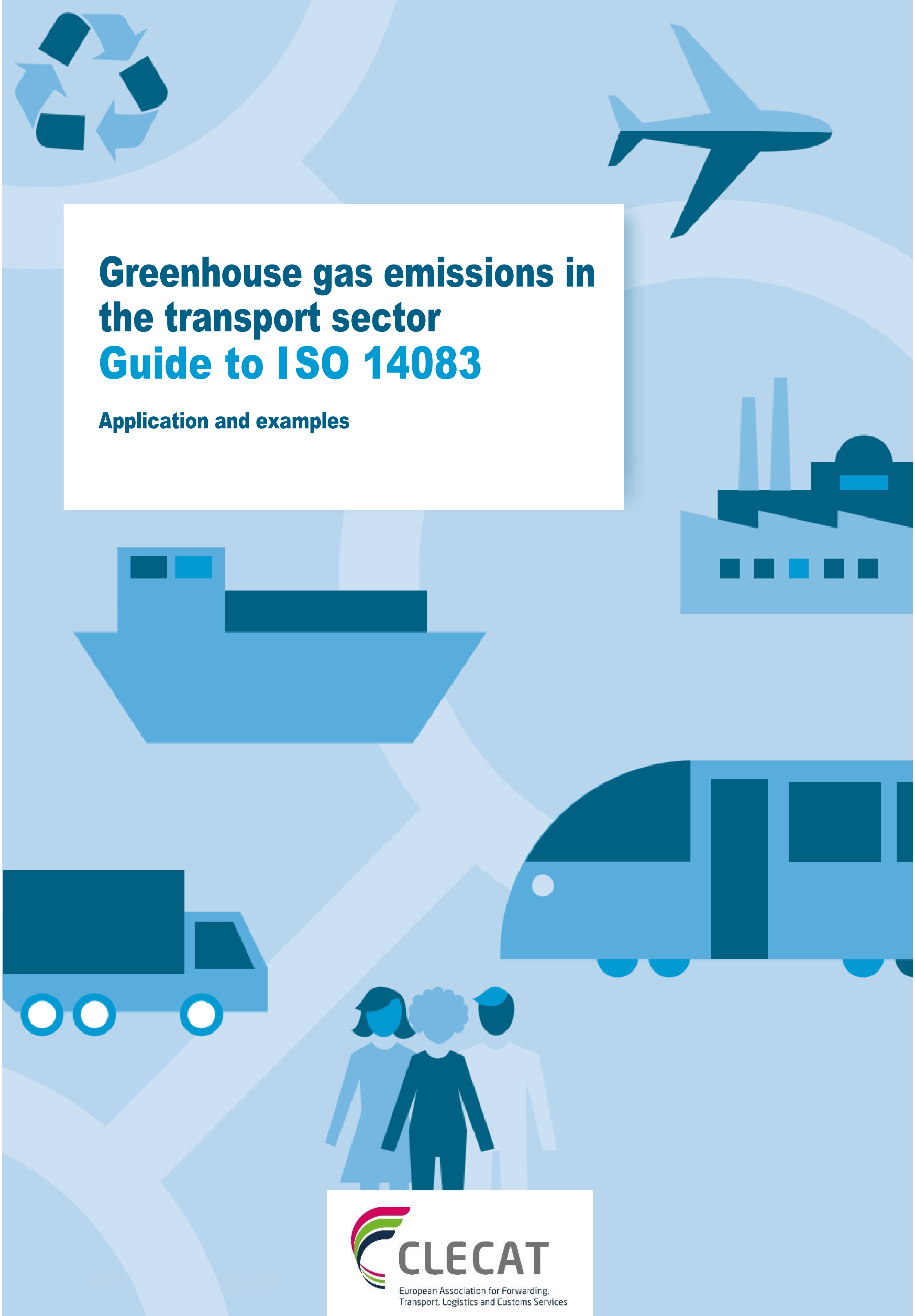
Greenhouse gas emissions in the transport sector
Guide to ISO 14083

Application and examples



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Foreword

As the global economy increasingly recognises the urgent need to decarbonise supply chains, the logistics industry faces rising expectations for reducing greenhouse gas (GHG) emissions. Transporting goods and passengers efficiently and sustainably has become crucial, as regulatory requirements, voluntary climate targets, and consumer demand for sustainable products intensify.

The quantification of GHG emissions in the transport sector is a significant challenge, one that will continue to gain importance with the EU Corporate Sustainability Reporting Directive (CSRD), which came into force on the 5th of January 2023. This Directive requires companies above a certain size to regularly report on their sustainability efforts, including emissions from their supply chains. As companies adapt to these new obligations, sound assessments and collaboration with supply chain partners will be essential.

The ISO 14083 'Greenhouse gases - Quantification and reporting of greenhouse gas emissions arising from transport chain operations', published in March 2023, provides a corresponding basis for the international standardisation of the calculation and reporting of emissions from (global) transport chains. This standard offers a comprehensive methodology for transport and logistics companies to calculate and assess GHG emissions from global and regional supply chains across different modes of transport. This facilitates consistent and comparable sustainability reporting.

Based on a competitive call, UBA commissioned ifeu and Fraunhofer IML to develop a practical guide to support businesses in implementing ISO 14083. This guide includes case studies relating to both freight and passenger transport, demonstrating the application of the standard and addressing challenges that may arise in the course of its application.

I am confident that this guide provides a valuable resource for assessing the climate impact of transportation activities and assisting companies in reporting their GHG emissions transparently.

Dirk Messner
President of the German Environment Agency (UBA)

Umwelt Bundesamt

Table of contents

Glossary of key terms

Term: English	Explanation / Reference
Total GHG emissions	summarises GHG emissions from energy provision and operation, see section 1.2; replaces term in EN 16258: Well-to-Wheel (WTW) Formula symbol G_T
Greenhouse Gas (GHG) Protocol Scope 1/2/3	supports the calculation of greenhouse gases and includes three perspectives, so-called "Scopes" that take different emissions into account, see section 1.1
Hub activity	quantifies the throughput of a hub, is usually expressed in tonnes (t) or number of passengers (pax), see section 3.2 Formula symbol H
Hub operation (HO)	describes the transfer of cargo (e.g. in a logistics site) or of people (e.g. in a passenger terminal), see section 3.2
Hub operation category (HOC)	summarises hub operations (HO) with similar characteristics, see section 3.2
Shortest feasible distance (SFD)	describes the shortest suitable route, taking into account the infrastructure options for a given vehicle type, see section 3.2.1
Great circle distance (GCD)	describes the shortest distance between two points of the earth's surface along the globe, see section 3.2.1
Primary data	result from a direct measurement or can be calculated based on direct measured values, see sections 2.2 and 4.2.3; replaces term in EN 16258: individual measured values / specific values of a transport service provider / fleet values of a transport service provider
Secondary data	do not meet the requirements for primary data and include modelled data and default values, see sections 2.2 and 4.2.3
GHG activity	includes activities that cause GHG emissions, such as energy consumption, methane slip, refrigerant losses, see section 1.2
Operation GHG emissions	refers to the release of greenhouse gases due to the operation of vehicles or hubs, see section 1.2; replaces term in EN 16258: Tank-to-Wheel (TTW) Formula symbol G_{VO} or G_{HEO}
Energy provision GHG emissions	refers to the release of greenhouse gases during the production, storage, processing and distribution of energy carriers (including electricity) for use in transport chains, see section 1.2; replaces term in EN 16258: Well-to-Tank (WTT) Formula symbol G_{VEP} or G_{HEEP}
GHG emission factor	allows the conversion of GHG activity (i.e. energy consumption (fuel, electricity) and refrigerant leakage) into GHG emissions, see section 4.2.1 Formula symbol ϵ
GHG emission intensity	describes the GHG emissions related to corresponding transport or hub activities, see section 4.2 Formula symbol g

Transport activity	quantifies the freight or passenger transport of e.g. a transport chain or a transport chain element, is usually measured in tonne-kilometres (tkm) or passenger-kilometres (pkm), see section 3.2 Formula symbol T
Transport chain (TC)	describes the transport of cargo or passengers from a point of origin to a destination and is specified by the sequence of transport chain elements (TCEs), see section 3.1
Transport chain element (TCE)	describes a section of a transport chain within which freight or persons are transported by a vehicle on a leg of the transport chain or pass through a hub, see section 3.1; replaces term in EN 16258: Leg
Transport operation (TO)	represents the use of a vehicle for the carriage of cargo and/or passengers, see section 3.2
Transport operation category (TOC)	summarises transport operations (TO) with similar characteristics over a certain period of time, see section 3.2; replaces term in EN 16258: Vehicle operation system

Figures

Tables

1 Introduction

Greenhouse gas (GHG) emissions such as carbon dioxide or methane are caused in transport chains for passengers and freight by transport activities, processes at individual sites or services. The quantification of these emissions with their corresponding classification is fundamental in the current sustainability discourse.

The European standard EN 16258 was published already in 2012 and focussed this topic. However, since there was still room for interpretation in the application of this standard and the standard was only applied at the European level, working groups were formed over time, aimed in particular at international standardisation. In this context, the Global Logistics Emissions Council (GLEC), which is managed by the Smart Freight Centre (SFC) and offers an industry guide for quantifying GHG emissions in the form of the GLEC Framework (Smart Freight Centre 2023), deserves special mention. The consideration of hub processes is being investigated by the Fraunhofer Institute for Material Flow and Logistics IML, among others, and described in more detail in the "Guide for Greenhouse Gas Emissions Accounting for Logistics Hubs" (Dobers and Jarmer 2023).

These and other activities have led to the development of an international standard since 2019, taking into account the latest findings. In March 2023, the ISO 14083 standard "Greenhouse gases – Quantification and reporting of greenhouse gas emissions arising from transport chain operations" was published, offering an international standardisation of the calculation and reporting of emissions from (global) transport chains. EN ISO 14083 replaces EN 16258:2012 and, in addition to transport operations, also covers processes and the associated GHG emissions at sites (hubs) that enable the transfer of passengers or freight.

The new ISO 14083 can be used for all applications in which GHG emissions from transports and hubs are quantified. It covers both passenger and freight transport by all means of transport and can be used for individual vehicles/transports as well as for vehicle fleets/groups of transport operations as well as for single or multiple hubs. Possible applications for the standard include company annual reports, GHG accounting tools for transports and hubs, disseminating information on GHG emissions from transport and transhipment/passenger transfer (either to specific groups of people or to the general public) and many other applications. This means that the standard is suitable for companies in the transport industry (e.g. public transport associations, shippers, freight forwarders) as well as for companies with another business area in which transports play a role in GHG reporting, and many other applications.

This guideline is intended to assist in the uniform calculation and reporting of GHG emissions along transport chains. Requirements and calculation options resulting from ISO 14083 are presented and new terms and abbreviations are explained. Continuous examples illustrate the application of the standard and address challenges that may arise in the application of the standard.

