Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 00 (2022) 000–000

Transportation Research Procedia

www.elsevier.com/locate/procedia

Transport Research Arena (TRA) Conference

Standardized logistics emission calculation in inland navigation: Status quo and challenges ahead

Laura Hörandner[a]*, Lisa-Maria Putz-Egger[a], Patrick Specht[b], Beil Denise[a]

[a]*University of Applied Sciences Upper Austria, Roseggerstraße 15, 4600 Wels, Austria*
[b]*Institute of Shipping Eonomics and Logistics, Universitätsallee 11-13, 28359 Bremen, Germany*

Abstract

The measurement of emissions is an essential prerequisite for managing the decarbonization of transport. Carbon accounting should be consistent, transparent and comparable across all transport modes. This paper creates an overview of emission calculation in inland navigation and discuss the results of the different calculation tools (1) EcoTransIT World, (2) CarbonCare and (3) manual calculation with the GLEC Framework 2.0 based on a selected transport case. Our results show that the emissions for IWT differ between the three tools. The reason for the broad range of results is that the different tools use different input parameters for the emission calculation which are not harmonized. We conclude that more effort is needed in the IWT sector that the models reflect the emissions as accurately as possible. A precondition for this is having scientifically validated data and emission factors.

Peer-review under responsibility of the scientific committee of the Transport Research Arena (TRA) Conference
Keywords: emission calculation; inland navigation; emission factors; greenhouse gas emissions; carbon accounting, inland waterway transport

1. Introduction

To limit the increase of the global average temperature to 1.5 °C compared to pre-industrial levels, atmospheric concentrations of greenhouse gases (GHGs) must be stabilized and require net zero annual emissions around 2050 (IPCC, 2014). GHG emissions from the transport sector in the EU increased steadily between 2013 and 2019, a trend that diverges significantly from those in other sectors during that period. Currently, 25 % of the emissions are produced by the transport sector including passenger transport, with around eight to ten percent originating from freight transport (Greene and Lewis, 2019). National projections compiled by the European Environment Agency indicate that even with measures currently planned by the EU Member States, domestic transport emissions will only drop below their

* Corresponding author. Tel.: +43-5-0804-33259
E-mail address: laura.hoerandner@fh-steyr.at

2352-1465
Peer-review under responsibility of the scientific committee of the Transport Research Arena (TRA) Conference

1990 level in 2029 (European Environment Agency, 2021). A major measure announced in the European Green Deal to decarbonize the transport sector is to shift cargo from road to more environmentally-friendly railway and inland waterway transport (European Commission, 2019). To allow for an efficient and controlled change process, the measurement of emissions, also known as carbon accounting, represents an essential prerequisite. One of the central goals of freight carbon accounting has been to produce estimates that are consistent, transparent, and comparable across all transport modes, operators, commodities, supply chains and geographies (Hofbauer and Putz, 2020). The quality of calculated emissions and emission intensities as well as their subsequent use in business reporting and decision-making concerning logistics emission reduction depends on availability, specification, quality and exchange of data (Dobers et al., 2019). While for the road transportation sector the collection of data to demonstrate environmental performance improvements has progressed in the past, the availability of data on inland waterway transportation is scarce (Greene and Lewis, 2019). Thus, to ensure an accurate comparison with other modes of transport, the measurement of energy consumption and related emissions of IWT needs to be qualitatively and quantitatively improved and brought up to the level of road traffic (Hofbauer and Putz, 2020). In the domain of cargo transportation, the CO_2 intensity of a given transport mode is commonly represented by observing CO_2 emissions in relation to its transport performance and thus in the form of g/tkm or g/TEUkm. This ratio is generally referred to as the "CO_2 emission factor". As is the case for other modes of transport, the CO_2 intensity is the key element for determining the carbon footprint of inland navigation (CCNR, 2012). Without accurate data, it is impossible to adequately commit science-based targets, assess options for decarbonization, and track progress in reducing emissions over time (Finger and Serafimova, 2021).

