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Evaluating the environmental sustainability of an intermodal freight logistic chain using the GLEC Framework

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Abstract. In the last years, evaluation of environmental sustainability of supply chains has become central in policies aimed at reducing polluting gas emissions (see, for example, Kyoto protocol, United Nations Framework Convention on Climate Change in Paris, Green Deal: Sustainable and Smart Mobility Strategy). The transport sector is one of the principal causes of global greenhouse gas (GHG) emissions. The sector consumes 25% of total final energy consumption and is responsible for nearly 40% of the emissions from end-use sectors. In 2021, global CO_2 emissions from the sector was about 7.7 Gt CO_2, of which 5.9 Gt CO_2 from road vehicles. In the European Union the transport sector accounts for 20% of anthropogenic GHG emissions. The main objective of the European Commission is to cut emissions by 90% within 2050. In March 2023, the International Standard Organization (ISO) released the ISO 14083 standard that provides requirements and guidance for the quantification and reporting of GHG emissions along the entire transport chains for passengers and freight. It is aligned with the ISO families 14060 and 14060. The ISO 14083 is in line, among the others, with the Global Logistics Emissions Council (GLEC) Framework for Logistics Emissions Accounting and Reporting.

This paper will focus its attention on a land-sea intermodal freight logistic chain, with an application to a real case study. In accordance with the ISO 14083 standard, the GLEC Framework, proposed by the Smart Freight Centre, will be used to calculate the energy consumption and the GHG emissions caused by supply chains.

Keywords : ISO 14083, GHG emissions, GLEC Framework

1 Introduction

In the last years, the evaluation of environmental sustainability of supply chains has become central in policies aimed at reducing polluting gas emissions (see, for example, Kyoto protocol, United Nations Framework Convention on Climate Change in Paris, Green Deal: Sustainable and Smart Mobility Strategy).

The transport sector (including transport of people, freights, and logistic operations) is one of the principal causes of global greenhouse gas (GHG) emissions. The sector consumes 25% of the total final energy consumption (of which 90% oil) and it's responsible for nearly 40% of the emissions from end-use sectors. Between 2010 and 2019, the transport sector recorded the largest growth in emissions of all end-use sectors due to the increasing demand for passenger and goods mobility. In 2021, global CO_2 emissions from the sector were about 7.7 Gt CO_2, of which 5.9 Gt CO_2 from road vehicles [1].

In the European Union the transport sector accounts for 20% of anthropogenic GHG emissions [2]. In order to become climate neutral, the main target is to cut emissions by 90% within 2050. Furthermore, more than 75% of freight traffic (measured in ton-kilometers) is performed by trucks [3].

For these reasons, the European Commission has presented the Sustainable and Smart Mobility Strategy, part of the European Green Deal, which defines that rail freight traffic should increase by 50% by 2030 and double by 2050, whereas transport by inland waterways and short sea shipping should increase by 25% by 2030 and by 50% by 2050. Moreover, it encourages the diffusion of zero-emission vehicles, vessels and aeroplanes, renewable & low-carbon fuels and related infrastructures (for instance, airports and ports) [4].

This decarbonisation process must necessarily start from the measurement of emissions; hence the standardization of emission calculation methods is fundamental to achieve the global GHG reduction targets and to realize sustainable supply chains [5]. Thus, a common carbon accounting framework is needed.

The objective of this paper is to analyse the evaluate the GHG emissions of a supply chain. We will focus our attention on a land-sea intermodal freight logistic chain, with an application to a real case study. The paper is structured as followed: chapter 1 introduces the paper's issue; chapter 2 proposes the main methodologies that are internationally used for the GHG emission calculations. Chapter 3 illustrates the chosen methodology while chapter 4 presents the case study. The paper end with chapter 5 that provides the main results and conclusions.

2 Literature review

In recent years, many efforts have been made to formalize a new global standard, that could harmonize measurements among stakeholders. The framework should be reliable, transparent, relevant, and accurate to allow consistency and comparability of emissions from all modes of transport. Furthermore, it should facilitate data collection and exchange between the involved partners of the transport chain. Among the others, the Global Logistics Emissions Council (GLEC) has promoted the standardisation of GHG emissions accounting methodologies and reporting standards with the publication of an internationally developed and applicable methodological framework for the calculation of transport chain emissions, the GLEC Framework.

