartWay tools the transport activity only has to be specified in weight terms.

#### 6.3.5 *$CO_2$ emissions*

SmartWay specifies emission factors for the fossil fuels, biofuels (also different biofuel and fossil fuel mixes are possible) and emission factors for electricity. The emission factors for fuels are considered to be TTW; biofuel-related emission factors are biofuel-specific and probably related to the carbon content of biofuels as they specify tailpipe emissions. It is suggested that the emission factors that are presented in the SmartWay Technical Documentation are used. Specifically, emission factors are presented in *2018 SmartWay Truck Carrier Partner Tool: Technical Documentation* in Table 1, Table 2 and Appendix C for electricity generation emission factors (SmartWay, 2018).

### 6.4 SmartWay carbon footprint output

SmartWay computes different KPIs for the different user types. An overview of these KPIs is given in Table 5. Subsections 6.4.1 and 6.4.2 explain how these KPIs are computed for shippers and logistics companies on the one hand, and for carriers on the other hand.

Table 5: Emission measurement units per SmartWay user type.

| **Emission measurement unit measured per year per pollutant ($CO_2$, $NO_x$, $PM_{10}$, $PM_{2.5}$, black carbon)** | **Shipper** | **Logistics company** | **Multimodal carrier**[21] | **Air carrier**[22] | **Truck carrier**[23] | **Rail carrier**[24] | **Barge carrier**[25] |
|---|---|---|---|---|---|---|---|
| tonnes (total emissions) | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| g/mile | ■ | ■ | ■ | ■ | ■ | | ■ |
| g/tonne-mile | ■ | ■ | ■ | | | ■ | ■ |
| g/average payload tonne-mile | | | | ■ | ■ | | |
| g/thousand cubic foot-miles | | | | | ■ | | |
| g/thousand utilized cubic foot-miles | | | | | ■ | | |
| g/railcar-mile | | | | | | ■ | |
| g/truck-equivalent-mile | | | | | | ■ | |

The total annual emission volume and emission per mile driven (or per railcar mile) are computed for all types of companies. The transport emission efficiency indicator is computed for all modalities in the form of emissions per tonne-mile, where for air and road the average payload (i.e. within vehicle class of a carrier) is used to determine the transport activity (the denominator of the indicator). Furthermore, for the road modality, emissions per available and per utilized unit of volume transported are computed and, for rail, emissions are presented per truck-equivalent mile. Note that transport emission efficiency is essentially computed as gram emissions per tonne-mile actually driven, with the variation for the units of payload (for road this is both average weight and volume, for air it is average weight).

In SmartWay reporting, different levels of disaggregation of the computation results are possible. This is different from the GLEC Framework, which disaggregates emission data to Transport Categories that are made to group similar transport market segments together. The SmartWay methodology disaggregates emission indicators according to Table 6, which is essentially per service provider, transport mode, fleet and fuel type. Further, some mode-specific subtypes are defined, such as per truck class for road and per vessel for inland navigation.

[21] The multimodal carrier tool is based on annual statute miles.
[22] The air carrier tool output is based on annual statute miles.
[23] The truck carrier tool reports these measurement units for different mileage types: total miles, loaded miles and revenue miles.
[24] The rail carrier tool reports g/gross tonne-mile, g/revenue tonne-mile, g/non-revenue tonne-mile.
[25] The barge carrier tool reports g/barge-mile and g/loaded barge-mile. Note that nautical miles are used in the barge carrier tool.

Table 6: Disaggregation levels per SmartWay user type.

| **Disaggregation levels** | **Shipper** | **Logistics company** | **Multimodal carrier** | **Air carrier** | **Truck carrier** | **Rail carrier** | **Barge carrier** |
|---|---|---|---|---|---|---|---|
| Per carrier-mode | | | | | | | |
| Per carrier | | | | | | | |
| Per SmartWay truck category | | | | | | | |
| Per company | | | | | | | |
| Per business unit | | | | | | | |
| Per fleet | | | | | | | |
| Per fuel type | | | | | | | |
| Per fleet type | | | | | | | |
| Per truck class | | | | | | | |
| Per vessel | | | | | | | |

### 6.4.1 *SmartWay carbon footprint output for shippers and logistics companies*

The carbon footprint of shippers and logistics companies is expressed as grams per mile, grams per tonne-mile and tonnes of total emissions. The $CO_2$ emissions per (tonne-) mile are calculated by dividing the total annual TTW $CO_2$ emissions by the total annual amount of (tonne-)miles.