Given the high relevance of reliable methods for carbon accounting in logistics as well as the lack of data for inland waterway transportation, this paper examines existing standardized and transparent emission calculation methods for IWT. To provide additional insight on the applicability and transparency of current practices, a IWT logistics scenario is analysed using available three selected emission calculation tools, i.e. (1) EcoTransIT World, (2) CarbonCare and (3) GLEC Framework 2.0 (manual calculation). The paper is structured as follows: section 2 presents a review on logistics emission calculation methods for inland waterway transportation and the emission calculator tools. Section 3 forms the core of this paper, presenting the case for the emission calculation and the results. Lastly, section 4 presents a conclusion and further research.

2. Review on Logistics Emission Calculation Methods for Inland Waterway Transportation

In this chapter we present the standards and tools for logistics emission calculation. Moreover, we investigate the status of emission values for IWT of each standard and tool. Starting with an explanation of the EN16258 and the GLEC framework which will lead into the ISO 14083 in 2022, we continue with an explanation of the tools Marco Polo, EcoTransIT World and Carbon Care. At the end of this chapter, we discuss results from studies focussing on the status of CO_2 emissions of IWT in the standards and tools. CO_2e (equivalent) is a unit of measurement designed to compare and aggregate the impact on global warming of all greenhouse gases (GHG) such as nitrous oxide (N_2O), methane (CH_4), perfluorocarbons, etc. It measures the 100-year global warming potential of GHG. It calculates the heat absorbed by any greenhouse gas for 100 years in the atmosphere as a multiple of the heat that would be absorbed by the same mass of CO_2 (Cadilhac, 2021).

2.1. EN16258, GLEC & ISO 14083

The European standard EN 16258 represents a methodology for the calculation and declaration of energy consumption and GHG emissions of transport services for freight and passengers, which was published in 2012 (European Standard, 2022). The EN 16258 standard suggests the use of default values, if there is missing information about fuel consumption for vehicles, the load utilisation and the proportion of empty trips. It has to be noted that if the energy consumption values are calculated using the default values rather than measured, then certain assumptions, e.g. about the load utilisation of the vehicles, are considered in the calculation. These assumptions lead to considerable effects on the CO_2e result. Sensitivity analyses – in which the assumed values are changed systematically – are recommended to reveal which input values have a crucial effect on the result. If it becomes clear that the default values have a marked effect on the result, they should be replaced by measured values (Schmied and Knörr, 2012). In 2016, the first Global Logistics Emissions Council (GLEC) Framework for Logistics Emissions Methodologies established by Smart Freight Centre (SFC) has been created to be the leading methodology for freight transports and logistics operations. The GLEC Framework was updated 2019 into the GLEC Framework 2.0 (Greene and Lewis, 2019). The GLEC framework in its third version serves as the basis for the new ISO 14083 which will replace the EN16258 by the end of 2022. Concerning inland waterway freight transport, the existing GLEC framework provides global default consumption factors without further (regional) distinction between e.g. vessel types, sizes, (operational) power and load factors. Moreover, factors for alternative fuels others than diesel cannot be found. Therefore, SFC has the objective to integrate a more detailed methodology for inland waterways into the third update of the GLEC framework which is planned by the end of 2022 (van Liere, 2018).

2.2. CO_2 emission calculation tools: Marco Polo, EcoTransIT World & Carbon Care

In 2012, the Central Commission for the Navigation of the Rhine (CCNR), the international institution with an administration which is responsible to address effectively several subjects concerning inland navigation on the Rhine, noted that many studies have attempted to quantify the CO_2 intensity of inland navigation. The CCNR found that the reviewed studies found a broad range of CO_2 intensity values for inland navigation. In fact, the range of the CO_2 values was too broad to determine reliable carbon footprint of inland navigation for the purposes of transport, climate protection policy or to accurately derive the CO_2 emissions of logistics chains. Besides other studies, the CCNR investigated the emission data used by the Marco Polo Calculator and EcoTransIT World (CCNR, 2012), which are described in the following paragraphs. In the Marco Polo calculator, the user can compare the monetised environmental impacts of the former road route with the shifted route to railway or inland waterways. The tool is a Microsoft Excel-based application and can be downloaded for free from the internet but provides only monetised outputs (Wolff et al., 2010). EcoTransIT World (Ecological Transport Information Tool, worldwide) is a free and publicly available web application, which calculates the environmental impact of freight transport for any route and transport modality. EcoTransIT offers a chargeable Business Solutions, which supplies the user with significantly extended options (IVE mbH, 2022). The emission data from the Marco Polo Calculator and EcoTransIT and real-life data provided by the shipping industry differ greatly, CCNR (2012) concluded, that the Marco Polo Calculator and EcoTransIT are based on data for the specific energy consumption of inland navigation that has neither been verified in practice nor compared with a study based on real data. The CCNR suggested that the emission factors available or to be redeveloped should be checked using the data from inland navigation companies on fuel consumption and the total transport performance of various vessel types in conjunction with the transport statistics recorded by the CCNR (2012). Another global emission calculator based on the EN16258 standard is Carbon Care which covers all modes of transport (road, rail, air, sea and inland waterways), emissions from cargo handling and cold storage. In addition to a free-of-charge version resulting in simple online CO_2 calculations, Carbon Care offers advanced automated computation of the GHG generated by the transportation of goods (Wild, 2021).