In March 2023, the International Standard Organization (ISO) released the ISO 14083 standard (Quantification and reporting of greenhouse gas emissions arising from operations of transport chains) that, for the first time, provides requirements and guidance for the quantification and reporting of GHG emissions along the entire transport chains for passengers and freight. It covers all modes of transport and includes the operational GHG emissions from hubs [10]. It is aligned with the ISO families 14040 and 14060 and also, among the others, with the Global Logistics Emissions Council (GLEC) Framework for Logistics Emissions Accounting and Reporting.

With the introduction of the ISO 14083 standard, the GLEC Framework becomes a valid support for the implementation of the ISO standard, functioning as guidelines to assist companies in understanding and implementing it.

Environmental characteristics of products are not always communicated to the users. Often the available information is unclear or partial. Furthermore, the comparison between the environmental characteristics can only be performed if the information is of the same type. If no information is provided, common guidelines are necessary to perform evaluations. Therefore, standardization of environmental labels (ecolabels) is needed [6].

Ecolabels and environmental declarations are environmental management tools that communicate specific information about the environmental impacts of a product or a service [7-10]. They are often also proposed as a possible support mechanism in the transition to Circular Economy [11].

The International Organization for Standardization (ISO) provides general definitions and principles and requirements for the establishment of voluntary environmental labels and environmental declarations through the ISO 14020 family of standards [10]. The ISO 14020 family of standards is structured as follows:

- ISO 14020:2022. Core document in the ISO 14020 family of standards; it sets principles and general requirements for all environmental statements. For example, it establishes that ecolabels must consider all relevant aspects of the product’s life cycle.
- ISO 14021:2016/Amd 1:2021. Self-declared environmental claims (Type II environmental labelling).
- ISO 14024:2018. Environmental labels known as ecolabels (Type I environmental labelling). It is third-party verified.
- ISO 14025:2006. Environmental product declarations (EPDs) (Type III environmental labelling). It is third-party verified.
- ISO 14026:2017. Principles, requirements and guidelines for communication of footprint information
- ISO/TS 14027:2017. Development of product category rules
- ISO/TS 14029:2022. Mutual recognition of environmental product declarations (EPDs) and footprint communication programs

Sustainability is a complex process that regards not only environmental aspects but social and economic aspects too [12-13]. Ceschin and Gaziulusoy [14] argue that it is not a property of the individual elements forming systems but rather a property of the system itself. For this reason, Life Cycle Assessment (LCA) is one of the most influential and robust methodologies - along with environmental labelling - to evaluate the environmental impacts of products and services [6]. It is regulated by the international standards ISO 14040 and ISO 14044 [15].

3 Methodology

The GLEC Framework was developed by the Global Logistics Emissions Council (GLEC), a voluntary and independent partnership of companies, green freight programs and industry associations, supported by researchers and experts, led by the Smart Freight Centre [16]. It aims at standardizing the calculation of GHG emission related to freight transport, specifically developed for transport chains, including all transport modes. This methodology focuses on the Kyoto Protocol greenhouse gases listed in Annex A (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride) plus nitrogen trifluoride. In particular, carbon dioxide (CO_2) comprises the majority of GHG emissions for logistics activities. For this reason, GHG emissions are expressed in a common standard unit, based on the global warming potential (GWP), called CO_2-equivalent (CO_2e or CO_2eq or CO_2-e) [17].

3.1 The carbon accounting methods

The carbon accounting methods used to develop the GLEC Framework are various. Among the others, it is aligned with the GHG Protocol (World Business Council for Sustainable Development & World Resources Institute) and the Intergovernmental Panel on Climate Change (IPCC) Guidance. Furthermore, it harmonizes numerous other existing methodologies. Table 1 provides the methodologies used for logistics sites, road and sea transport.

Table 1. Carbon accounting methods used to develop the GLEC Framework. Source: authors adaptation from GLEC Framework.

Transport mode	Carbon accounting method	References
Logistic sites	Guidance for Greenhouse Gas Emissions Accounting at Logistics Sites	[5]
	Guidance for Greenhouse Gas Emission Footprinting for Container Terminals	[18]
Road transport	European Committee for Standardization EN 16258: Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passengers)	[19]
	SmartWay Road Carrier Tool	[20]
Sea transport	International Maritime Organization Ship Energy Efficiency Operation Index	[21]

3.2 Scopes

According to the GHG Protocol and the ISO 14064, the GLEC Framework classifies the emissions into three categories called scopes:

- Scope 1: direct emissions from assets that are owned or controlled directly by the reporting company (e.g.: combustion of fuel).
- Scope 2: indirect emissions from the production and distribution of electricity, heat, and steam purchased by the reporting company.
- Scope 3: indirect emissions from the reporting company's supply chain. It also covers the production and distribution of fuels burned in Scope 1.