When shippers enter their data, SmartWay allows linking shippers' data with carriers who work for the shipper. Linking shippers with their service providers in the SmartWay database provides the shippers with the real-world measured emission data related to the operations of their service providers. Note that for the road carriers an average per performance group of carriers is used (i.e. the shippers get data based not on the performance of their service provider, but based on the performance of a group of similar service providers to which the shipper's service provider belongs). This is probably done in order to avoid sharing of carrier specific sensitive information, as discussed in section 6.3.3. In case a carrier is not in the database, SmartWay provides a way to estimate emissions for the shipper.

The way of estimation is mode specific, namely:

1) **Barge**. Non-SmartWay barge carrier gram per mile and gram per tonne-mile performance is set to be 25% higher than the worst performing SmartWay barge carrier.
2) **Air**. Performance levels for non-SmartWay air freight are based on publicly available data. Emissions per tonne-mile are estimated as the upper bound estimates for grams of $CO_2$ per tonne-mile for short- and long-haul air freight; emissions per aircraft-mile are estimated using these obtained tonne-mile emissions, which are multiplied by the assumed average payload of 22.9 metric tonnes.

3) **Rail**. The rail emission factors are based on the industry average: gram per tonne-mile factors are determined by dividing total fuel use by total tonne-miles and then multiplied by a rail diesel $CO_2$ factor. $NO_x$ and $PM_{10}$ for rail carriers are also based on industry averages.
4) **Road**. Emissions are determined based on the worst performing SmartWay truck partner per truck type plus some extra allowance for poor performance. In other words, if a carrier is not in the SmartWay database, emissions are assumed to be somewhat higher than the most emitting SmartWay carrier of the specific equipment category.

The approach for estimation of shippers' emissions in case their service providers are not in the SmartWay dataset, uses a very conservative approach to emission estimation and probably overestimates the emissions by design of the scheme. This is due to the fact that the lowest performing carrier from the database is selected and its performance is further "downgraded" to estimate shippers' emissions. The approach of SmartWay has a number of advantages, as the shippers have an incentive to ask their carriers to become a SmartWay partner on the one hand, and SmartWay does not allow the shipper to "shop around", i.e. to use industry averages in case the service provider performs worse than those averages. The downside is that the shipper gets in most cases overestimated emissions assigned if its carrier is not a SmartWay partner.

The emission report for the shippers and logistics companies provide data per mile and per tonne-mile, as well as annual total emissions. An important omission in the SmartWay methodology is the absence of emission data per tonne shipped, which is important information for the shippers, and which is relatively easy to compute based on the data collected for the provision of the SmartWay output report.

Shippers and logistics companies get emission data further disaggregated per carrier and mode; road transport operations are further disaggregated per SmartWay truck category.

#### *6.4.2 SmartWay carbon footprint output for carriers*

The carbon footprint of carriers (i.e. service providers), specifically road, rail, air carriers, barge operators and multimodal carriers, is computed based on the data provided by these carriers. Total emissions are determined using the data on fuel and energy used by the carrier, and are further disaggregated per fleet and per fuel type and other mode-specific segmentations. The per tonne-mile[26] (as well as per cubic feet-mile for road transport) emissions are computed based on the carrier's transport activity data. These computations are based on the data supplied by the carriers. The indicators are computed conform the set of indicators presented in Table 5 and disaggregated according to mode-specific disaggregation levels presented in Table 6.

### 6.5 SmartWay report generation by BigMile™

At the design level, SmartWay computes the carbon footprint on the annually aggregated data; the emissions are allocated to the cargo proportionally to tonne-miles (tonne-kilometres) or cubic foot-miles.

[26] Table 5 provides types of distance measure appropriate to the scope.

SmartWay uses some specific TTW emission factors, as opposed to WTW emission factors. There are some specific transport segmentation approach and the necessity to provide cargo volume data for the road mode.