2.3. Studies about CO_2 emissions of IWT in the tools & standards

Schweighofer and Szalma (2014) did an evaluation of a one-year operational profile of a Danube vessel and found significant variations in the relative fuel consumption depending on the locations and times considered. They calculate the respective CO_2 emissions by multiplying the fuel consumption with a factor and concluded, that an unambiguous calculation of the CO_2 emissions was not possible, using the EcoTransIT emission calculation tool. The definition of the input parameters in the tool was too confusing in order to establish confidence in the results obtained (e.g. a vessel load factor of 100 % results in less total CO_2 emissions in t as the ones obtained with a vessel load factor of 50 %). They concluded that the results of the EcoTransIT emission calculation tool must be taken with caution if transports with inland waterway vessels are considered on the Danube (Schweighofer and Szalma, 2014).

Simenc (2016) evaluated existing emission calculator that could be used for estimating emissions of IWT and concluded that the range of available ready-to-use practical solutions is relatively narrow. There are few options available and even the estimation capabilities of existing ones could be thought of only as educated guesses, at best. They are only as good as the quality of emission factors and other parameters that are considered, over which the prospective users have no influence and are subject to uncertainties regarding the underlying calculation algorithms and ability to produce reliable results (Simenc, 2016).

Van Liere (2018) focused on refining modal default carbon footprint factors for GLEC Framework 2.0. to further increase the accuracy of logistics emissions in global supply chains. Therefore, they calculated the GHG emission factors for representative vessel classes in Europe based on real-life data from barge operators for multiple trips or year-round navigation. Primary sources were the European research project PROMINENT and few companies that provide IWT services. Nevertheless, they note, that the GHG emission factors considered are still estimates rather than exact values. For example, in practice substantial differences can be experienced on similar trips carried out by similar vessels. This can be caused by differentiated water levels and currents, different load factors, operational profile and related power distribution. The dataset includes information on only approx. 1% of the vessels operating in Europe. They recommended to continue expanding the dataset with annual information on transport performance (distance covered, load factor, tonnes transported) and fuel consumption per representative vessel class and emphasize the value of real-life data, because the data collected by barge owners / inland shipping lines has resulted in lower GHG emission factors in comparison to other recognized studies. To reach global representative GHG emission factors for IWT more effort is needed. Validation of European GHG emission factors could be a first step, to be followed by onboard measurements on the most important river basins / waterways in the World (van Liere, 2018). In conclusion, the review of related literature shows that there are already many efforts in the direction of standardization in carbon accounting and in the area of default values. However, the lack of harmonization and generability of calculation results may still represent a barrier to overcome.