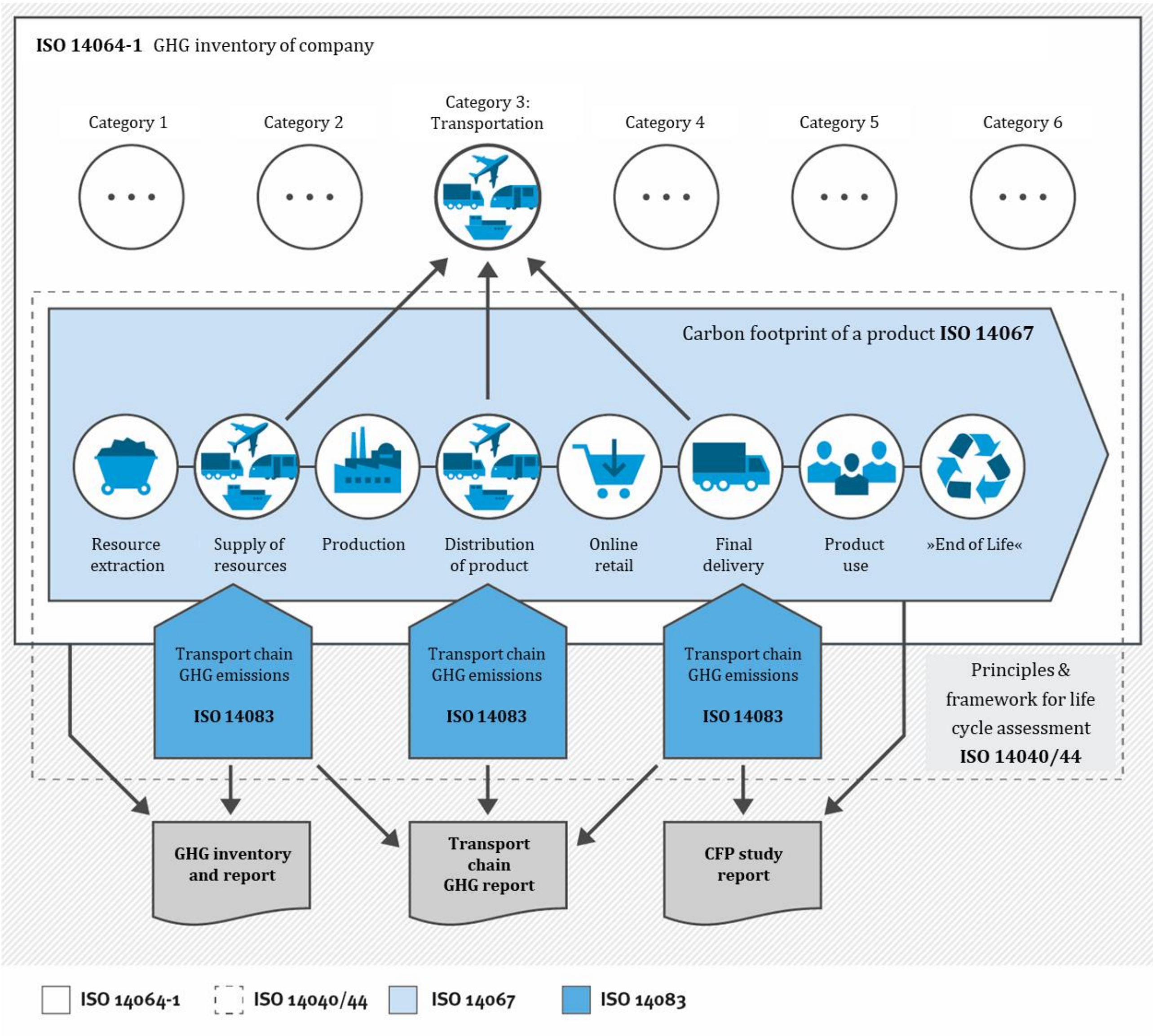
1.1 Overview

1.1.1 How does ISO 14083 relate to other standards and regulations?

ISO 14083 does not stand alone but is part of a number of other international standards for the quantification of environmental impacts and GHG emissions and specifies general principles for calculating GHG emissions in passenger and freight transport. Thus, the results of ISO 14083 can be used as a starting point for many further analyses, e.g. corporate carbon footprint (see ISO 14064), product carbon footprint (see ISO 14067or life cycle assessment

Figure 1

Context of the standards



Source: Detail from ISO 14083 Image 3

(14040/44). Figure 1 shows links between ISO 14083 and other international standards using the example of a freight transport chain. In addition, ISO 14083 takes the requirements of the Greenhouse Gas Protocol (GHG Protocol) into account with its standards on corporate accounting and reporting (World Resource Institute and World Business Council for Sustainable Development 2011) and Scope 3 processes (Ranganathan et al. 2004).

In addition, the publication of the new European standard EN 17837 "Parcel delivery Environmental Footprint: Methodology for calculation and declaration of GHG emissions and air pollutants of parcel logistics delivery services" has been published. This specifies some of the requirements of ISO 14083 with a focus on the parcel sector. In order to comply with the international standardisation work, it is therefore recommended that ISO 14083-compliant GHG emission calculations and reports to be implemented. This is because a proposal for a Regulation on the reporting of greenhouse gas emissions from transport services has already been submitted at the level of the European Commission (European Commission 2023). This provides for the use of the EN ISO 14083 standard as a reference method for the calculation of GHG emissions from transport services and is to be accompanied in the future by a central EU database for GHG emission factors, which are essential in GHG emission calculations.

1.1.2 How is ISO 14083 structured?

The wide variety of ways of transporting passengers and freight makes it necessary to establish calculation rules and uniform specifications on the system boundaries for GHG emission calculations. Therefore, ISO 14083 defines which processes that release GHG emissions into the atmosphere must be included in the quantification. These emissions fall under the normative scope. In addition, the ISO describes optional processes that may be covered. These emissions fall under the informative scope. In addition, processes that shall not be included are explicitly excluded.

The main body of ISO 14083 first provides general content and information on the calculation of GHG emissions (Sections 1 to 5) and then specific topics on data collection, allocation and reporting in the context of the passenger and freight transport (sections 6 to 13).

The main part is supplemented by the annexes. Annexes A to J cover the normative scope and describe details of the modes of transport and hubs where they are part of a transport chain, as well as refrigerant leakages and GHG emission factors.

The informative scope includes Annexes K to R, which – in addition to further guidance on selected topics such as the modelling of GHG emissions of transport chains – optionally classify topics to be taken into account, such as transport packaging, or refer to example default values for selected transport or logistics services.

For information: the German version DIN EN ISO 14083 also has an informative Annex S, which summarises the main technical differences between EN 16258 and ISO 14083, e.g. with regard to system boundaries and terms, in tabular form. The glossary of key terms at the beginning of this guide reproduces parts of Annex S.

1.2 Terms and basics

GHG emissions from transport processes come from various sources. For this reason, ISO 14083 introduces corresponding terms to differentiate GHG emissions, as the previously common terms such as well-to-tank (WTT), tank-to-wheel (TTW) and well-to-wheel (WTW) are already used in other standards and are not suitable for hub-specific processes. The new term **energy provision GHG emissions** refers to the release of greenhouse gases during the production, storage, processing and distribution of energy carriers (including electricity) for use in transport chains. It replaces the terms indirect or WTT emissions. **Operation GHG** emissions on the other hand, refer to the release of greenhouse gases due to the operation of vehicles or hubs, replacing the former direct or TTW emissions. They are caused by the combustion or leakage of fuels and the leakage of refrigerants. GHG emissions from energy provision and operation are combined into **total GHG emissions.** In addition, the standard also uses the term **Packaging life cycle GHG emissions**.

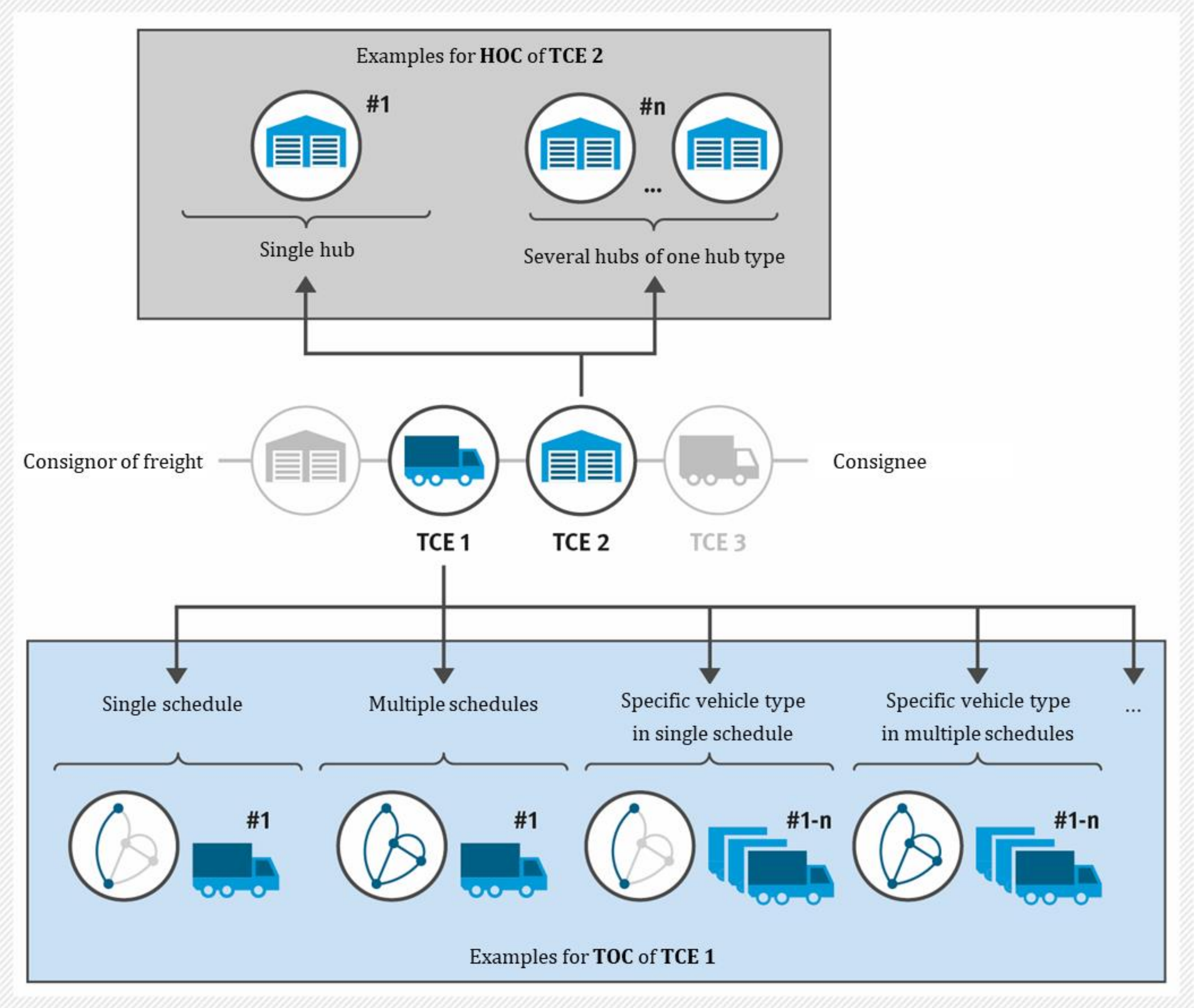
This includes all GHG emissions generated during the life cycle of (transport) packaging that is used, for example, at hubs for the (re)packaging of freight and can be optionally taken into account.

To put these terms and emissions in the context of transport, ISO defines a **transport chain** as a sequence of elements that are associated with the carriage of passengers and freight from a point of origin to a place of destination. The elements of a transport chain within which passengers or cargo are transported by a vehicle or transferred through a location (hub) are referred to as **transport chain elements (TCEs)**. ISO 14083 uses the term **vehicle** to encompass all means of transport. This is used in this document as an umbrella term for all modes of transport.

In order to group transport operations or transport chain elements that share similar characteristics, so-called **transport operation categories (TOCs)** are used (see ISO 14083 Section 3.1.29). These include, for example, the consideration of different vehicles or passengers or freight types and different levels of granularity. For example, a TOC can be formed for a vehicle on a specific route, but also for a group of vehicles in a network. If a vehicle transports people and freight at the same time, for example, the associated TOC may contain several TCEs with different GHG emission intensities (see ISO 14083 Section 6.3).

Figure 2

Example of a transport chain of freight with possible transport and hub operation categories



Source: own illustration based on ISO 14083 Figs. 6 and 7

A similar term is used for transport chain elements that describe hub processes. **Hub Operation Categories (HOCs)** are defined as a group of hub operations that share similar characteristics (see ISO 14083 Section 3.1.12), such as processes, cargo type, or ambient temperature/temperature control. These include, for example, the temperature control of goods and air conditioning for passengers. A HOC must fully encompass each hub operation, so typically one or more hubs are considered as a whole. Details on individual cases in which a hub can be assigned to multiple HOCs are described in section 4.1.2.

In order to be able to calculate GHG emissions for these operation categories, the relevant activities of processes that cause GHG emissions are analysed and the necessary data is collected. This data is called **GHG activity data**. The GHG activity data for transports and hubs generally refer to the use of fuels, other energy consumption, the leakage of refrigerants and, optionally and in the case of hubs, to the use of transport packaging material. The assessment shall include all relevant greenhouse gases. In transport chains, the most relevant greenhouse gases are usually (fossil) carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and climate-relevant refrigerants, e.g. R-452a, R-404A or R-134a. Further information can be found in the reports of the United Nations Intergovernmental Panel on Climate Change (IPCC) (IPCC 2023).

All reported GHG emissions are expressed in carbon dioxide equivalents (CO_2e). Here, the so-called **Global Warming Potential (GWP)** comes into play. The GWP reflects how much a greenhouse gas contributes to global warming in relation to carbon dioxide over a chosen time horizon (usually 100 years). These conversion factors are continuously published by the IPCC in reports: the latest is the Sixth Assessment Report (Smith et al. 2021).

Once GHG activity data has been collected and **GHG emissions** have been calculated using appropriate **GHG emission factors**, GHG emission intensities can be calculated taking into account transport activities or hub activities. **Transport activity** should be expressed in either tonne-kilometres (tkm) or passenger-kilometres (pkm), so that GHG emission intensities for transport can be calculated using the amount of GHG emissions per tkm or pkm. The GHG emission intensities for hubs are described using the **hub activity** as throughput in tonnes or passenger transfers, so that the GHG emission intensities for hubs per tonne or per passenger can be calculated.

These key figures are suitable for internal purposes, e.g. for setting emission intensity targets, as well as for exchanging information with customers or shippers for ISO-compliant transport chain calculations.

The next sections provide a precise procedure for the greenhouse gas calculation according to ISO 14083 and further information on the central basics.

1.3 Guide to the guide – Where can you find what?

The guideline serves as a guide for the application of ISO 14083 and begins with some basics of the required procedures:

- The most important basics are summarised in Section 2.1: What needs to be considered with regard to system boundaries? Which processes must be considered and which will not? Since hubs are now mandatory (normative) compared to EN 16258, what are the system boundaries for hubs?