3.3 Fuel emissions

As required from the GHG Protocol, all climatic emissions caused by the use of fuels should be included while accounting fuel emissions. For this reason, the Framework takes into account the entire fuel life cycle, known as Well-to-Wheel (WTW) emissions. There emissions are sub-classified in:

- Well–to-Tank (WTT) emissions. They include all the processes between the energy source (well) and the various stages of refining, storage and delivery up to the point of use (tank). They are reported as Scope 3.
- Tank-to-Wheel (TTW) emissions from fuels combusted to power Scope 1 activities. They are reported as Scope 1.

3.4 Calculation Steps

The GLEC Framework suggests the use of three steps for an efficient calculation of logistic carbon accounting. The first step includes the creation of the emission calculation boundaries, the definition of the end goals and the identification of the needed data. The issue of the second step is to calculate Scope 1 and Scope 2 emissions while in the third step Scope 3 is calculated.

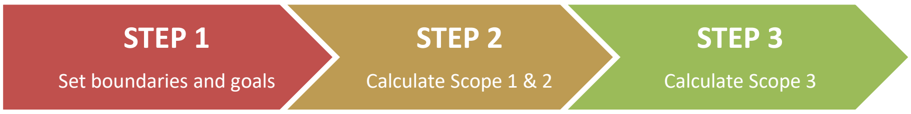

Fig. 1. The GLEC Framework's calculation steps. Source: Authors' adaptation

In order to to generate a reliable and transparent logistics emissions calculation output, the GLEC Framework highlights the importance of a rigorous methodology, starting from the consciousness of the problem. It suggests to:

- Set the boundaries.
- Think about end goals a use of the results.
- Determine what kind of input data are necessary to our final goal.

For Scope 1 and 2, fuel and electricity data are converted to emissions using a standard fuel or electricity emission factor (GLEC).

In order to calculate Scope 1 direct emissions, it is necessary to primarily know the fuel information that can be gleaned from payment receipts, management systems or annual expenditures. Fuel data should cover the entire journey, i.e. including laden, part-laden and empty trips. Once fuel data is known, it can be converted into emissions. Since each type of fuel emits different amounts of CO_2e it is essential to convert each fuel type separately. In the event that detailed fuel data is not available, the methodology recommends estimating the quantity of each fuel based on the available information. Equation 1 shows how to calculate the fuel emissions for n types of fuel.

$$\text{kg } CO_2e = \sum_1^n \left(\text{fuel (kg)} \cdot \text{fuel emission factor } \left(\frac{\text{kg } CO_2e}{\text{kg fuel}} \right) \right) \tag{1}$$

Scope 2 indirect emission information can be gathered from electricity bills. The following equation is used to calculate it.

$$\text{kg } CO_2e = \sum_1^n \left(\text{electricity (kWh)} \cdot \text{electricity emission factor } \left(\frac{\text{kg } CO_2e}{\text{kWh electricity}} \right) \right) \tag{2}$$

The target of step 3 is to evaluate Scope 3 supply chain emissions. The emissions are calculated as the amount of fuel or CO_2e used for moving a certain quantity of freight for a certain distance in a period of one year. The GLEC Framework suggests expressing it in tonne-kilometers.

The calculation for Scope 3 emissions can be carried out following two different approaches, depending on the factor being adopted:

- with a fuel efficiency factor (f.ef.f.):

$$\text{kg } CO_2e = \sum_1^n \left(\text{total tkm} \cdot \text{f.ef.f. } \left(\frac{\text{kg fuel}}{\text{tonne}-\text{km}} \right) \cdot \text{fuel emission factor } \left(\frac{\text{kg } CO_2e}{\text{kg fuel}} \right) \right) \tag{3}$$

- with a CO_2e intensity factor:

$$\text{kg } CO_2e = \sum_1^n \left(\text{total tkm} \cdot CO_2e \text{ intensity factor } \left(\frac{\text{kg } CO_2e}{\text{tonne}-\text{km}} \right) \right) \tag{4}$$

4 Case study

For the application of the GLEC methodology, an intermodal freight logistic company - that operates in the Mediterranean basin - was chosen. This company offers to its customers integrated logistics solutions using its network of warehouses, terminals, and road transport services for last mile distribution. It also offers Ro/Ro and containerized cargo line services. The peculiarity of this company is its ability to operate in Door-to-door mode, managing the entire transport cycle.