3. Evaluation of current Emission Calculation Tools

Based on the review of relevant literature we decided to use the popular calculation tool EcoTransIT and Carbon Care since they are (1) frequently mentioned in publications and used, (2) available in English, (3) free-of-charge and accessible without registration and (4) including CO_2e emissions from Well-to-Wheel (WTW) for IWT. Moreover, we calculate the emissions ‘manually’ using the GLEC Framework 2.0. The EcoTransIT tool is based on the GLEC Framework 2.0, allowing to compare the results of the tool with the manual calculation following the GLEC Framework 2.0. For the transport analysis we used the following transport case: 25 tonnes of average goods (weight type) are transported via truck (diesel propulsion) from St. Florian (Austria: coordinates: 48.20505 / 14.37790) to Enns (Austria: coordinates: 48.2254 / 14.4933), see Fig. 1. The coordinates originate from OpenStreetMap. In Enns, the goods are transferred to an inland vessel and transported along the Danube to Constanta (Romania). The navigable length of the Danube available to international waterway freight transport is 2,415 kilometres, starting from Sulina at the end of the middle Danube distributary into the Black Sea in Romania (river-km 0) to the end of the Danube as a German federal waterway at Kelheim (river-km 2,414.72). From Regensburg to Budapest (except for the Straubing–Vilshofen section in Bavaria) the Danube is classified as waterway class VIb and is navigable by 4-unit pushed convoys (viadonau, 2019). A motor cargo ship (length: 85 m, width: 9,5 m, max. draught 2,5 m, max. load capacity 1.350 t) (Meinel, 2022) with diesel propulsion takes the goods further to Constanta (Romania: coordinates: 44.0989 / 28.6572) and then again via truck (diesel propulsion) to Ovidiu (Romania: coordinates: 44.25762 / 28.55861). According to Transport Trade Services GmbH, the waterway distance is 1.872 km (Leitner, 2022).

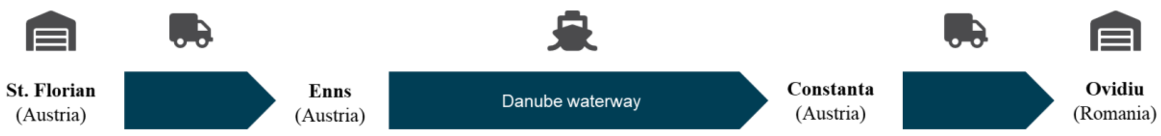

Fig. 1. Transport case from Austria to Romania

3.1. Emission Calculation Tools & Input Parameters

Based on the review of relevant literature, three calculation tools were used for the analysis: (1) EcoTransIT World, (2) Carbon Care and (3) GLEC Framework 2.0. For the calculation, we used the Well-to-Wheel (WTW) CO_2e emissions values. The input parameters and the results of the three calculations are summarized in Table 1.

(1) EcoTransIT World

In EcoTransIT World the input parameters were as following: Barge (Euro ship bulk I-IV 0-1,500t capacity), emission standard: CCNR 1 (2002-2006), Load factor: 52%. Shipping point: 48.20505 / 14.37790; Receiving site: 44.25762 / 28.55861. EcoTransIT automatically calculates the coordinates of the ports, but in the case of Enns the coordinates are in a field and one can`t change these coordinates.

(2) Carbon Care

For the calculation of CO_2e emissions in the Carbon Care tool we needed to define the cargo weight in kg, whether the cargo is refrigerated, whether the cargo handling is to be included in the calculation, transported by a 40 t truck from 4490 St. Florian (Austria) to 4470 Enns (Austria), then by an inland vessel (type of vessel: Rhine/Herne/IV – 1,537 t) to 78462 Constanta and again by truck to 905900 Ovidiu (Romania).

(3) GLEC Framework 2.0

We used the GLEC Framework 2.0 to calculate the CO_2e emissions manually using the emission intensity factor 19 g CO_2e/tkm (WTW) of the category motor vessels 85–110 m (1,000–2,000 t). The load factor which is a combined load factor including empty running is fixed in the GLEC Framework with 52 % for this vessel category (Greene and Lewis, 2019).

3.2. Transport Case Results

(1) EcoTransIT World

In EcoTransIT, the described transport case causes CO_2e emissions of 1.526 t. 0.053 t are attributable to the road transportation leg, 1.473 t to the inland waterway vessel. The tool calculated the distances as followed: 10.58 km for the truck, 1,789.65 km for the vessel and 17.25 km for the truck. EcoTransIT World added 0.012 t for the handling.

(2) Carbon Care

Carbon Care calculated a transport distance of 2,183.52 km for the entire route. This are more than 366 km more than in EcoTransIT. Even if one can't enter the coordinates at Carbon Care, but only the zip code, this difference is still significant. And although there are more transport kilometres, the CO_2e emissions according to Carbon Care are lower than with the EcoTransIT. They are 1.351 t CO_2e. If the transhipment is included, the total emissions increase to 1.372 t CO_2e.

If the transport relations were calculated separately, the first mile of 7.27 km causes 0.011 t CO_2e and the last mile of 12.46 km 0.0195 t CO_2e by road. This means 0.031 t CO_2e for the whole truck transport. The transport with the inland vessel (2,163.80 km) causes 1.320 t CO_2e.