Note that SmartWay includes other pollutants ($NO_x$, $PM_x$ and black carbon) in its output. The weight of these non-$CO_2$ emissions is estimated using technical characteristics of the vehicles and their use pattern. SmartWay's documentation provides detailed computational specifications on how these emissions are computed within the tools. These computations are oriented at the North American market through inclusion of the dominant transport means intrinsic to that market. This report does not specify on how to compute $NO_x$, $PM_x$ and black carbon emissions; for the detailed instructions on computing these emissions we refer to the SmartWay's technical documentation.

The main reason for not including the SmartWay's methodology for $NO_x$, $PM_x$ and BC computation is that SmartWay's computations are made available for the equipment specific to the North American market. Another reason is that such computations are based on mathematical models and are relatively rough approximations of the reality. It should also be considered that computations of $NO_x$, $PM_x$ and BC emissions require information on driving patterns and conditions, as well as on more detailed information on fleet composition such as the Euro class. These data are generally not available in BigMile™. Therefore, it is suggested to prioritize implementation of $CO_2$ emission computation according to SmartWay in BigMile™ over implementation of the $NO_x$, $PM_x$ and BC computations. Future implementations of these functionalities may include other than $CO_2$ pollutants. This section further deals with the computation of $CO_2$ emissions conform SmartWay.

### 6.5.1 *Based solely on BigMile™ data*

At a very general level it is possible to generate SmartWay carbon footprint output based solely on the BigMile™ data, however, at the cost of some discrepancy that stems from the use of different emission allocation methods between BigMile™ and SmartWay and approximation of the missing data.

#### 6.5.1.1 *Calculational recipe*

The main difference in carbon footprint computation between the BigMile™ and SmartWay is that SmartWay uses the TTW emission factors and that actually driven distance is used for determining transport activity. Furthermore, emissions per vehicle-mile driven are to be reported (for rail emissions per railcar mile driven) and belong to the core indicators. For the road mode, both weight-normalized emissions per tonne-mile and volume-normalized emissions per cubic foot-mile are computed. Other modalities are at the weight-normalized units only.

The following steps need to be performed to generate basic output.

1) **Distance measure.** Use actually driven distance to determine transport activity. In case the actually driven distance is not known (as is the case in basic BigMile™ input), estimate the actually driven distance. In line with the reasoning in the recipe for compliance with the GLEC Framework (see section 4.5 of this report), it is suggested to use the fastest route for the road mode and the shortest feasible network distance for rail and barge

in order to estimate the actually driven distance required by the SmartWay methodology. For the air modality, the distance driven should be the Great Circle Distance (GCD) flown between departure and arrival airports (for the fleet this is the sum of GCD distances flown between the airports).

2) **Determining $CO_2$ emissions.** Use TTW emission factors (preferably those provided by SmartWay, Figure 7) to convert the amount of (bio-)fuel and electricity used to $CO_2$ emissions. Note that SmartWay uses a specific approach to TTW emissions of biofuels and electricity, as those are not set to zero, which is more common for the TTW emission schemes.

| | g/gal |
|---|---|
| Gasoline | 8,887 |
| Diesel | 10,180 |
| Biodiesel (B100) | 9,460 |
| Ethanol (E100) | 5,764 |
| CNG | 7,030 |
| LNG | 4,394 |
| LPG | 5,790 |

Figure 7 : SmartWay $CO_2$ factors per fuel type.

3) **Time aggregation.** Data has to be aggregated to the level of annual aggregation. In case carbon footprinting has recently been started, this requirement can be relaxed to a minimum of three months of data.

4) **Cargo units.** For road transport, SmartWay output is normalized per tonne-mile (weight units) and cubic foot-mile (volume units); for other modalities it is tonne-miles only. Therefore, for road transport cargo measurement has to be in both units and for other modalities in weight only. In case weight or volume cargo measurements are not known, a conversion will have to be performed. Ideally commodity-specific conversion volume-weight factors should be used. In case these are not known, some *possible conversion factors* are for air cargo[27] 1 tonne per 6 $m^3$; and for general road cargo[28] 1 tonne per 3 $m^3$.

5) **Activity segmentation.** SmartWay provides some specific ways on how to segment operations and further split carbon footprint indicators per activity type, as is shown in Table 6. Generally, for carriers the activities are segmented (i.e. disaggregated) per fleet (as it is defined by the reporting carrier – here it is up to the carrier to categorize vehicles into the fleets) and per fuel type (except multimodal, barge and rail).
Air carriers can further segment per fleet type at their discretion. Road carriers can further segment per truck class (SmartWay distinguishes between eight truck classes). The barge operators can disaggregate per individual vessel.