The chosen case study for this application is a land-sea intermodal supply chain integrally operated by the company previously mentioned. The phases of the land-sea supply chain that will be taken into account are:

- road transport
- maritime transport
- road transport

Therefore, there is a first phase of capillary collection and positioning of the goods from the single customers to the warehouses first and then to the port. The second phase refers to the maritime transport from the origin port to the destination one. Last, the third phase is yet again a road transport from the destination port to the final client, that can occur with a direct or an undirect delivery. In addition to the transport phases, also operations at the port terminals will be analysed. In fact, in the port terminals, goods are handled and stored in the terminal’s warehouses. In this chapter, planning and calculation of emissions for each phase of the supply chain will be presented.

4.1 Planning and calculation of emissions for maritime transport

Based on the GLEC guidelines, a first preparatory planning phase was carried out, including the selection and collection of data. For each voyage, the data included:

- Consumption of fuel
- Distance
- Volumes of goods transported

The data provided from the company for the volumes of goods were expressed in heterogeneous load units, such as 20ft, 24.5ft, 40ft and 45ft containers or trailers expressed in linear meters. Subsequentially, these volumes of goods were homogenized in equivalent TEUs (TEUeq). The conversion was accomplished by dividing the total linear meters of containers and trailers by the standard length of 20ft containers, defining a single unit of measurement. This homogenization was necessary since the company operates a mixed type of transport; thus, it did not allow a correct use of the GLEC methodology. Furthermore, the quantities of goods weren’t expressed in weight values, attribute that is necessary for the purposes of implementing the GLEC methodology.

In absence of further information, CCWG and EcoTransIT guidelines propose an allocation of an average load between 10 and 14 tonnes per full TEU and 2 tonnes per empty TEU. Therefore, an average load of 12 tonnes per full TEU and 2 tonnes per empty TEU has been allocated. These estimated weights were considered in line with the monthly transported quantities declared by the company.

Once the preparatory phase was defined, we proceeded with the calculation of the emissions of Scopes 1, 2 and 3. GHG emissions were calculated for two different types of fuel used by the ships, namely the HFO (heavy fuel oil), used during navigation and manoeuvring phases and the MDO (marine diesel oil), used during the mooring phases in port.

The evaluation of the emissions generated by the ship is based on equation 5, applied both for Scope 1 (TTW) and for Scope 3 (WTT). Table 2 provides the fuel emission factors for both Scopes.

$$\text{kg } CO_2\text{e emissions} = \sum_{1}^{n}\left(\text{fuel (kg)} \cdot \text{fuel emission factor } \left(\frac{\text{kg } CO_2\text{e}}{\text{kg fuel}}\right)\right) \quad (5)$$

Table 2. Fuel emission factors. Source: authors' elaboration. (*European values**)**

	WTT	TTW	WTW	WTT	TTW	WTW
	[kg CO_2e/ kg fuel]			[kg CO_2e/ l fuel]		
Heavy fuel oil (HFO)	0.26	3.15	3.41	0.25	3.06	3.31
Marine diesel oil (MDO)*	0.68	3.24	3.92	0.61	2.92	3.53
Marine gas oil (MGO)*	0.68	3.24	3.92	0.61	2.88	3.49
Diesel*	0.69	3.21	3.90	0.57	2.67	3.24

As regards to the GHG emissions generated by the use of heavy fuel oil during navigation (Scope 1 - TTW emissions), Table 3 provides the total result for the year 2021, calculated as the sum of the single trips. The input data were the quantity of fuel oil, the total travelled distance, the tons of transported freight and the fuel emission factor. GHG emission intensity was also found equal to CO_2e per ton-km.

Table 3. Scope 1 - heavy fuel oil (HFO) - TTW. Source: authors' elaboration.

Fuel (HFO) [ton]	Fuel emission factor [kg CO_2e/ kg fuel]	GHG emissions [ton CO_2e]	Voyage distance [km]	Freight [ton]
14,428	3.15	45,448	282,266	1,461,477

Scope 3 emissions (WTT emissions) were calculated using a different fuel emission factor that gave a value of about 8,400 kg CO_2e per voyage and 7.3 g CO_2e per ton-km (see Table 4).