Changing the vessel type from Rhine/Herne/IV – 1.537 t to Rhine/Herne/Va the emission of the IWT increase to 1.953 t CO_2e. And taking the Rhine/Herne/VIb the emissions are 1.904 t CO_2e.

Using Carbon Care it was not possible to calculate emissions for a transport example with more than 40 t, due to an error that occurs during the calculation. We assumed the error happens as the tool does not automatically recognize that two or more trucks are needed to carry 40 t. This means, for larger cargo quantities the calculator is not suitable, but exactly these types of heavy goods are relevant for inland navigation.

(3) GLEC Framework 2.0

The truck kilometres were calculated using Google maps and the coordinates. We used the Europe road emission intensity factors of a diesel fuelled artic truck up to 40 t the calculation of the first mile with 11 km. The emission intensity of 80 g CO_2e/tkm is for an averaged/mixed load, with a load factor of 60 % and 17 % empty running. A motor vessel 85-110 m (1,000-2,000 t) will transport the goods for the main run for a distance of 1,872 km. A combined load factor and empty running of 52 % is specified in the GLEC Framework. Therefore, an emission intensity factor of 19 g CO_2e/tkm for the inland vessel was used. The last mile (27 km) was done with a diesel fuelled artic truck up to 40 t. The described transport case causes CO_2e emissions of 0.9652 t. Emissions of 0.076 t CO_2e are attributable to the truck, 0.8892 t CO_2e to the inland waterway vessel.

Additional CO_2e is generated for the transhipment, the current study results on transhipment assessment are still poorly known, the values are initial estimates assuming the 'worst case'. 1.2 kg CO_2e/t is charged for the transhipment. In this case this would be 0.06 t CO_2e. As EcoTransIT World is a tool which is GLEC certificated, we assumed that the calculation with the tool and the manually calculation achieve the same result, but due to varying vessel categories, differences in the calculation of the kilometers, the load factor, the empty trips and the emission standard of the vessel, the results obtaining for a simple transportation example are different.

Table 1: calculation parameters and results of the logistic scenario

		Logistic scenario	EcoTransIT World	Carbon Care	GLEC Framework 2.0
	Cargo	25 tonnes of averaged goods (weight type)	25 tonnes of averaged goods (10t/TEU)	25.000 kg (not refrigerated)	25 tonnes of averaged/mixed load
road leg	**Vehicle type**	truck (diesel propulsion)	n/a	40 t truck	artic truck up to 40 t (diesel)
	Transport route	St. Florian (Austria: coordinates: 48.20505 / 14.37790) to Enns (Austria: coordinates: 48.2254 / 14.4933)	St. Florian (Austria: coordinates: 48.20505 / 14.37790)	4490 St. Florian to 4470 Enns	St. Florian (Austria: coordinates: 48.20505 / 14.37790) to Enns (Austria: coordinates: 48.2254 / 14.4933)
	Load factor/Empty Running	n/a	n/a	n/a	60% / 17%
IWT leg	**Vehicle type**	motor cargo ship (length: 85 m, width: 9,5 m, max. draught 2,5 m, max. load capacity 1.350 t) with diesel propulsion	Euro Ship bulk I-IV 0-1.500 t capacity	Rhine/Herne/IV - 1537 t	motor vessels 85–110 m (1000–2000 t)
	Emission standard	n/a	CCNR 1 (2002-2006)	n/a	n/a
	Transport route	Enns to Constanta (Romania: coordinates: 44.0989 / 28.6572)	n/a	4470 Enns to 78462 Constanta	n/a
	Waterway km	1872	n/a	n/a	1872
	Load factor	n/a	52%	n/a	52% (combined load and empty running factor)
road leg	**Vehicle type**	truck (diesel propulsion)	n/a	40 t truck	artic truck up to 40 t (diesel)
	Transport route	Ovidiu (Romania: coordinates: 44.25762 / 28.55861)	Ovidiu (Romania: coordinates: 44.25762 / 28.55861)	78462 Constanta to 905900 Ovidiu	Ovidiu (Romania: coordinates: 44.25762 / 28.55861)
Results in t CO_2e emissions (WTW)	**truck**		0.053 (28 km)	0.031 (20 km)	0.076 (38 km)
	ship		1.473 (1,790 km)	1.320 (2,164 km)	0.8892 (1,872 km)
	total		**1.526 (1,818 km)**	**1.351 (2,184 km)**	**0.9652 (1,910 km)**
	handling		0.012	0.021	0.06