[27] https://www.icao.int/Meetings/STA10/Documents/Sta10_Wp005_en.pdf
[28] https://www.rohlig.com/infocenter/air-freight/weightvolume-ratio.html

#### *6.5.1.2 Description of discrepancy*

When generating a SmartWay report based on BigMile$^{TM}$ inputs, the following discrepancies are likely to occur:

1) **Distance measure.** Due to the use of actually driven distances to compute transport activity, the intrinsic discrepancy stemming from the use of BigMile™ data is very similar to the case of the GLEC Framework, see section 4.5.1.2 on the GLEC Framework. The use of computed fastest routes to determine road transport distances and the use of shortest feasible network distances for rail and barge operations should provide relatively accurate approximations for the dedicated operations, such as Full Truck Load haulage. In case of combined loads (e.g. groupage networks) or distribution activities including “milk runs”, the use of network distances between loading and unloading locations would result in possibly large underestimations of actually driven tonne-kilometres of transport activity, as vehicles do not go directly from loading to unloading locations, but optimize the routes as to minimize distance driven or total travel time. This is done by software that solves the travelling salesman problem, or by other optimization means, including drivers’ knowledge of the routes and operational conditions. The distance measure for the air mode will be 100% accurate as SmartWay and BigMile™ both use the GCD as the measure of distance.
2) **Determining $CO_2$ emissions.** The use of SmartWay’s emission factors presented in section 6.5.1.1 converting fuel amounts into $CO_2$ emissions should lead to a 100% correctness of reporting conform SmartWay. For electricity, regional or electricity-vendor specific emission factors can be used, which would be accurate with respect to SmartWay reporting.
3) **Time aggregation.** Time aggregation of data over one year (or start-up period of three months) does not incur any discrepancy. Shorter period data aggregation and subsequent extrapolation can incur discrepancies due to seasonality in transport demand; climatic conditions resulting in different patterns of weather and its impact on the amount of fuel or energy used; large random deviations from the mean values that are intrinsic to smaller data samples.
4) **Weight-volume conversions.** Conversion of the volume of goods into weight can entail a substantial error margin, as volume-weight density of goods varies a lot for different commodities, as well as within the same commodity group. The same applies for the conversion from weight to volume. Section 6.5.1.1 suggests industry default conversion factors; if better factors are known related to commodity (e.g. liquid bulk) or operation, those conversion factors should be used. However, a consistent application of volume-weight conversion factors should alleviate the problem due to aggregate cancellation of errors (e.g. overestimation of weight for certain goods will be compensated by the underestimation of weight for other goods).
5) **Activity segmentation.** SmartWay segments activities around fuel type, fleets and vehicle types: this should be followed as much as there are data on vehicles and vehicle types available. The minimum set of BigMile™’s input, however, does not contain vehicle related data. Therefore, estimation of emission per vehicle-mile, or per SmartWay’s vehicle category may result in a substantial error.

The problem can be alleviated if the SmartWay's road vehicle types are not disaggregated (i.e. not following SmartWay's vehicle specifications, as they are more suitable for the North American transport market than for the European transport market).

### 6.5.2 *Full SmartWay conformity*

Corresponding to the items of the list of differences presented in section 6.5.1.1, the following data have to be collected in addition to the minimum BigMile™ data input:

1) Collect data on distances driven by the vehicles and data on the transport activity expressed as tonne-miles (also cubic foot-miles for road transport) actually driven. Data on distance driven is necessary for the carbon footprint indicator showing gram of $CO_2$ emitted per mile travelled, transport activity data are necessary for the carbon footprint indicator showing gram of $CO_2$ emitted per tonne-mile (cubic foot-mile) travelled.
   Specifically for road transport, collect data on total and loaded miles driven, as SmartWay provides output normalized per these types of miles.
   Specifically for rail, collect gross tonne-mile, revenue tonne-mile and non-revenue tonne-mile. For the barging operations, collect total miles and loaded miles.
2) Use conversion of the fuel quantity or energy use into $CO_2$ emissions as shown in section 6.5.1.1. Use regional or vendor-specific electricity emission factors.
3) Collect data over the period of one year. At the initial phases of data collection, a minimum requirement is the aggregation over three months.
4) Collect freight weight data for all modalities and freight volume data for the road mode. As BigMile™ allows both weight and volume units for the quantity of freight transported, make sure that data are collected on the weight of goods transported for all modalities and on the volume of goods transported for the road modality. The volume data concerns the volume of goods transported for computation of the utilized cubic foot indicator, and the available volume of the trucks for the computation of cubic foot indicator conform Table 5.
5) Follow the segmentation as presented in Table 6. In case road vehicles cannot be matched with the eight road vehicle types specified by SmartWay, fit them as much as possible into the eight classes provided by SmartWay, possibly extending them with their own categorization.