- What should be considered in principle with regard to data quality and data categories used for GHG emission calculations? Answers are given in Sections 2.2 and 4.2.3.

- Section 2.3 presents the procedure for calculating GHG emissions in accordance with ISO 14083.

The further structure of the guideline is based on the steps of a GHG emission calculation of transport chains, which are described individually and explained with examples.

- Chapter 3 describes how a defined transport chain is divided into transport chain elements and how the transport or hub activity of the transport chain or the TCE is calculated. In this chapter, the case examples (Part 1) are also presented and the first steps of a GHG emission assessment are applied as examples.

- Chapter 4 focuses on data collection and GHG emission calculations: it describes how transport and hub operations categories (TOCs, HOCs) are established (see Section 4.1).

- How the determined consumption data are converted into GHG emissions and, based on this, GHG emission intensities are calculated, is explained in Section 4.2. What are GHG emission factors and where can I find the appropriate values (see Section 4.2.1)? How are emissions allocated in accordance with the standard and when is this necessary at all (see Section 4.2.2)? And, somewhat more detailed than in Chapter 2: What exactly are primary data, what are secondary data and when can the latter be used (see Section 4.2.3)? Insights on refrigerant types and potential losses can be found in Section 4.2.4.

- Part 2 of the case examples rounds off Chapter 4: It is shown by way of example how TOCs and HOCs are selected for the defined transport chains, data is assigned and GHG emissions and the associated emission intensities are calculated.

- Chapter 5 explains how the interim results obtained for the TOCs and HOCs can be applied to the GHG emissions calculation of the entire transport chain. Part 3 of the case examples illustrates the application of the explained concepts.

- Chapter 6 presents the reporting requirements according to ISO 14083. Examples of reports are presented in the case examples in Part 4.

- Finally, the Annex sets out relevant GHG emission factors that are taken into account in the GHG emission calculation or reference is made to sources for other factors.

It should be noted at this point that the abbreviations used usually refer to the English terms of ISO 14083. For example, TCE stands for transport chain element or TOC for transport operation category. For this reason, the glossary at the beginning of the guide contains the technical terms as well as the abbreviations and a short explanation or reference to the corresponding chapter.

Case examples in this guide

The guide offers two central case examples, for which the calculation of GHG emissions is described step by step and which are taken up and continued in the chapters. For selected questions, further examples complement the explanations to highlight details separately.

2 Basic procedure

In addition to transparency, a central principle of any greenhouse gas accounting is the application of a uniform and consistent methodology based on correct data. In case of doubt, a conservative approach should always be chosen and, in the case of several accounting options, a uniform approach should always be chosen within one calculation and report that is presented in a clear and transparent way. It is also important to select the reporting period correctly. According to ISO 14083, periods of up to one year are permissible here in order to be able to compensate for possible short-term or seasonal fluctuations. In certain cases, shorter periods need to be taken into account, e. g. if a bus used for passenger transport of tourists only runs during a certain time of the year. Completeness of the calculation is also key: no greenhouse gases or processes causing GHG emissions must be omitted, and if the total emissions are divided among passenger or freight groups, the total sum of the individual GHG emissions must always be equal to the calculated total.

2.1 Basics of assessment and system boundaries

ISO 14083 prescribes which processes must be included in a calculation, can be included and which must not be included. Of course, it is optional to add other non-included processes, but this is done outside of the ISO 14083-compliant calculation and must be reported separately.

2.1.1 Which processes must be considered?

Included processes

All transport operations by air, cable car, inland waterway, pipeline, rail, road and sea transport, as well as all hub operations within the transport chain must be included. Here, all parts of a transport chain in which GHG emissions are generated by the use of energy carriers or refrigerants must be included. All GHG-emitting activities due to loaded and empty trips (including diversionary and/or out-of-route distance) as well as start/stop and idling processes and operation of all propulsion or auxiliary engines must be included.

This must include, in particular:

- GHG emissions from vehicle or hub operation through fuel combustion or leakages and losses of refrigerants
- GHG emissions from the provision of all energy carriers used, including electricity, over their entire life cycle (including energy infrastructure)

In addition to the processes included, ISO 14083 also enables several optional processes: (re)packaging processes, storage of freight, use of information and communication technology, and black carbon emissions.

It is important that no processes or emissions are omitted from the quantification unless this is clearly indicated by a cut-off criterion within the reporting. To this end, a justification must be provided as to why a cut-off criterion is necessary and permissible. For example, it can be shown that the calculation result is not changed as a result. A cut-off criterion can refer to a certain percentage of transport or hub activity or energy consumption of the transport chain, or to a certain percentage of GHG emissions. In doing so, the ISO 14083 does not give information on the height of this cut-off criterion. However, care should be taken to ensure that the cut-off criterion and its height are chosen in such a way that the statement is not changed in a comparison between two similar transport chains.

An example of the application of such a cut-off criterion is the consideration of infrastructure in the GHG emissions of energy provision. For example, it has been shown that in the case of fossil fuels, infrastructure is responsible for less than one percent of total GHG emissions (i.e. the sum of GHG emissions from operation and GHG emissions from energy provision) (John Beath et al. 2014). This means that this one percent of GHG emissions can be used as a cut-off criterion if the data used for the GHG emission factors of fossil fuels do not take into account the infrastructure.

Processes not included

Importantly, ISO 14083 is used to quantify the reporting body's real GHG emissions over a period of time. This means that it is prohibited to include the results of emission trading measures or offsetting.

In addition, the following processes according to ISO 14083 are not part of the quantification:

- Manufacture, maintenance and scrapping of vehicles as well as transport and hub infrastructure
- Production of refrigerants
- Processes at the administrative (overhead) level of the transport service providers
- Waste
- Businesses co-located in a hub (e.g. retail and hospitality services) that are not needed to operate the hub

2.1.2 Hub-specific system boundaries

Hubs are their own transport chain elements. Since these were not included in the previous EN 16258, they will be presented in more detail below. The boundaries for assessing GHG emissions from hubs starts when

- the shipment is unloaded from the incoming means of transport, or
- the passenger disembarks from the incoming means of transport or begins their journey at the hub.

It ends when

- the consignment is either handed over to the recipient or reloaded onto the outgoing means of transport, or
- the passenger boards the next means of transport or ends their journey at the hub.

The system boundaries of the ISO refer to transhipment processes (freight) or transfer processes (passengers) that require energy or release refrigerants. Comparable storage and (re)packaging processes for freight are optional; the standard does not specify a precise definition of dwell time to categorise hubs as transhipment or storage sites, as this depends heavily on the respective industry. It also often happens that part of the freight is transhipped directly at one hub, while another part of the freight is (temporarily) stored, so that in this case it may be necessary to split the respective emissions. How a hub can be narrowed down and how related HOCs can be defined is explained in Section 4.1.2.

For a more detailed limitation of the GHG emission calculation, the following compilation of the processes to be included and excluded for hubs is used. The respective possible GHG-emitting processes or equipment are described and illustrated with examples. Whether they are normatively within the system boundaries of hubs ("yes"), excluded ("no") or considered an optional aspect ("optional") is explained in the right-hand column.

Table 1

Hub operations to be included (yes), excluded (no) and optional in the GHG emissions calculation

Description	Examples	yes/no/ optional
Vehicles and other equipment for the transport, movement and handling of cargo or passengers	Industrial trucks, automated guided vehicles (AGVs), conveyor belts, shuttle systems, cranes, reach stackers, escalators, elevators, apron buses, shuttle boats	yes
Vehicles and equipment for the shunting of vehicles/ships, trailers, containers on the hub's premises (see note 1)	Converter, push boats, pilot/tow boats, shunting locomotives, aircraft tractors (in so-called aircraft dispatch towing procedure, aircraft pushback, tow tractor)	yes
Transport of employees at roll-on-roll-off terminals who steer the self-propelled vehicles to be transhipped	Shuttle vehicles	yes
Drive energy of self-propelled vehicles used for loading (i.e. driving to or from the means of transport*)	Cars, tractors, trucks	no
Technical building equipment of the hub	Lighting, heating, air conditioning	yes
Handling of baggage carried by passengers is part of a passenger transfer	Check-in counters, baggage carousels, cargo tugs	yes
Handling of pre-shipped baggage is part of cargo transhipment (see note 2)		yes
Information and communication technology (ICT) services through hub infrastructure	Server rooms, data centres, cloud services	yes
ICT services purchased from external server providers		optional
Commuting to/from the hub of the hub	Commuter traffic	no
Transport of crew members of vehicles/vessels of inbound or outbound transport	Drivers, train drivers, train attendants	no
Shopping malls, restaurants, hotels located at the hub	Shopping centres, restaurants	no
Equipment for the storage of goods	Stacker crane, high-bay warehouse, small parts warehouse	optional**

* e.g. car train, ferry, ship
** The original German version of this guide contains an error here where it should read “optional” instead of “no”. This error has been corrected in this version.

Note 1: This refers to processes inside and outside buildings. If a vehicle or equipment is used between two terminals, as is conceivable at a seaport, for example, the energy consumption must be allocated to one or both terminals on a pro rata basis. However, the assigning rule must be applied consistently.

Note 2: While baggage carried by passengers can be clearly assigned to passenger transport, baggage that is transported by a logistics service provider independently of a person's actual journey (and the course of travel) is baggage shipment and thus goods transport.

In addition to the GHG-emitting operations mentioned above, other operations that occur geographically in hubs must be included in the GHG emission calculation in accordance with ISO 14083 (see Table 2). However, the ISO recommends that these GHG emissions should not be assigned to the hubs, but that they should be taken into account as part of the transport chain elements for transport.

The ISO recommends that the GHG emissions associated with this consumption is assigned to upstream or downstream transport TCEs. However, if the reporting organisation assigns them to the hub, this must be applied consistently.

Table 2

GHG emissions of operations at hub premises that should be assigned to inbound or outbound transport

Description	Examples
Energy use of vehicles/ships that temporarily stay in the hub	Auxiliary/main engines, ground power unit, shore power
Energy use of vehicles of incoming or outgoing transport on the hub premises, incl. refuelling, or charging of electrically powered transport means at the hub or refilling of refrigerants in vehicles, superstructures, reefer containers	Vehicles, ships, airplanes, trains

In the future, clearer specifications will have to be developed in order to avoid gaps in the assessment of the transport chain and to create further consistency in the calculation of emissions along the transport chains. In the future, both the GHG Protocol and Incoterms[1] may form the basis for assignment rules.

2.2 Data quality and data categories

An important basis for any GHG emissions calculation is the selection and collection of appropriate and high-quality data. Regardless of which step of the calculation a quantification is needed, it is important that data are used that are representative of the transport chain (elements) under consideration and that fit geographically as well as in terms of time and technology, in order to obtain a meaningful result.

According to ISO 14083, there are basically two different types of data that are used in the calculations: **primary data**, which result directly from a measurement (or are calculated on the basis of measured values), and **secondary data**. In the case of secondary data, a distinction is made between modelled data and default data. In principle, ISO 14083 prescribes the use of primary data specifically determined for the transport chain. Only if such primary data is not available, secondary data may also be used, provided that a justification is provided. In this context, modelled data is to be given preference over the use of default values.

The report must show which data types were used for what and why. Since many transport service providers do not have (complete) operational or financial control over the entire transport chain, the use of pure primary data is often limited in reality, and many calculations will be based on a mixture of different data types.