4. Discussion, conclusion and future work

In our paper we investigated the differences of CO_2e emission calculations for IWT transport using the three common tools (1) EcoTransIT World, (2) Carbon Care and (3) a manual calculation based on the GLEC 2.0 framework. The obtained results were subject to a broad range of fluctuating values. A major challenge was that the three tools do not allow to use the same parameters for the emission calculation: For example, the EcoTransIT World, the Carbon Care tool and the GLEC framework have varying vessel categories. We found differences in the calculation of the kilometers, the load factor, the empty trips and the emission standard of the vessel. Due to this large number of unclear factors involved in the emission calculations with default values, it is of major relevance to harmonize the emission calculation method and recommend companies to set targets for emission improvements or compare multimodal options based on a single calculation method. It is important, that the drive for consistency, transparency and comparability is strongly maintained in the future for the data input and for the collection of freight emission data. A comparison of EcoTransIT emission factors in a report commissioned by the GLEC has shown deviations ranging from -28% to about +38%, to the average CO_2 emission factors by ship type cited from several studies for China, the U.S. and the Rhine basin. The assumptions on speed, cargo capacity utilization, or inclusion/exclusion of auxiliary engine fuel consumption from the studies are partially unknown, which may explain some of the differences (Anthes et al., 2021).

The future framework for calculating CO_2e emissions needs to be reliable, relevant, and accurate to enable adequate comparison of emissions from transport operations, thereby placing all modes and operations on equal footing. Because the greater the importance of emissions for making logistical decisions becomes, the greater the interest in the various transport sectors should be in keeping their emissions low and that the models reflect the emissions as accurately as possible. A precondition for this is having scientifically validated data and emission factors that are accepted by the various sectors of the industry (CCNR, 2012). Efforts are made to introduce the current establishment of the global ISO standard 14083 on the quantification and reporting of GHG emissions arising from operations of transport chains (Greene and Lewis, 2019). Therefore, data collection programs are necessary to get to a more accurate picture of the CO_2e emissions per tkm from inland waterways, although this is quite extensive in comparison to other modes. The reason is that the specific energy consumption of an inland vessel in relation to the transported freight weight and distance (grams of diesel per tkm) can take on very different dimensions, because the energy consumption in inland navigation is strongly influenced by several factors. The width and depth of the waterway alone, and thus the distance between the ship's side and the river bottom, have a massive influence on diesel consumption. For example, if the water depth increases from four to five meters, the energy consumption is reduced by about half at a speed of 16 kilometers per hour. CO_2e emissions from inland shipping can therefore only be determined with a degree of accuracy if energy consumption data are available for individual waterways and the type of ship used (Bauer et al., 2011). Data collection programs for more real-life data from barge operators are necessary to get a more accurate picture of the GHG emission per tkm from inland waterways. The data should include annual information on transport performance (distance covered, load factor, tones transported) and fuel consumption per representative vessel class. Future research should focus not only on the CO_2e emissions from the transportation, but also those emissions which are related to handling, where the data situation is currently inadequate.

Such data should enter the update to the GLEC Framework by the end of the year 2022 and in the upcoming ISO 14083 standard (Quantification and reporting of greenhouse gas emissions arising from operations of transport chains). Moreover, the calculation tools should be unified and adapted. A comparison with paid tools would be interesting, to show which parameters are used there and whether more correct or more accurate results can be achieved. Because the improved access to reliable data will help both business and governments make better decisions to collectively reach climate goals.

Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 861377.

References

Anthes, R., Notter, B., Biemann, K., Dobers, K., 2021. EcoTransIT World Environmental Methodology and Data Update 2020. Available online at https://www.ecotransit.org/wordpress/wp-content/uploads/20210531_Methodology_Report_EcoTransIT_World.pdf.