Table 4. Scope 3 - heavy fuel oil (HFO) - WTT. Source: authors' elaboration.

Fuel (HFO) [ton]	Fuel emission factor [kg CO_2e/kg fuel]	GHG emissions [ton CO_2e]	Voyage distance [km]	Freight [ton]
14,428	0.26	3,751	282,266	1,461,477

Once the TTW and WTT emissions were calculated, it was possible to calculate the final WTW emissions (see Table 5).

The evaluation of the GHG emissions caused by the marine diesel oil had to necessarily take into consideration that its use does not include transport activities. Therefore, it was not possible to calculate a GHG emission intensity. Table 6 shows the results. The GHG TTW emissions associated to the use of MDO was about 10,500 kg of CO2e.

Table 5. Scope 1&3 - heavy fuel oil (HFO) - WTW. Source: authors' elaboration.

	GHG emissions [ton CO_2e]
TTW	45,448
WTT	3,751
WTW	**49,199**

Table 6. Scope 1 - marine diesel oil (MDO) - TTW. Source: authors' elaboration.

Fuel (MDO) [ton]	Fuel emission factor [kg CO_2e/ kg fuel]	GHG emissions [ton CO_2e]
1,129	3.24	3,658

Scope 3 emissions (WTT emissions) were calculated using its fuel emission factor. (see Table 7).

Table 7. Scope 3 - marine diesel oil (MDO) - WTT. Source: authors' elaboration.

Fuel (MDO) [ton]	Fuel emission factor [kg CO_2e/kg fuel]	GHG emissions [ton CO_2e]
1,129	0.68	768

Once the TTW and WTT emissions were calculated, it was possible to calculate the final WTW emissions (see Table 8).

Table 8. Scope 1&3 - marine diesel oil (MDO) - WTW. Source: authors' elaboration.

	GHG emissions [ton CO_2e]
TTW	3,658
WTT	768
WTW	**4,426**

Finally, the emissions derived from the two fuels can be added together to obtain the total GHG WTW emissions. Table 9 summarizes the results.

Table 9. Scope 1&3 - maritime transport phase. Source: authors' elaboration.

Type of fuel [-]	TTW GHG emissions [ton CO_2e]	WTT GHG emissions [ton CO_2e]	WTW GHG emissions [ton CO_2e]
HFO	45,448	3,751	49,199
MDO	3,658	768	4,426
Total	**49,106**	**4,519**	**53,625**

4.2 Planning and calculation of emissions in the port terminal

To calculate the emissions produced by the port terminal operations, the IML methodology [5] was used. In this case, the database provided by the company was incomplete and data were often aggregated. Hence, the evaluation was brought out considering the total annual consumption of the vehicles operating in both port terminals, 546,120 litres of diesel. The vehicle fleet consists of:

- 20 port terminal tractors
- 10 reach stackers
- 2 forklifts

To calculate the emissions, the following equation was used. In the absence of further detailed information, we have considered the European value of WTW fuel emission factor of diesel (3.24 kgCO_2e/litre). In this case, Scope 1 and Scope 3 emissions are calculated together.

$$\text{kg } CO_2\text{e emissions} = \sum_1^n \left(\text{fuel (kg)} \cdot \text{fuel emission factor } \left(\frac{\text{kg } CO_2\text{e}}{\text{kg fuel}} \right) \right) \tag{6}$$

The annual emissions produced by the vehicle fleet amount to about 1,769,400 CO_2e. It can be noticed that the emissions deriving from port logistics operations can be considered negligible compared to the ones associated to the maritime transport phase.

4.3 Planning and calculation of emissions for road transport

The last step is the evaluation of the emissions related to road transport activities. It is important to notice that this evaluation will be applied only to the freight handled directly by the company. Therefore, only 30% of the total freight transported by sea will be considered in this analysis.

When planning and calculating emissions from road transport, the GLEC Framework considers the standard EN16258, the EcoTransIT method and the CLECAT one. The latter are particularly useful in the event of a lack of specific data regarding transport means and activities.

The data provided by the company include the transport activities carried out during 2021 and include the type of vehicle, the total distances covered, the number of trips and the number of TEUs transported. No specific data about gross weight and fuel consumption were available. For these reasons, in accordance with EcoTransIT and CLECAT, we identified the average default attributes necessary to evaluate GHG emissions. The vehicle fleet consists in thirty-five B-double road trains and ninety semi-trailer trucks. Both types of trucks have a capacity of 2 TEUs per trip. At each TEU was assigned a load of 12 tons. Table 10 describes the input data.