In principle, the mere indication of the extent to which primary or secondary data has been used does not make it possible to assess the quality of the data. Although further information on data quality

[1] International trade clauses

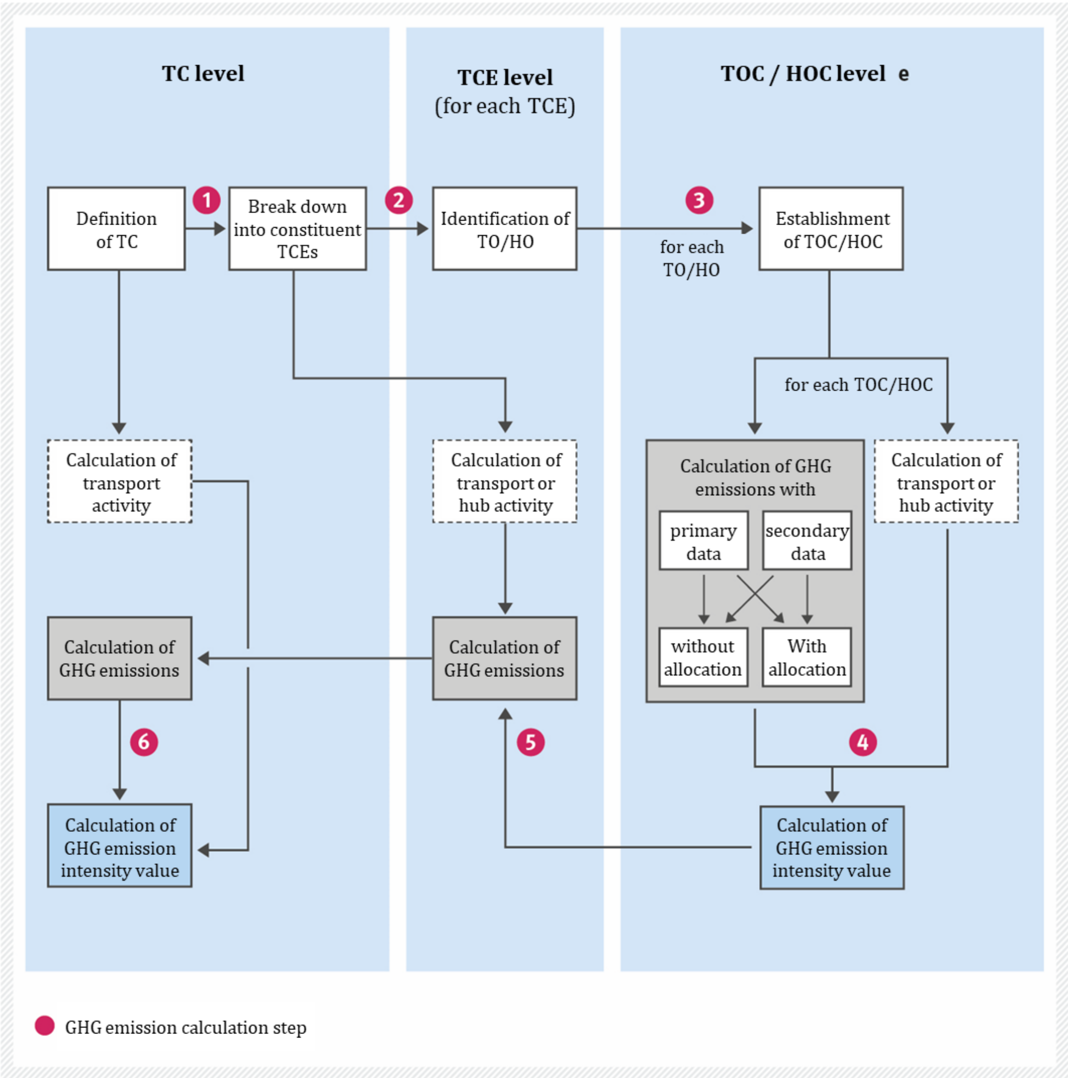
would be desirable, ISO 14083 does not stipulate any requirements in this regard. One possible quality criterion could be the granularity of the TOC or HOC used: the more specifically, for example, the transports are grouped together according to purpose/route and vehicles used (e.g. the same vehicles/vehicle types, combination of a group of similar vehicle types in certain regions and routes), the more specific the assessment and thus probably higher the data quality. According to the authors, secondary data derived from specific modelling (which in turn uses high-quality primary data as input data) can be used to generate comparable quality of GHG emission calculation such as primary data (i.e. measurement data) – provided that all parameters relating to GHG activities are sufficiently taken into account.

2.3 Introduction to step-by-step GHG emissions calculation

Every greenhouse gas calculation according to ISO 14083 must be carried out in six steps, whereby the specific procedures in the individual steps differ depending on the case under consideration. The basic procedure is as follows:

Figure 3

Steps to calculate GHG emissions for a transport chain



Source: own illustration, ifeu/Fraunhofer IML, based on ISO 14083

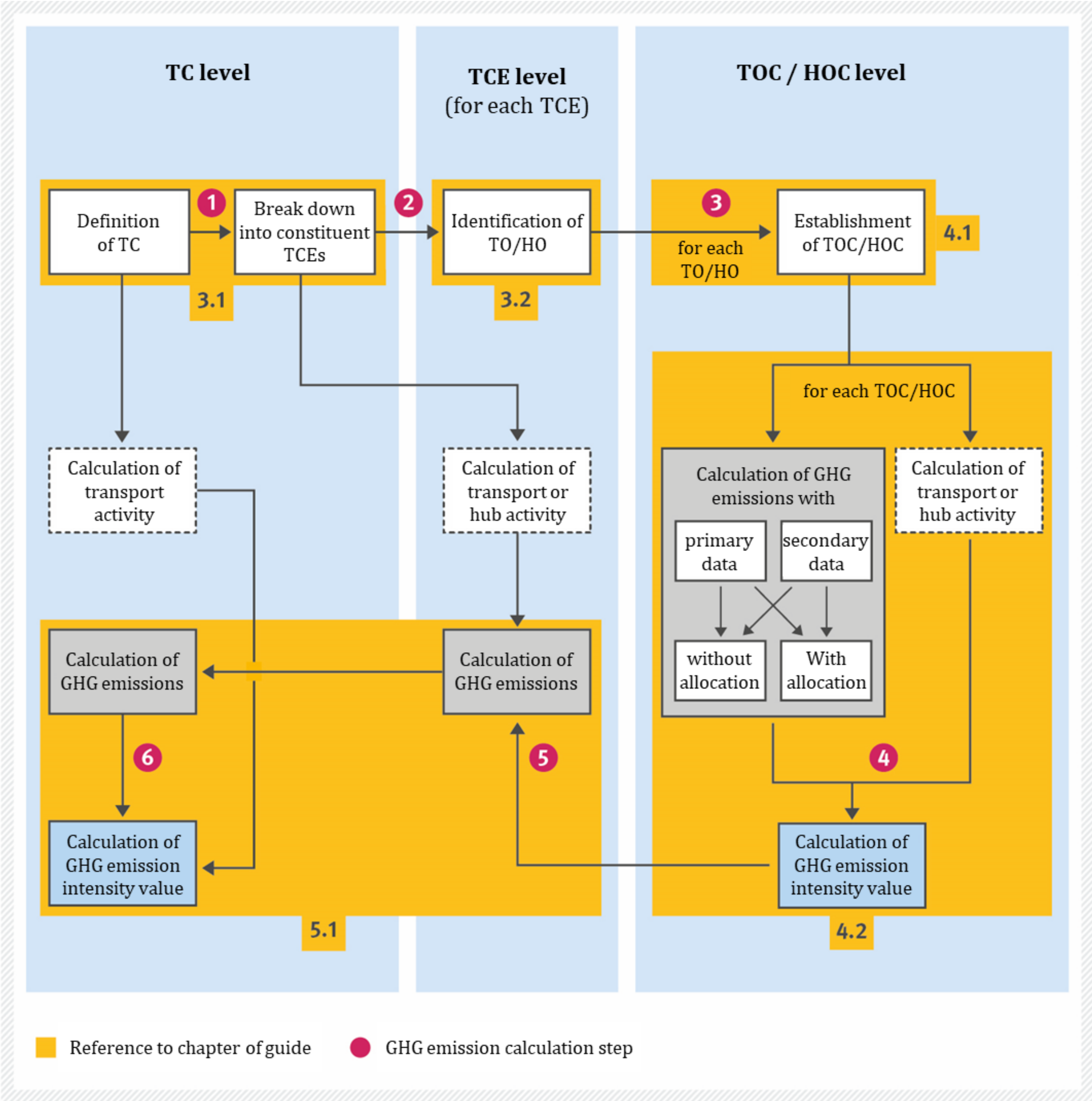
- Step 1: Definition of the transport chain and breakdown into individual transport chain elements
- Step 2: Identification of the related transport/hub operations
- Step 3: Grouping of transport/hub operations into transport/hub operation categories
- Step 4: Calculation of GHG emission intensities at TOC/HOC level based on transport/hub activity and GHG emissions of TOCs/HOCs
- Step 5: Calculation of the GHG emissions of the TCEs based on the transport/hub activity of the TCEs and the GHG emission intensity of the related TOCs/HOCs
- Step 6: Calculation of the GHG emission intensity of a transport chain from the sum of the GHG emissions of the individual TCEs and the transport activity at the transport chain level

Figure 3 visualises this flow diagram.

In the following chapters, the individual calculation steps are discussed in more detail: steps 1 and 2 are described in more detail in Chapter 3, steps 3 and 4 in Chapter 4 and steps 5 and 6 in Chapter 5, clearly explained using two case examples.

Figure 4

Which steps are described in which chapter?



Source: own illustration, ifeu/Fraunhofer IML, based on ISO 14083

3 Transport chain elements and activity data

3.1 Breakdown of the transport chain into transport chain elements

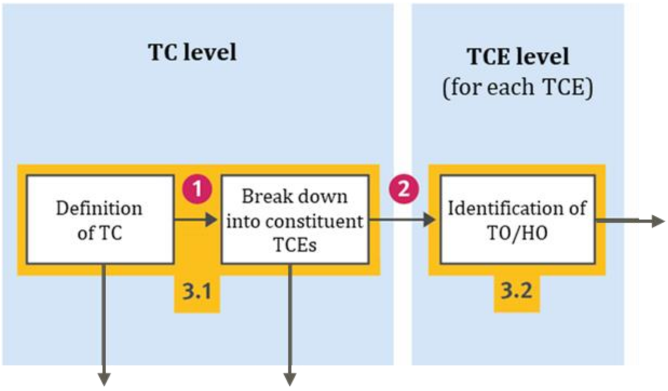
At the beginning of the GHG emissions calculation, the relevant transport chain is defined, whereby the requirements for system boundaries listed in Section 2.1 must be considered. A transport chain describes the transport of freight or people from a point of origin to a destination. It can be divided into a sequence of individual transport chain elements (TCEs), each of which describes a section of the transport chain (e.g. a freight transport with a certain type of vehicle on a section of the entire transport chain). ISO 14083 leaves open whether the transport chain begins and/or ends with a hub TCE (e.g. a finished goods warehouse). This is at the discretion of the reporting organisation.

3.2 Calculation of the transport and hub activity of the transport chain elements

Each transport chain element has a corresponding transport or hub activity. This describes and quantifies the associated transport or hub operation for a certain number of passengers or quantity of freight.

3.2.1 Transport activity and transport activity distance

First, the associated **transport activity** is determined for the individual transport chain elements.



This refers to a certain number of passengers or quantity of freight transported over a certain distance.

In the case of passenger transport, the transport activity is expressed in passenger-kilometres (pkm) and is calculated as follows:

Number of passengers x transport activity distance

In the case of freight transport, the transport activity is determined by the quantity of freight transported (i.e., actual freight mass including the original packaging, but without additional transport packaging used by the forwarder, such as pallets[2] or container) and the distance. It is usually expressed in tonne-kilometres (tkm) and is calculated as follows:

Freight mass x transport activity distance

[2] If different cargo items on a pallet are consolidated and packed by the shipper (e.g. by shrink wrap), then this is considered as one consignment and thus the pallet as a component of the load.

In certain cases, the freight mass can also be the mass of empty containers or pallets, if the purpose of the transport is to transport them. In addition, other units such as TEU or number of items (for mail and parcel operations) can also be used in justified cases.

To determine the transport activity, the corresponding **transport activity distance** is required in each case, i.e. the distance travelled by the freight or passenger.

According to ISO 14083, two types of distance are generally permitted: the **great circle distance** (GCD) and the **shortest feasible distance** (SFD).

The great circle distance (GCD) is the shortest distance between two points on the earth's surface along the globe. The shortest feasible distance (SFD) is the shortest suitable route, taking into account the infrastructure options for a given vehicle type. Smaller detours, for example to avoid traffic jams in city centres or to avoid certain road types for particularly large vehicles, can already be included.

In order to enable comparability of the values between different providers of transport services, the use of a uniform distance is important. In principle, all transports must be calculated either with the GCD or with the SFD. Air transports should always use GCD. For road, rail, cable cars, pipelines and water, either the SFD or the GCD should be used, whereby the type of distance used must be clearly stated and mixtures are not permitted. In practice, the use of SFD is probably more relevant for all transports except air transport, as it is much closer to the real distance.

In order to obtain correct and realistic calculation results, the distance on which the GHG emission intensity is based and the distance underlying the calculation of the transport activity must always be the same.

If only the actual distance is available, a distance adjustment factor (DAF) is required to determine the transport activity distance. This describes the relationship between actual distance and transport distance. With a distance adjustment factor of 1.05, this means that the actual distance is 5 percent longer than the shortest feasible distance[3].

The annexes to ISO 14083 list the type of distance and possible distance adjustment factors for each means of transport. In the case of rail transport, inland waterway vessels, pipeline transports and cable cars, it can be assumed that the actual distance corresponds to the shortest feasible distance, as the specified transport route network (e.g. rail infrastructure or waterway network). Common adjustment factors for air, road or sea transport are shown in Table 3.

Even in the case of collection and delivery rounds, either the GCD or the SFD must be used as the distance between the respective loading and unloading points. In this case, the distance is not based on a real route, but merely represents a fictitious distance between the loading and unloading points, by means of which the total emissions of the tour are apportioned to the individual consignments, using the tonne-kilometres calculated with the fictitious distance.

Example 5 in Section 4.2.2 illustrates the GHG emission calculation of a collection and delivery rounds. The use of a distance adjustment factor in road transport is shown in Case example A.

3.2.2 Hub Activity

To calculate the GHG emission intensity of hubs, the hub activity is required. This is the quantity of freight or the number of passengers leaving a hub. For freight handling, the standard unit is "tonne," although in justified cases, such as with transport activity, alternative units like TEU or the number of shipments (for postal and parcel operations) may be used.