Bauer, B., Kranke, A., Rauser, T., 2011. CO_2 Berechnung. Das Sonderheft zur Ermittlung von Treibhausgas-Emissionen in der Logistik. Available online at http://media1.verkehrsrundschau.de/fm/3576/VR-CO2_Spezial_2011_Juni.pdf?_gl=1*11qip1t*_ga*NTY1Mjg1OTkxLjE2NDkwMTU3NTU.*_ga_VZTE521QZ8*MTY0OTAxNTc1NS4xLjEuMTY0OTAxNTc3MS4w&_ga=2.77305362.649737176.1649015755-565285991.1649015755.

Cadilhac, E., 2021. Everything you need to know on the GLEC Framework and the calculation of CO_2 emissions. Available online at https://searoutes.com/2021/06/10/everything-you-need-to-know-on-the-glec-framework-and-the-calculation-of-co2e-emissions/.

CCNR, 2012. Possibilities for reducing fuel consumption and greenhouse gas emissions from inland navigation. Available online at https://www.ccr-zkr.org/files/documents/rapports/Thg_ber_en.pdf.

Dobers, K., Lewis, A., Smith, C., 2019. Deliverable 2.4 - Guidelines for validation and reporting of emissions. Available online at https://learnproject.net/.

European Commission, 2019. The European Green Deal. Available online at https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf.

European Environment Agency, 2021. Greenhouse gas emissions from transport in Europe. Available online at https://www.eea.europa.eu/ims/greenhouse-gas-emissions-from-transport.

European Standard, 2022. CSN EN 16258. Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passengers). Available online at https://www.en-standard.eu/csn-en-16258-methodology-for-calculation-and-declaration-of-energy-consumption-and-ghg-emissions-of-transport-services-freight-and-passengers/.

Finger, M., Serafimova, T., 2021. Policy Brief - European Transport Regulation Observer. Available online at https://cadmus.eui.eu/bitstream/handle/1814/72264/QM-AX-21-039-EN-N.pdf?sequence=1

Greene, S., Lewis, A., 2019. Global Logistics Emissions Council Framework for Logistics Emissions Accounting and Reporting, version 2.0. Smart Freight Centre. Amsterdam.

Hofbauer, F., Putz, L.M., 2020. External Costs in Inland Waterway Transport: An Analysis of External Cost Categories and Calculation Methods. Sustainability 12.14. 5874.

IPCC, 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland.

IVE mbH, 2022. Emission calculator for greenhouse gases and exhaust emissions. Available online at https://www.ecotransit.org/en/emissioncalculator/.

Leitner, H., 2022. Kilometrage Danube from Izmail to Kelheim. Transport Trade Service GmbH.

Meinel, U., 2022. Schiffstypen. Available online at https://www.viadonau.org/wirtschaft/transportachse-donau/schiffstypen.

Schmied, M., Knörr, W., 2012. Calculating GHG emissions for freight forwarding and logistics services in accordance with EN 16258. Terms, Methods, Examples. Available online at https://www.clecat.org/media/CLECAT_Guide_on_Calculating_GHG_emissions_for_freight_forwarding_and_logistics_services.pdf.

Schweighofer, J., Szalma, B., 2014. Evaluation of a one-year operational profile of a danube vessel. Available online at https://www.researchgate.net/publication/266088659_EVALUATION_OF_A_ONE-YEAR_OPERATIONAL_PROFILE_OF_A_DANUBE_VESSEL.

Simenc, M., 2016. Overview and comparative analysis of emission calculators for inland shipping. International Journal of Sustainable Transportation 10.7. 627–637.

van Liere, R., 2018. GHG emission factors for IWT. Final report. Available online at https://www.smartfreightcentre.org/pdf/GLEC-report-on-GHG-Emission-Factors-for-Inland-Waterways-Transport-SFC2018.pdf.

viadonau, 2019. Manual on Danube Navigation. 4th edition. Vienna: via donau – Österreichische Wasserstraßen-Gesellschaft mbH.

Wild, P., 2021. Recommendations for a future global CO_2-calculation standard for transport and logistics. Transportation Research Part D: Transport and Environment 100.

Wolff, J., Gaffron, P., Flämig, H., 2010. Tools and Guidelines for Assessing Modal Shift, Environmental Impact & Socio-Economic Impact in MoS-Applications. Available online at http://www.vsl.tu-harburg.de/stratmos/archiv/StratMoS_WPB_ImpactAssessment_100810_nn.pdf.