#### 6.5.2.1 *Calculational recipe*

Table 7 provides the calculational recipe for computing the emission indicators specified in Table 5.

Table 7: Computation recipe per SmartWay output indicator.

| $CO_2$ emission measurement unit measured per year | Computation |
|---|---|
| tonnes (total emissions) | Sum up all relevant $CO_2$ emissions for the reporting period. |
| g/mile[29] | Sum up all relevant $CO_2$ emissions for the reporting period and divide them by the miles travelled by the vehicles that produced those emissions. |
| g/tonne-mile<br>g/average payload tonne-mile[30] | Sum up all relevant $CO_2$ emissions for the reporting period and divide them by the transport activity carried out by the vehicles that produced those emissions. Measure transport activity as tonne-miles actually travelled. |
| | |
| g/thousand cubic foot-miles | Sum up all relevant $CO_2$ emissions for the reporting period and divide them by the transport activity carried out by the vehicles that produced those emissions. Measure transport activity as available cubic foot-miles actually travelled. |
| g/thousand utilized cubic foot-miles | Sum up all relevant $CO_2$ emissions for the reporting period and divide them by the transport activity carried out by the vehicles that produced those emissions. Measure transport activity as utilized (i.e. loaded) cubic foot-miles actually travelled. |
| g/railcar-mile | For rail operations: sum up all relevant $CO_2$ emissions for the reporting period and divide by the number of railcar-miles travelled. Railcar-miles can be considered as wagon-miles. An alternative way of computation is to multiply train-kilometres by the number of wagons. |
| g/truck-equivalent-mile | For rail operations: sum up all relevant $CO_2$ emissions for the reporting period and divide by the number of truck-equivalent miles travelled. The truck-equivalent miles can be defined as train-kilometres multiplied by the number of truckloads that the train carries out. SmartWay provides a default volume value for available volume per railcar as to be 6 091 cubic feet. Available volume per truckload is set to be 3 780 cubic feet. |

[29] Note that SmartWay distinguishes several types of miles. The appropriate distance measures should be used for computation of the output indicators.
[30] Note that SmartWay distinguishes several types of tonne-miles. The average payload tonne-mile should be interpreted as tonne-mile transported.

# 7 Conclusions

Carbon footprinting is an important instrument for the decarbonization of transport and logistics. As a result of this importance, there are a number of tools and methodologies available that allow determining the carbon footprint of transport and logistics activities. Of those, BigMile™, the GLEC Framework v1.0, Objectif $CO_2$ and SmartWay are considered in this report. Although all these tools and methodologies aim at determining the carbon footprint, they have slightly different ways of computing it. Hence, the data requirements, computation algorithms, computation results and reporting data may differ between them.

There is a clear need for harmonization among the tools and methodologies, at least in order to make the results comparable. Once the results are available according to one tool or methodology, they should be translatable into another. This report shows that one-way harmonization of BigMile™ with the other considered methodologies is possible. Specifically, this report shows that:

a) Solely using BigMile™ input, it is possible to compute and report $CO_2$ / GHG emissions in reasonable accordance to the GLEC Framework, Objectif $CO_2$ and SmartWay. The usage of BigMile™-only data inputs will result in some discrepancies with respect to an ideal situation when all methodology-specific data are available. The report specifies the nature of the discrepancy and estimates the level of discrepancy when BigMile™-only input is used.

b) It is possible to reach a full conformity with the emission computation in accordance to the GLEC Framework, Objectif $CO_2$ and SmartWay when data additional to the BigMile™ standard dataset are collected and additional computations are performed. The report specifies what data have to be additionally collected in order to reach full conformity. The software of BigMile™ should be extended accordingly to implement this functionality.