[3] This is important for a comparable GHG emission calculation in two respects: When calculating GHG emissions based on real distances, the distance travelled should not be underestimated (because GHG emissions must also include detours, etc.). When determining the GHG emission intensity, in turn, the transport activity distance should not be overestimated in order to allow a fair comparison.

Table 3

Distances and distance adjustment factors

Modes	Examples	Distance adjustment factor	Actual distance
Air transport	GCD		GCD + 95 km
Road transport	SFD	1.05	SFD + 5 %
Maritime transport	SFD	1.15	SFD + 15 %

Source: ISO 14083

3.3 Case examples Part 1

The guide will illustrate the step-by-step calculation process using two (greatly simplified) fictitious case examples. In the following, both case examples are briefly presented, and the first two calculation steps are followed.

The calculations in the case examples represent fictitious cases, the quantification of which is based on the most realistic boundary conditions possible. Nevertheless, the GHG emissions and GHG emission intensities calculated in this way are only to be seen as examples and serve to illustrate the calculation processes. Moreover, the procedure does not claim to be complete. In order to address typical peculiarities and questions in the GHG emission calculation of transport chains in parallel to the examples, the case examples are supplemented by individual examples, which in turn do not always reflect the level of detail required by ISO (e.g. differentiation of GHG emissions due to operation and energy provision).

Example A: Transport services in freight transport

A company wants to quantify and report GHG emissions for a specific freight transport service.

The transport service is the transport of containerised average goods at ambient temperature, which is to be transported from point A to point B in Germany. The means of transport used in the pre-carriage and onward carriage are a modern articulated truck with diesel drive in combined transport[4](CT). The main leg is realised by rail with an electrically powered freight block train with containers (TEU).

The company has neither financial nor operational control over the transports carried out and therefore has no primary data for the GHG-emitting activities. However, it knows the route and the freight mass (including the packaging originally supplied), which is 10 tonnes, and asks the companies carrying out the transport operations for further data. Since the transport service involves the use of different modes of transport, the hub operations at an intermodal terminal, i.e. the transfer of the container to the train and vice versa, must also be taken into account.

[4] In combined transport, goods are transported using different means of transport without changing the load carrier (in this case a container). Although articulated trucks are normally allowed to weigh a maximum of 40 tonnes, total weights of up to 44 tonnes are permitted in combined transport.

Step 1: Breakdown of the transport chain into individual transport chain elements (TCEs)

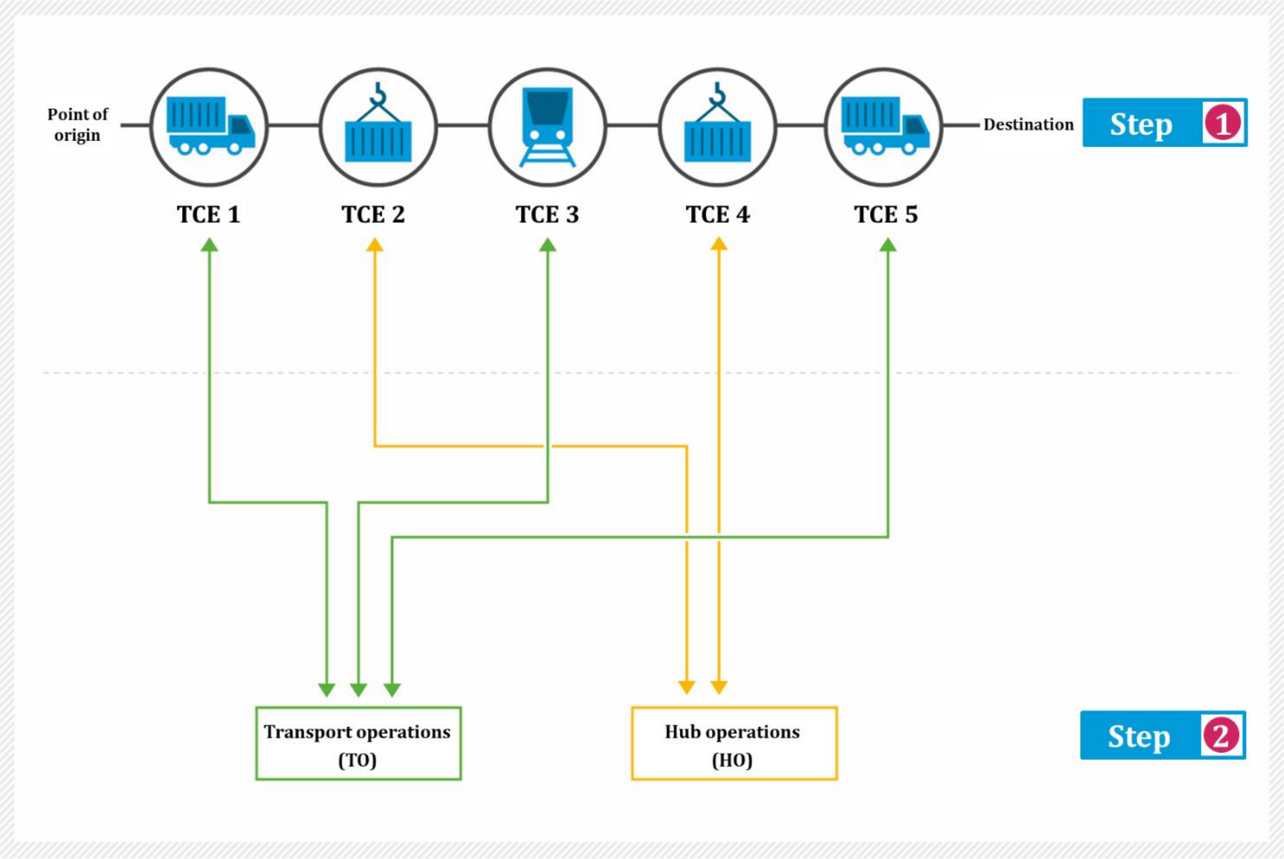
In the first step, the transport chain is broken down into the individual transport chain elements after it has been defined. These are:

- TCE 1: Road transport
- TCE 2: Transhipment at CT Terminal A
- TCE 3: Transport by train
- TCE 4: Transhipment at CT Terminal B
- TCE 5: Road transport

Figure 5 visualises the transport chain and its transport chain elements.

Figure 5

Illustration of steps 1 and 2: Transport chain elements



Source: own illustration, ifeu/Fraunhofer IML

Step 2: Identifying the TO/HO for each TCE
In the second step, the relevant transport or hub operation is identified for each transport chain element and the associated transport or hub activity is calculated.

The two road transports in TCE 1 and TCE 5 are each carried out by a diesel articulated truck in combined transport. For these, the respective transport activity distances are required. For the pre-carriage (TCE 1), the company determines a shortest feasible distance (SFD), taking into account the transport network of 50 km, and for the on-carriage (TCE 5) an SFD of 100 km. Since the vehicle consumption was determined for actual distances travelled, a distance adjustment factor is used to calculate the GHG emissions of the articulated truck in step 3. The company uses the 5% surcharge on the SFD recommended in the ISO for this purpose.

Rail freight transport is carried out by an electrically powered freight train. An inquiry with the railway company reveals that the freight train covers a distance of 500 km between the loading and unloading of the container in question. Since the actual distance of a train usually does not deviate from the shortest feasible distance, no distance adjustment factor has to be used here. Only the freight mass of 10 t in the container counts as mass here, as the container dead weight of 2.25 t influences the energy consumption of the transport, but is not counted as freight mass.

This results in the following transport/hub activities:

- Transport activity for TCE 1: 50 km x 10 t = 500 tkm (SFD) or 525 tkm (actual distance)
- Hub activity for TCE 2: 10 t
- Transport activity for TCE 3: 500 km x 10 t = 5,000 tkm (SFD)
- Hub activity for TCE 4: 10 t
- Transport activity for TCE 5: 100 km x 10 t = 1,000 tkm (SFD) or 1,050 tkm (actual distance)

Example B: Passenger transport of an organisation

In the second case example, a calculation according to ISO 14083 is carried out for an organisation that wants to calculate GHG emissions of its provided passenger transport during a calendar year.

In this case, it is a bus company that operates in local transport and maintains its own vehicle fleet. This fleet consists of a total of 21 buses: including 2 articulated buses with electric drive, 14 articulated buses with diesel drive and 5 standard diesel buses. The diesel busses are of different age and therefore partly have different emission classes. The electric buses are charged exclusively at the bus depot of the organisation. The company has primary data on the annual driven distance of the busses as well as for fuel and electricity consumption. The bus occupancy is also based on primary data, however the company uses collected data from passenger counts for selected lines and times. Care was taken to ensure that the data included various weekdays and times so that the average occupancy rate of the buses is as reliable as possible. The company now wants to publish an annual report on the GHG emissions from passenger transports it has carried out.

Step 1: Breakdown of transport chain(s) into individual transport chain elements (TCEs)
In this case example, the sum of all transport chains carried out by the bus company, i.e. the use of all buses for passenger transport, is used. A separate transport chain element is defined for each individual bus of the company, which includes the transport service provided within one year.

For clarity, similar TCEs are summarised here:

- TCEs 1 to 12: Bus no. 1 to no. 12 (articulated buses, diesel, purchased between 2015 and 2018)
- TCEs 13 and 14: Bus no. 13 and no. 14 (articulated buses, diesel, purchased in 2022)
- TCEs 15 and 16: Bus no. 15 and no. 16 (articulated buses, electric)
- TCEs 17 to 20: Bus no. 17 to no. 20 (standard bus, diesel, purchased in 2017)
- TCEs 21: Bus no. 21 (standard bus, diesel, purchased in 2013)

Step 2: Identifying the TO/HO for each TCE
Now the corresponding TO and the transport activity (in passenger-kilometres) are determined for each TCE. The organisation can access primary data for the individual buses.

To determine the TO, the properties of the buses purchased in different years are determined. In particular, it shows that the diesel buses sometimes have different emission classes.

Here, too, similar TO are listed together:

- TO of TCEs 1 to 12: articulated buses, diesel, Euro 6a-c
- TO of TCEs 13 and 14: articulated buses, diesel, Euro 6d
- TO of TCEs 15 and 16: articulated buses, electric
- TO of TCEs 17 to 20: standard bus, diesel, Euro 6a-c
- TCE 21: standard bus, diesel, Euro 5

Since the primary data for the distances travelled are not based on the actual mileage of the buses, but on the planned routes, the distance corresponds to the shortest feasible distance in each case. In doing so, the organisation makes sure that it does not use the planned timetables, but the actual schedules. Thus, detours or other journeys that are not related to the transport service provided are included in fuel consumption, but they do not count as transport activity. In order to calculate transport activity, the capacities of the buses (seats) and the average occupancy rate of 18 per cent are also required. For the sake of simplification, a list of all individual transport activities is omitted here and only the calculation is briefly outlined as an example for a single TCE.

- Transport activity of TCE 1: 55,0000 km/a x 90 seats x 0.18 = 819,000 pkm/a

Similarly, the transport activities of the other TCEs can also be calculated.

4 Getting started with calculation and data collection

4.1 Establishment of transport and hub operation categories

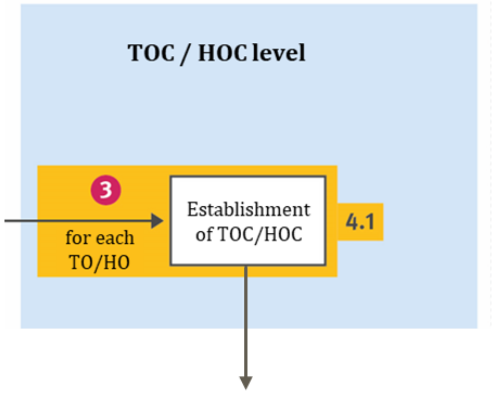
In order to simplify calculations and data collection, it makes sense to group comparable transport or hub operations into so-called **transport/hub operation categories** (TOCs/HOCs). Operations with similar characteristics (e.g. in terms of vehicle type, number of vehicles, route, freight type) over a fixed period of time (up to one year).

Each transport chain element with its associated transport or hub activity is then assigned to a transport or hub operation category to facilitate data collection and quantification.

The identification of the transport/hub activity of a TOC or HOC is analogous to that of a single transport chain element.

4.1.1 Transport operation category

Each individual transport operation (and thus also the individual transport chain elements) must always be considered in the context of the entire system. Transport operation categories (TOCs) are therefore used to group transport operations with similar properties over a certain period of time (of up to a calendar year).



TOCs are influenced by the following factors:

- Number and type of vehicles as well as special vehicle features
- Type of cargo and necessary conditions during transport (e.g. refrigeration)
- Period

The individual TOCs can have different granularity. Thus a TOC can be applied to

- a specific vehicle on a specific route,
- a specific vehicle on different routes,
- a specific type of vehicle on a specific route,
- a certain type of vehicle on different routes,
- a group of vehicles on a specific route,
- a group of vehicles on different routes.

It is quite possible that vehicles with different drivetrains or fuels are grouped in the same TOC.