Table 10. Input data for the road transport phase. Source: intermodal freight logistic company

Type of vehicle [-]	Total distance travelled [km]	Number of trips [n.]	Average distance per trip [km]	Load factor [%]	Freight [TEU]	Freight [ton]
B-double road trains	2,002,514	8,756	229	93.5	16,369	196,428
Semi-trailer trucks	2,310,680	11,392	203	100	22,784	273,408
Total	**4,313,194**	**20,148**	**214**	**1.94**	**39,153**	**469,836**

As for Scope 1 emissions calculation, we have first estimated the total fuel consumption utilising a specific consumption of about 0.34; then the GHG emissions were calculated applying the correct fuel emission factor (see Table 10). Table 11 presents the evaluation of Scope 1 emissions while Table 12 Scope 3 emissions.

Table 11. Scope 1 - road transport - TTW. Source: authors' elaboration.

Type of vehicle [-]	Total distance travelled [km]	Specific consumption [l/km]	Total fuel consumption [l]	Fuel emission factor [kg CO_2e/l]	GHG emissions [kg CO_2e]
B-double road trains	2,002,514	0.34	680,855	2.67	1,817,883
Semi-trailer trucks	2,310,680	0.34	785,631	2.67	2,097,635
Total	**4,313,194**	**0.34**	**1,466,486**	**2.67**	**3,915,518**

Table 12. Scope 3 - road transport - WTT. Source: authors' elaboration.

Type of vehicle [-]	Total distance travelled [km]	Specific consumption [l/km]	Total fuel consumption [l]	Fuel emission factor [kg CO_2e/l]	GHG emissions [kg CO_2e]
B-double road trains	2,002,514	0.34	680,855	0.57	388,087
Semi-trailer trucks	2,310,680	0.34	785.631	0.57	447,810
Total	**4,313,194**	**0.34**	**1,466,486**	**0.57**	**835,897**

Finally, Table 13 provides the total GHG emissions derived from the road transport phase.

Table 13. Scope 1&3 - road transport. Source: authors' elaboration.

Type of vehicle [-]	GHG emissions [kg CO_2e]
Scope 1	3,915,518
Scope 3	835,897
Total	**4,751,415**

5 Results and discussions

From the results obtained through the implementation of the GLEC methodology it emerges that the evaluation of the GHG emissions caused by the maritime transport phase was the most complete, due to better detailed information provided by the company and a wider literary documentation.

The analysis of the road transport phase was limited to assessing the emissions due to the company's internal operations. Compared with the total freight shipped by sea (1460,000 tons), the share of road freight was under 30% (469,800 tons). Despite this issue, the results highlight the impact of the maritime transport in this specific supply chain. Indeed, if we consider the hole intermodal supply chain, it’s easy to notice that the maritime transport phase contributes the most (about 89%) to the total GHG emissions. Table 14 summarizes the main results.

Table 14. Total supply chain GHG emissions. Source: authors' elaboration.

Supply chain phase [-]	**Scope 1 [kg CO_2e]**	**Scope 3 [kg CO_2e]**	**Total [kg CO_2e]**	**% on the total [%]**
Sea transport	49,106,000	4,519,000	53,625,000	89%
Port terminal	-	-	1,769,400	3%
Road Transport*	3,915,518	835,897	4,751,415	8%
Total			**60,145,815**	

The results also highlight the differences between Scope 1 and Scope 3 GHG emissions, with the first resulting highly impactful on the total emissions. In the case of the port terminal’s emissions, it wasn’t possible to separate the two scopes.

6 Conclusions

From this application it emerged that the GLEC Framework is certainly useful for calculating the GHG emissions of an entire supply chain. However, it should be noted that it does not take into consideration the different types of cargo. The incorrect homogenization of the different units can bring to errors when comparing results with similar situations.

Further studies must be made in order to analyse the application of the Framework to other typical transport chains.

This study was carried out before the publication of the ISO 14083. The authors suggest a comparison between the application of the GLEC Framework and the new ISO standard (Quantification and reporting of greenhouse gas emissions arising from operations of transport chains) that, for the first time, provides requirements and guidance for the quantification and reporting of GHG emissions along the entire transport chains for passengers and freight.

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