Each of the considered tools and methodologies has its main focus. BigMile™ is both a carbon footprinting methodology and an accounting tool, allowing different levels of data granularity serving the aim of emission analysis and subsequent emission reduction. The GLEC Framework (a methodological framework) and Objectif $CO_2$ (a program) provide methodologies with the emphasis on carbon reporting and carbon accountancy. SmartWay (a program) is a collection of tools aimed at estimation of $CO_2$ emissions and linking the carriers' data to the operations of the shippers.

The roots of BigMile™, the GLEC Framework and Objectif $CO_2$ can be traced back to the general approach of the EN 16258 standard and the methodological recommendations of the FP7 COFRET project. The SmartWay methodology is different in a way that it was an original development by the US Environmental Protection Agency and grew up independently. The SmartWay methodology has an intrinsic relation to the most used vehicle types on the North American transport market; it also goes beyond $CO_2$ emissions and includes $NO_x$, PM and Black Carbon emissions.

Nonetheless, this report shows that it is possible to achieve one-way compatibility between all these methodologies with respect to $CO_2$ emissions, while leaving aside $NO_x$, PM and Black Carbon.

Further research in the domain of carbon footprinting should consider scope extensions with an explicit treatment of the following areas:

1 Proper emission allocation and assignment methods for the combined passenger-freight operations, such as in aviation, shipping (ferries) and possibly trains. Once the outcome of the CF computation is used as an input into the decisions on logistics organization, the allocation of emissions to passengers and freight may result in substantial real-world emission reductions (or – if it is not done properly – may result in undesired effects). Especially in the case of aviation, emission allocation should stimulate whenever possible utilization of available belly freight capacity, and facilitate avoidance of dedicated freighter movements.

2 Energy use by transport and logistics activities: It is expected that zero emission technological solutions will be more accepted and wide spread in the coming years. These solutions may include the use of biofuels, hydrogen-based and electric solutions. Each solution relies heavily on clean energy production and distribution, which although climate neutral, may entail other societal costs (i.e. food crop diversion, land use and land allocation, heavy industry nuisance, NIMBYism, etc). Therefore, inclusion of energy use into the carbon footprinting activities is becoming more and more important.

3 Traffic footprint (traffic nuisance): Current carbon footprint methods are also suitable for measuring and controlling traffic footprint of logistics activities, where, similarly to $CO_2$ emissions, traffic can be measured and assigned to activities causing it. Minimization of the traffic footprint is one of the societal and company level measures that would make logistics operations cause less externalities and reduce costs.

4 Adequate approaches to the treatment of IT infrastructure and other services that facilitate logistics: New developments, such as the internet of things, physical internet, logistics visibility, cloud computing, etc. make logistics operations rely more and more on the IT infrastructure. There is some indirect evidence that IT infrastructure consumes substantial amounts of energy, though this consumption cannot be currently attributed to the activities that cause it; moreover there are no good quantitative insights into the volume of energy consumed, aside from some rough approaches (LEAN ICT, 2019). As digitalisation and automation of activities becomes more widely spread, so is the energy consumption by the underlying IT equipment becoming larger. It makes the need for absorption of ICT energy consumption into carbon footprinting methods more evident.

These extensions of the scope should eventually be formalized into a widely accepted set of performance indicators, similarly to the $CO_2$-equivalent measure of current carbon footprint indicators. Subsequently an adequate methodological solution and software implementation should follow to achieve comparable and uniform target setting for these indicators.

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# 9 Signature

The Hague, 31 October 2019

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# A Overview of BigMile™ developments

The analyses in this report were based on BigMile™ version 1.31 dated 07 October 2018. Based on that version, the report makes recommendations on how to extend BigMile™. The developer decided to follow most of the recommendations, as shown in Table 8.

Table 8: Possible developments in harmonising BigMileTM and their status at the moment of publication of this report, which is based on BigMileTM version 1.31 dated 07 October 2018.

| **Possible changes** | **Status** |
|---|---|
| Use the GLEC Transport Service Categories (TSC) | Next release |
| Different distance measures: planned, driven and fastest | Next release |
| User or method-specific emission factors (GLEC, Objectif $CO_2$, SmartWay) | Next release |
| Default and user-specific (auditable) conversion tables to convert other units to weight | Next release |
| $NO_x$, PM, BC | Not scheduled yet |