However, a single transport operation may not be divided into several TOCs, even if two different transport chain elements are involved. (e.g. freight and passenger transport).

Transport operation categories are divided into different basic types, each of which differs in its method of calculation. In general, it is divided into

- passenger-only TOCs (general or subdivided into different passenger classes),
- freight-only TOCs (general or subdivided according to different temperature levels),
- mixed freight and passenger TOCs, and
- other TOCs.

Depending on the type of TOC, an allocation (see Section 4.2.2) may be necessary.

It is important that a TOC should always cover the entire round trips (i.e. journeys with different loading levels, including empty runs as well as outward and return journeys) in order to balance out GHG emissions within asymmetric transport operations.

To facilitate the establishment of meaningful TOCs, ISO 14083 provides an overview of the possible characteristics in each of the mode-specific annexes on the basis of which the establishment can be made. In addition to these more general requirements, additional specific factors can also be included, such as the topography, the type of route, the vehicle size, other information about the vehicle or the emission classes. Further information on the different modes of transport and their TOC characteristics can be found in Annex A.2.

4.1.2 Hub operation category

On the one hand, hubs can include **entire locations**, such as distribution centres, combined transport terminals or a metro station. On the other hand, they can be self-contained facilities **within a larger infrastructure of passenger or freight transport**, as is the case with airports, seaports, ferry ports or larger railway stations, for example. Here, several hubs (e.g. terminals for liquid goods and containerised cargo) are often located in one location, operated by different companies, and the relevant hub (or hubs) should be distinguished as a separate entity from other services and facilities[5].For example, individual terminals at a seaport can each be separate hubs (e.g. container port, roll-on-roll-off terminal, liquid bulk terminal), just as an airport can include hubs for passenger transport (various passenger terminals, regional or long-distance railway stations) as well as different freight terminals of individual logistics service providers for cargo transhipment.

Basically, a HOC must fully encompass every hub operation. So, if a GHG-emitting activity serves several processes (e.g. industrial trucks move different freight groups), these processes and their consumption must be grouped in a HOC. If the activities as a whole serve different processes, they can be defined as separate HOCs of a hub.

If a hub includes several different hub operations (e.g. cold warehouse lighting, dry warehouse lighting, cooling, industrial trucks), of which

- one part (e.g. cold warehouse lighting, dry warehouse lighting, cooling) completely serves two different processes, e.g.
- storage of refrigerated goods (cold warehouse lighting, cooling) or
- storage of ambient goods (dry warehouse lighting),
- one part (e.g. industrial trucks) serves, however, both (storage of refrigerated and ambient goods),

this hub is to be regarded as one HOC. Also, a hub can serve freight groups of different seasons.

[5] This partly deviates from the usual language and use of the term "hub". Accordingly, sea and inland ports, for example, are often referred to as hubs.

In this example, the hub with its respective hub operations could be broken down into two HOCs according to these seasonal periods.

With regard to the large infrastructures, it may make sense to orient oneself to the company boundaries. If a port comprises two terminals for different cargo groups, both operated by the same company, they can be considered as follows:

- two hubs with one HOC each,
- one hub with two HOCs, if all hub operations can be completely assigned to only one HOC,
- one hub with one HOC for which two emission intensity values are calculated by means of allocation (see Section 4.2.2).

If the terminals in the port are operated by two different companies, it is common to consider them as two separate hubs, each with one HOC, due to the limited availability of data or the sensitivity of the data to external parties.

In order to be able to establish relevant HOCs, Annex H of ISO 14083 lists examples of relevant HOC characteristics.

For example, hubs can be grouped into one HOC due to different **processes** (1) such as sole or combined freight transhipment or passenger transfer, or (2) combined freight transhipment and storage. In addition, the characteristics can be further specified with regard to the inbound and outbound modes of transport (e.g. road/rail, road/water), size of the hubs (e.g. main and regional stations), age or level of technology of the site (e.g. non-/electrified processes, automated/manual processes). In addition to the processes, the ISO also lists the **freight type** as a HOC characteristic. The freight type is usually accompanied by different equipment and processes, making it a quick and universal differentiation criterion. And finally, it makes sense to distinguish between different temperature requirements (listed in ISO as "**condition**") of the goods. The processes can be carried out at ambient temperature (e.g. above +8 °C) or with temperature control, the latter including both heated (e.g. for liquid goods) and refrigerated (e.g. sensitive (0 °C to +2 °C), pharmaceutical products (+2 °C to +8 °C), frozen (below 0 °C or in the case of foodstuffs below -18 °C)).

Based on this, hub operation categories can be structured with a sensible combination of characteristics influencing GHG emissions.

4.2 Calculating the GHG emission intensities

In principle, the calculation of the GHG emission intensities of a TOC or HOC requires the GHG emissions and the associated transport or hub activity.

The calculation of GHG emissions is usually based on information on the GHG activities, i.e. data on the use of fuels and electricity, leaks and refrigerant losses are required.

Table 4

HOC characteristics

Processes	Freight type	Condition
freight transhipment only	average/mixed	ambient
passenger transfer only	containerised/swap bodies	temperature-controlled
combined passenger and freight transfer	palletised	
freight transhipment and storage	piece goods/break bulk	
	dry bulk	
	liquid bulk	
	vehicle transport	
	other	

Source: ISO 14083 Table H.1

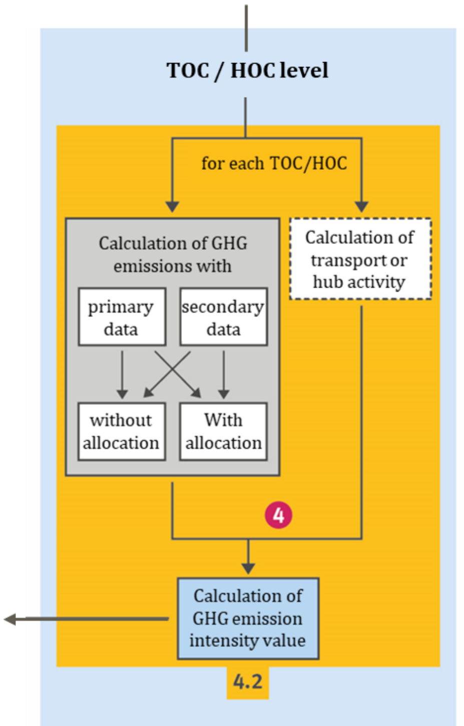
The GHG emissions are then calculated as follows:

$$GHG\ emission\ = GHG\ activity \times GHG\ emission\ factor$$

This is established item by item for each GHG activity of the TOC or HOC. By summing up the calculated GHG emissions afterwards, the total GHG emissions of the TOCs or HOCs can be derived.

A GHG emission intensity is then derived from the GHG emissions:

$$GHG\ emission\ intensity = \frac{GHG\ emissions}{transport\ or\ hub\ activity}$$



In steps 3 and 4, the GHG emissions and GHG emission intensities are initially calculated only for the TOC and HOC levels, respectively.

4.2.1 GHG emission factors

In order to convert energy consumption (or fuel/electricity consumption) and refrigerant leakage into GHG emissions, reliable GHG emission factors of the various energy carriers and the refrigerants used are required. For energy carriers, these comprise of GHG emissions from operation and GHG emissions from energy provision. In the case of refrigerants, GHG emission factors refer only to GHG emissions from operation (i.e. leakage), i.e. excluding emissions from provision.

A central requirement in ISO 14083 is to list the GHG emission factors used by the various energy carriers and to specify their source. In addition, the fuel type, lower heating value, density (for all liquid fuels) and (if used) biofuel blend (in % energy content) must be specified in each case. It is important that GHG emissions from operation do not only relate to (fossil) carbon dioxide emissions, but must also include GHG emissions of other gases with climate impact (nitrous oxide, methane) that can be produced during operation.

In the case of biofuels, the approach in ISO 14083 is based on the EU Directive for Renewable Energy (European Parliament 2018). Accordingly, the cultivation and extraction of raw materials, GHG emissions from direct land use change, processing, transport and distribution are included in the GHG emissions of energy provision. The atmospheric CO_2 bound during the cultivation of biomass is not accounted for, so the CO_2 emissions generated during combustion are not taken into account, as both offset each other. However, other GHG emissions (e.g. from nitrous oxide or methane) also occur in the combustion of biofuels and must be taken into account.

ISO 14083 also contains specifications on the methodology for deriving GHG emission factors for fuels and electricity, which must cover the entire life cycle of energy supply. In case of electricity, ISO 14083 prescribes the use of location-based grid mixes. The GHG emission factors for electricity should refer to location-based consumption mixes; in contrast to the production mixes, they therefore also include net electricity imports from neighbouring countries. For regions or countries with low net electricity imports, the production mix and consumption mix are very similar in terms of production mix and consumption mix.

In the case of high electricity imports, the GHG emission factors of the consumption mixes can be either lower (if electricity is imported from countries with lower GHG emissions) or higher (if electricity is imported from countries with high GHG emissions) than those of the production mixes. In addition (not alternatively), GHG results that have been calculated using a market-based approach[6] may also be reported. Possible sources and values for ISO 14083-compliant GHG emission factors of various fuels, energy carriers and refrigerants are contained in Annex A.5.

Excursus: What should be considered for self-generated electricity at hubs?

The GHG emissions of a hub are calculated on the basis of the energy carriers or refrigerants used in the hub, regardless of what they are used for. At some hubs, electricity may partly be generated from energy carriers such as diesel. While the respective location-based grid mix must be used for the electricity purchased by the hub, diesel consumption is used as the basis for calculation in cases a diesel-powered emergency power generator is in use, for example (this happens in some countries due to the unstable grid power supply). Even though ISO 14083 does not specify any requirements in this regard, the authors believe that this concept can also be transferred to renewable electricity generated within a hub, provided that the construction, operation and disposal of a corresponding plant infrastructure are taken into account. However, it is important that the electricity generated in this way is used exclusively internally (i.e. for the hub processes) and not made available to others (i.e. fed into the public power grid or sold elsewhere). Otherwise, the same applies to hubs: the location-based mix must always be used – but a parallel calculation with a market-based mix is allowed and can be reported additionally.

Example 1: Calculating GHG emissions and GHG emission intensities at a passenger station

The HOC under consideration is a single station, at which annually 114,489,327 passengers start or finish their journey or have to change trains. The operator of the station measured the following consumption during this period: electricity (2,121,094 kWh), natural gas consumption (121,495 kWh) and district heating (703,125 kWh).

The emission factors relevant to this calculation are listed in Annex A.3. The factor 3.6 MJ/kWh is used to convert the megajoule figures into kilowatt hours.

GHG emissions of the HOC for operations

- 121,495 kWh x 198.26 g CO_2e/kWh = 24,088 kg

CO_2e GHG emissions of the HOC for energy provision

- 2,121,094 kWh x 493.96 g CO_2e/kWh + 121,495 kWh x 64.77 g CO_2e/kWh + 703,125 kWh x 382.02 g CO_2e/kWh = 1,324,218 kg CO_2e

GHG emission intensity of the HOC

- Operation: 24,088 kg CO_2e / 114,489,327 pax = 0.21 g CO_2e/pax
- Energy provision: 1,324,218 kg CO_2e / 114,489,327 pax = 11.57 g CO_2e/pax
- Total: 0.21 g CO_2e/pax + 11.57 g CO_2e/pax = 11.78 g CO_2e/pax

4.2.2 Partitioning emissions by allocation

Whenever a (transport or hub) process fulfils more than one function and these different functions are inextricably linked, the GHG activities or GHG emissions must be partitioned between the different freight or passenger groups.

[6] In the market-based method, the reporting organisation uses the GHG emissions of the electricity they purchase based on the values submitted by the electricity producer/seller. Various contractual instruments such as electricity purchase contracts, guarantees of origin, certificates for renewable electricity and energy certificates can be used. Further specifications for the calculation of market-based mixes can be found in ISO 14083 Annex J.3.

Table 5

Passenger-equivalent values of Ro-Pax ferries and trains

Passenger transport	Passenger equivalent	Freight transport	Passenger equivalent
Passenger (including luggage)	1.0	Light Commercial Vehicle N1-I/III	1.3
Passenger car	1.3	Light Commercial Vehicle N1-III	3.5
Bus	10.0	Solo truck, rigid truck	10
Caravan, small	1.1	Articulated truck	18
Caravan, medium	2.3	Unaccompanied trailer	14
Mobile home/ caravan, large	3.5		
Motorcycle	0.3		

Note: The information on the vehicles does not yet include the passengers (e.g. on the bus), these must be taken into account additionally.
Note: Deviations from the standard values given here are possible, but must be justified.

Source: based on ISO 14083 Table G.5

This process is called "allocation". It must always be carried out if the primary data of the respective process cannot be recorded separately for the freight or passenger groups, for example when the same means of transport transports passengers and freight at the same time, as in air transport or ferries. ISO 14083 stipulates that the allocation between freight and passengers must be based on the real mass. This also includes the baggage carried by the passengers and the outer packaging (but without additional cargo packaging such as pallets or the like, see Section 3.2.1). Since the exact masses are often not known, it is also possible to work with standard values. For example, when freight and passengers are transported together in air traffic, 100 kg per passenger including baggage can be applied in order to standardise different measured variables. An alternative to mass allocation can be the use of passenger equivalents, with the mode-specific annexes to ISO suggesting standard values for the passenger equivalents of the cargo that can be used. In the case of ferry transports, where passenger cars are also transported, this is even the recommended procedure.

The following standard passenger equivalent values shown in Table 5 can be used for Ro-Pax ferries[7] and trains.

Example 2: Allocation between cargo and passengers

In this example, we are looking at a car train that transports vehicles as well as people. Since the energy consumption of the train is used to transport passengers and cars alike, the GHG activities and the GHG emissions of the train must be partitioned between the two functions.

The car train under consideration here consists of 5 wagons each for passenger transport (on average there are 60 seats in each wagon) and 5 wagons with car parking spaces (double-decker wagons with space for a total of 10 cars). On average, 6 vehicles are loaded on each car wagon, whereas it is generally assumed that the train transports only cars. The passenger wagons have an average occupancy rate of 50%. On average, the car train transports 30 cars and 150 passengers. Now the passenger cars can be converted into passengers by using the passenger equivalents (see Table 5) of 1.3. Since each passenger transported corresponds to one passenger equivalent, the entire car train carries 189 passenger equivalents; of these 150 passenger equivalents are attributable

[7] Ro-Pax ferries transport both freight and passengers at the same time.

to passenger transport and 39 passenger equivalents to passenger car transport. The ratio of the passenger equivalents of the passenger transport to the total passenger equivalents then results in the allocation key. In this case, 21% of the train's total GHG emissions would be attributed to passenger cars and 79% to passengers.

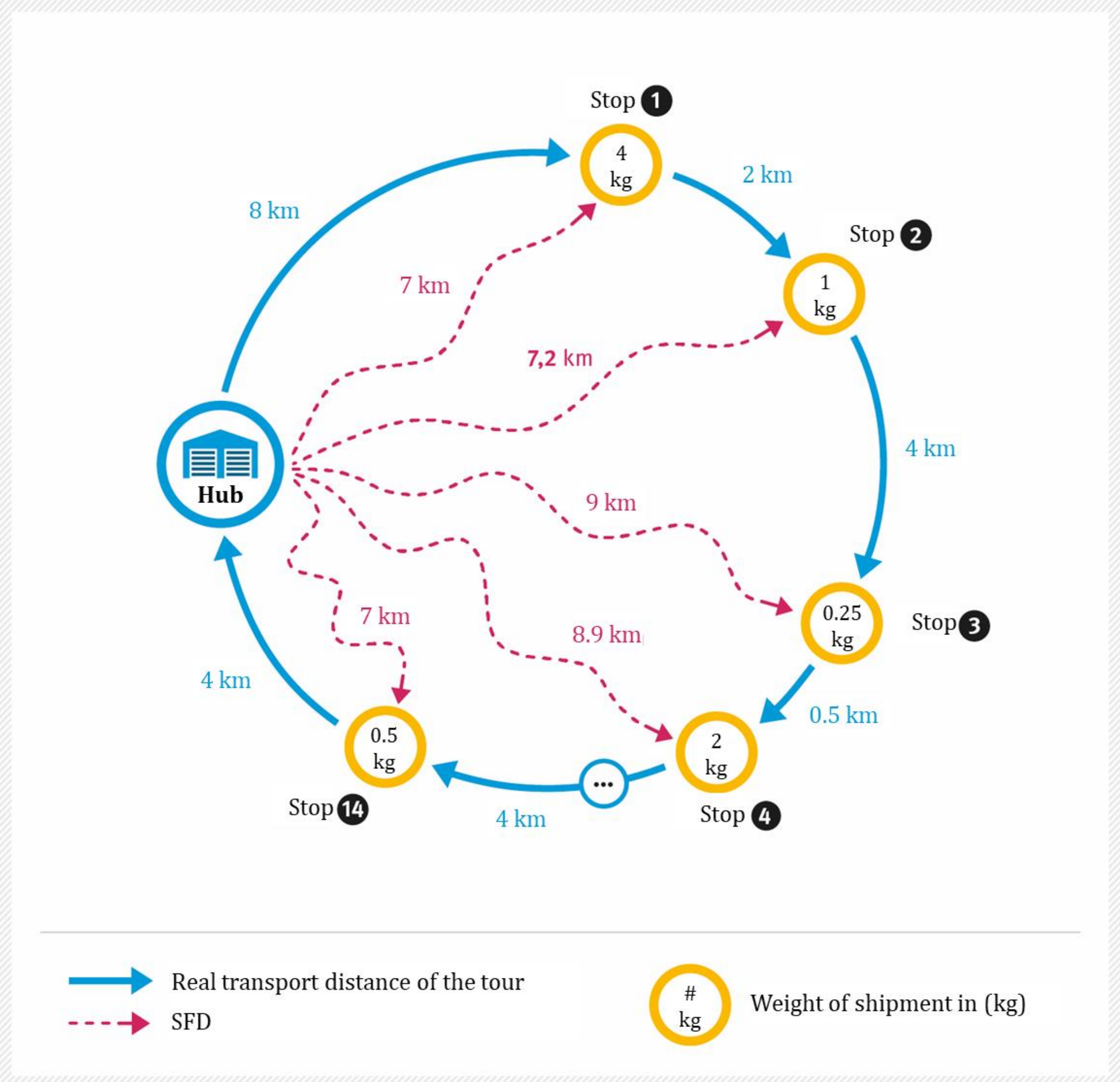
Example 3: Calculation of a collection/delivery round

Collection and delivery rounds are trips where goods are collected or delivered at various locations along a vehicle's route. Since it is not reasonable to partition the GHG emissions of a collection and delivery round to the freight based on the actual distances travelled (as freight delivered early in the tour would fare much better than freight remaining in the vehicle for a long time), an allocation is usually applied here as well. In this example, the SFD between the respective pick-up and delivery locations of a shipment is used for calculation. Alternatively, the use of the GCD would also be possible.

If the respective freight masses as well as the pick-up and delivery locations are known, the allocation can be made on the basis of the transport activity data of the individual shipments (or the sum of the total transport activities of the tour).

Figure 6

Collection and delivery round



Source: own illustration, ifeu/Fraunhofer IML

Table 6

Allocation of a collection and delivery round

	Actual distance travelled (cumulative) (km)	Distance hub - destination (SFD) (km)	Weight of shipment (kg)	Tonne kilometres (SFD) (tkm) (1)	Allocation key (2)
1	8	7	4	0.0280	7.7 %
2	10	7.2	1	0.0072	2.0 %
3	14	9	0.25	0.0023	0.5 %
4	14.5	8.9	2	0.0178	4.9 %
…	…	…	…	…	…
14	40	7	0.5	0.0035	1.0 %
Hub	44	–	–	–	
Tour	44	–	45.3	0.3632	100.0 %

Note: (1) Tonne-kilometres = SFD x shipment weight;
(2) Allocation key = tonne-kilometres of the stop / tonne-kilometres of the tour

Source: own calculation, ifeu/Fraunhofer IML

An example calculation of the allocation key per shipment is shown in Table 6.

It is important to note that if measured primary data for the fuel consumption of the entire collection and delivery round are available, the distance actually driven by the vehicle is not required for the calculation of GHG emissions. Only if the fuel consumption of the tour is calculated using GHG emission intensities, that has been determined on the basis of actual distances, the actual distances must also be known.

If the freight masses are not known, an allocation can also be made on the basis of the number of shipments; however, this (trivial) calculation method is not outlined here.

Example 4: Allocation of GHG emissions in temperature-controlled maritime transport

A container ship sails from Hamburg to Singapore (approx. 16,000 km) and has loaded 6,000 TEU. Of these, 950 TEU are reefer containers. This sea freight represents the transport operation category (TOC) (characteristics according to ISO Table G.1: "Container, mixed ambient and temperature-controlled, scheduled"). The GHG emission intensities for ambient and reefer containers for this TOC are to be determined. As GHG activities, the propulsion and cooling of the reefer containers are considered, both consuming maritime fuel oil (MFO).

At best, the consumption for cooling is measured separately. In this example, however, it is not known how much of the MFO consumption is caused by cooling. An allocation key is therefore required for the allocation of partial consumption to cooling. For this purpose, research results from the Universidad de los Andes on container terminals are used, according to which reefer containers cause 17% more GHG emissions than ambient containers (Dobers et al. 2023b).

If it is assumed that 950 TEU of the total containers transported (6,000 TEU) are cooled, this results in 6,162 TEU equivalents. This key can be used to divide the total MFO consumption of 88,090,000 MJ, for example: For this purpose, a consumption per TEU equivalent is first calculated (14,298 MJ/TEUeq), and then this value is multiplied by the respective TEU equivalents of the ambient and reefer containers. As a result, 72,199,059 MJ are allocated to the transport of ambient containers and 15,890,941 MJ to the transport of reefer containers. GHG emissions are then calculated, as explained elsewhere in the guide.

- 950 TEU x 1.17 + 5,050 TEU x 1 = 6,162 TEUeq
- 88,090,000 MJ / 6,162 TEUeq = 14,297 MJ/TEUeq
- 14,297 MJ/TEUeq x 5,050 TEUeq (ambient) = 72.199.059 MJ (ambient)
- 14,297 MJ/TEUeq x 1,112 TEUeq (reefer) = 15,890,941 MJ (reefer)

Example 5: Hub calculation with allocation

One company operates two transhipment hubs (A) and (B) in Germany and, at the request of its customers, requires the GHG emission intensities for the handling of goods. Both hubs handle both ambient and chilled goods, both hubs have comparable equipment and comparable process flows and are therefore combined into one hub operation category (HOC). In addition to the ambient goods, a specific group – the group of chilled goods – is defined for this HOC. The GHG emission intensities are calculated for both product groups. This is therefore an example of the case of a HOC of freight with multi-temperature conditions (see ISO 14083 section 9.5.3).

The table below lists all primary data on energy consumption and refrigerant leakage. Refrigerant leaks were measured by the annual refill quantity. In addition, there are separate metering points on the cooling systems (CS), so that 40,300 kWh (Hub A) or 44,020 kWh (Hub B) can be allocated to cooling. However, the amount of electricity required to light indoor areas in which only cooled goods are handled (e.g. cold warehouse) and those in which all goods are handled (e.g. goods receipt, dispatch) is unknown. In order to estimate the respective electricity consumption, it is first assumed that 32% of site consumption (130,000 kWh (Hub A) and 142,000 kWh (Hub B)) can be attributed to lighting (Dobers et al. 2023a), i.e. 41,600 kWh at Hub 1 and 45,440 kWh at Hub 2. The proportion of the cooled area can serve as an allocation key: the cooled area accounts for one fifth of the area of the respective hubs, resulting in an electricity consumption of 8,320 kWh (Hub A) or 9,088 kWh (Hub B) for the lighting of the cooled surfaces (L). (Note: This is a simplified example. in reality there are probably also illuminated areas with only ambient goods.)

The natural gas or district heating is used to heat the hubs and is therefore only allocated to the ambient goods. All other GHG activities (i.e. residual electricity consumption, diesel and LNG) are assigned to all goods.

In the first step of the calculation, the emissions of the respective specific group and the emissions affecting all goods/groups are calculated. To do this, the respective quantities of energy carriers or refrigerants are multiplied by the relevant GHG emission factor.

The conversion and GHG emission factors relevant to this calculation are listed in Annexes A.1, A.3 and A.4.

The GHG emissions of the HOCs of the respective groups are now calculated as follows:

Group "cooled"

- for operation: 9 kg x 2,255.5 kg CO_2e/kg = 20,300 kg CO_2e
- for energy provision: 101,728 kWh x 493.96 g CO_2e/kWh = 50,250 kg CO_2e

Group "ambient"

- for operation: 52,000 kWh x 198.26 g CO_2e/kWh = 10,310 kg CO_2e
- for energy provision: 52,000 kWh x 64.77 g CO_2e/kWh + 37,000 kWh x 382.02 g CO_2e/kWh = 17,503 kg CO_2e

Group “all”

- for operation: 11,110 l x 2,639 g CO_2e/l + 5,500 kg x 2,467 g CO_2e/kg = 42,888 kg CO_2e
- for energy provision: 170,272 kWh x 493.96 g CO_2e/kWh + 11,110 l x 801 g CO_2e/l + 5,500 kg x 1,050 g CO_2e/kg = 98,782 kg CO_2e

Table 7

Primary data on the freight transhipment in Hub 1 and Hub 2

GHG activity	Hub	Specific groups – chilled	Specific groups – ambient	All (chilled and ambient)	HOC
Electricity [kWh/a]	A B	CS: 40,300 L: 8,320 CS: 44,020 L: 9,088 101,728		81,380 88,892	272,000
Natural gas [kWh/a]	A		52,000		52,000
District heating [kWh/a]	B		37,000		37,000
Diesel [l/a]	A B			7,654 3,456	11,000
LNG [kg/a]	A B			3,200 2,300	5,000
Refrigerant R-410A [kg/a]	A B	5 4			9
Hub activity [tonnes/a]	A B	**4,000** **2,000**	**70,000** **67,000**		**143,000**

In the next step, the emission intensities for cooled and ambient goods are calculated in the HOC.

GHG emission intensity of the HOC of cooled goods

- for operation: 42,888 kg CO_2e / 143,000 t + 20,300 kg CO_2e / 6,000 t = 3.68 kg CO_2e/t
- for energy provision: 98,782 kg CO_2e / 143,000 t + 50,250 kg CO_2e / 6,000 t = 9.07 kg CO_2e/t

GHG emission intensity of the HOC of ambient goods

- for operation: 42,888 kg CO_2e / 143,000 t + 10,310 kg CO_2e / 137,000 t = 0.38 kg CO_2e/t
- for energy provision: 98,782 kg CO_2e / 143,000 t + 17,503 kg CO_2e / 137,000 t = 0.82 kg CO_2e/t

The calculated GHG emission intensities (cooled: 12.75 kg CO_2e/t or ambient 1.19 kg CO_2e/t) can be multiplied by the customer-specific quantity of cooled or ambient goods, so that the emissions for the customer's goods handling can be reported.

Allocation can be quite a complex task, depending on the number of hubs grouped together in a HOC and the number of different types of energy carriers and refrigerants, as well as specific groups according to which a distinction is to be made. It is therefore useful to check whether all emissions are actually reflected in the emission intensity values. For this purpose, all GHG emissions are summed up on the one hand and the emission intensities are multiplied by the respective HOC activities of the groups on the other. Both results should result in the same amount of total GHG emissions.

4.2.3 Data collection and level of detail

Data collection must be carried out both for determining transport and hub activities and for identifying GHG activities.

As described in Section 2.2, the use of primary data (measured data) is preferable to the use of secondary data (modelled data or default data).

The use of the various data types depends primarily on the availability of primary data (or the effort required to collect such primary data itself). However, under no circumstances should the decision on the chosen data type be made on the basis of a lower GHG emission result (see ISO 14083 Section 7.2.2).

Measured data / primary data

Measured data or primary data will be used primarily in the quantification of GHG activities (e.g. energy consumption data and refrigerant losses). However, other values can also be determined on the basis of primary data, such as the transport and hub activity (e.g. based on measured freight amounts/passenger counts and distances). In addition, GHG emission factors of the various energy carriers (including electricity) or of refrigerants and GHG emissions from operation can also be based on measured data (e.g. measured methane or nitrous oxide emissions from fuel combustion or slippage).

A central field of application for measured data is the (usually relatively easily obtained) energy consumption of transport and hub operations. The collection can be carried out, for example, by:

- Use of measurement interfaces (e.g. reading out a vehicle diagnostic system or electricity meters at hubs or selected equipment (e.g. cooling system)
- Evaluation of energy bills (e.g. energy carriers or heat quantities supplied to hubs or refuelling protocols or electricity quantities for vehicles)

It is important here that a distinction is made between the energy carriers used (different types of fuel / electricity) so that GHG emissions can then be calculated from these consumption data using suitable GHG emission factors. Refrigerant losses can be determined and documented on the basis of the measured refill quantities per refrigerant type.

The measured data does not necessarily have to be collected by the reporting organisation itself, it can also be fed by data provided from a subcontractor or supplier.

The quality of primary data is determined primarily by the application of the correct measurement methods and an (independent) verification of the data obtained.

Modelled data / secondary data

In the case of the use of secondary data, modelled data is particularly noteworthy, as it often allows for a high degree of detail. This means that modelled data can deliver much more specific results than the use of default values. Many of the models used are originally based on measured data that were determined for representative vehicles and operational situations and later generalised to cover other areas.

Modelled data can also cover the various data requirements. Among other things, the transport operations can be modelled on the basis of routing that is as realistic as possible, taking into account the transport network and other local and technical conditions (e.g. access restrictions for vehicles above a certain weight class), and this, with the help of information on freight/passengers, can be used to determine the relevant transport activity.

By modelling the energy consumption of the various energy carriers (supplemented by statistical data on biofuel shares, if required) and the use of GHG emission factors, GHG emissions can be determined for the individual transport and hub operations. GHG emissions from operations can also be modelled, taking into account the specific circumstances and by using suitable model data (e.g. emission data from the Handbook for Emission Factors (INFRAS 2023)).

It is important that the model used and its data bases are documented as well as possible in order to enable sufficient transparency and verifiability of the calculation results. It is advantageous if the model includes all relevant characteristics, such as specific vehicle characteristics (vehicle type, configuration, size, emission class, age), the fuel types used, the proportion of empty runs and load factor, as well as the local conditions (topography and traffic situation).

Default values / secondary data

Default values are always used when neither primary data nor modelled data is available. They are often used as a supplement to the other two data types to fill data gaps, and are also suitable for evaluating processes with low effort, if those are less relevant to the overall result of the GHG emission calculation.

Default values can also be of different data quality. Both rough estimates for processes for which no measured data is currently available as well as default values that have been determined on the basis of a (large) amount of different measured data can be used. The better the default values match the TOCs under consideration and their essential characteristics, the better they are suitable for the specific application.

Excursus: Differentiation between primary and secondary data

The input data used is essential for any GHG emission calculation. As explained above, the respective data must be representative of the transport chain element under consideration and fit as well as possible geographically, in terms of time and technology, in order to obtain a meaningful result. The following explanations are not taken directly from ISO but have been prepared for this guide for illustrative purposes. They do not claim to be complete and can only serve as a guide in distinguishing between primary data and secondary data.

Table 8 uses examples of consumption data (e.g. fuel consumption of a vehicle, electricity consumption in a hub) to illustrate the types of data that can exist and their origin and use. The following text explains how this consumption data could be classified.

Table 8

Origin of consumption data

Data cases for GHG activities	Origin	Examples	Use in GHG emission calculation
(1) Consumption (total)	Measurement	1,000 litres diesel	1:1
(2) Consumption (subset)	Measurement	800 litres diesel	Extrapolation, e.g. with transport/ hub activity, time
(3) Activity-based **consumption metric** differentiated according to TOC characteristics: Measurement of a. same processes, same period * b. same processes, different time period** c. other processes***, same period of time d. other processes***, other time period**	Calculated on the basis of measured values	x litre diesel /tkm x kWh electricity /t x litre diesel /t	Multiplication by transport or hub activity
(4) Activity-based **consumption metric** differentiated according to TOC characteristics: Measurement of usually other processes*** and other time period**	Calculated on the basis of measured values or by modelling	x litre diesel /km x litre diesel /tkm	Modelling, e.g. based on load factor and transport activity

Continued next page

Table 8 (continued)

Origin of consumption data

Data cases for GHG activities	Origin	Examples	Use in GHG emission calculation
(5) Activity-based **GHG emission indicator** differentiated according to TOC characteristics: Measurement of usually other processes*** and other time period**	Calculated on the basis of measured values or by modelling	x g CO_2e/km x g CO_2e/tkm	Modelling, e.g. based on occupancy and transport activity
(6) GHG emission intensity e.g. differentiated according to TOC characteristics	Modelling of application scenarios ****	x g CO_2e/tkm x g CO_2e/pkm	Multiplication by transport or hub activity

* i.e. direct measurement and comparable to (1) or (2)
** e.g. previous year, average value over several years
*** e.g. in your own company or in another company
**** e.g. inner-city transport with a bus-type A, with a truck-type B

Typical examples of **primary data** are thus case (1) the measured total consumption of a transport or hub operation or case (2) the measured and subsequently extrapolated partial consumption of a transport or hub operation in a selected observation period of one year (e.g. consumption is only available for 11 out of 12 months).

A company can also decide to measure its own fuel consumption and the associated transport performance, for example, and to map it using its own key figures by calculating activity-based consumption figures, e.g. in litres of diesel per tonne-kilometre (tkm). Depending on the measurement period or vehicle (transport operation) to which the key figures refer, they are direct measured data of the transport operation under consideration, i.e. case (1), (2) and (3a) (see Table 8), or they refer, for example, to another measurement period, possibly to other vehicles as in case (3c) or (3d). This is the case, for example, if a company uses indicators that have been calculated with measurement data from the previous year or from the entire fleet. For the GHG emission calculation, the company must decide whether the key figures are representative for the transport chain element under consideration.

Two typical examples of **modelled data** are cases (4) and (5) when activity-based consumption or GHG emission indicators taken from a general database are used in the GHG emission calculation. These key figures are given, for example, in litres of diesel per vehicle kilometre (possibly differentiated between empty and fully loaded vehicles) or already converted into grams of GHG emissions per vehicle kilometre. The data used in cases (4) and (5) are based on measurements. But they are measurements of other transport operations at different time periods than those of the transport chain(s) under consideration, or they come from measurements in test rigs for engines in which transport processes are reproduced. By means of a vehicle load factor and transport activity suitable for the application, the total consumption or GHG emissions of the TOCs can be modelled. This can be done in a very differentiated way depending on the level of detail of the indicator.

ISO 14083 does not clearly define where exactly consumption data is to be classified as secondary data or as primary data, such as the sub-cases in case (3). For example, "direct measurement" (see ISO 14083 Section 3.3.3) can mean very narrowly that the data has to refer to the same transport operations in the same period as the TCE under consideration (case (3a)) in order to be considered primary data; however, data from the same transport operations (e.g. the same vehicle, same tour) of another period (case (3b)) not.

This would even also be the case if the measured data were independent of the actual measurement period in a very constant process and thus constant consumption.

Default data are, for example, GHG emission intensity values, which are included in the GHG emission calculation by multiplying it by the relevant transport or hub activity, see in particular case (6). These indicators may have been worked out on the basis of measurements, but apart from matching TOC characteristics, they have no direct relation to the transport or hub operation under consideration.

4.2.4 Excursus: Refrigerant leakage in transport and transhipment

The task of temperature-controlled transports is to maintain a specified temperature during transport (see ISO 14083 Annex I.1).
For this purpose, air conditioning systems and temperature-control units are used in both passenger transport and freight transport. These temperature-control units are filled with refrigerants but may lose a proportion of the refrigerants during operation. Since most refrigerants are gases that have a strong impact on the climate, they must be included in the GHG emission assessment of transport chains.

The consumption of refrigerants can usually be measured on the basis of the amount refilled. Refilling is usually carried out during the annual inspection at hubs of the companies or external partners. When refrigerants are refilled in vehicles or loading units (e.g. reefer containers), the corresponding amount must be added to the GHG emission calculation of the transport TCE and not in the TCE of the hub where the refilling takes place.

The emission factors to be used for refrigerants should reflect GHG emissions from operation and must not include production and supply processes (see ISO 14083 Section 5.2.4). Corresponding GHG emission factors of refrigerants are compiled in the annex.

Refrigerant leakage in transport

If no primary data can be collected for the refill quantity of refrigerants, ISO 14083 provides an approach to quantity estimation in Annex I. For trucks for which the load factor is not known, it specifies a value range of 3 to 8 kg of refrigerant and recommends using the average value of 5.5 kg for mobile freight units with temperature-control.

The annual loss rate can range from 15% to 50%. At this point, however, the use of the highest value for the loss rate (i.e. 50%) is recommended to use in order to follow the principle of a conservative calculation. Freight forwarders report an annual refill rate of approx. 1 kg per temperature-control unit as part of inspection for mobile freight units with temperature-control (Wagner vom Berg et al. 2023), which is rather in the lower range of the ISO recommendation and equals a refill quantity of 32.5%.

In addition to the amount lost, the type of refrigerant used in each case is also essential for the GHG emission calculation due to the very different emission factors (see Annex A.4). According to the NOW-study on temperature-control units in road freight transport published in 2023 (Wagner vom Berg et al. 2023), the refrigerants R-404A, R-410A and R-452a are currently frequently used. In addition, the newer refrigerants R-449A and R-454C are mentioned. It is expected that R-404A will successively be replaced by R-452a, as it is less harmful to the climate and R-404A has also been banned since 2020 according to the F-Gas Regulation (Regulation (EU) No. 517/2014) is prohibited in new vehicles (Wagner vom Berg et al. 2023). If it is not known which refrigerant is used in the temperature-controlled transports, a conservative approach is recommended, i.e. R-404A should be used for older vehicles and R-452a for newer vehicles.

Example 8: Loss of refrigerants during transport

In Case example A, transports in a truck with a temperature-control unit are also conceivable as an alternative. For this the leakage of the refrigerant R-452a used is unknown and should be estimated by means of the annual refill quantity.

To this end the freight forwarder assumes the average refill rate (32.5%) of a medium-sized refrigeration unit (5.5 kg) according to ISO 14083 Annex I for the truck, which in this example represents the TOC.

- 5.5 kg R-452a x 32.5% = 1.7875 kg R-452a

If the freight forwarder documents the refill quantity during the regular inspection of his trucks, he can use this primary data in the calculation instead of an estimate. However, it should be noted here that the inspection and refill cycles may not correspond to the reporting period of the TOC to be evaluated. For example, the transport performance is to be calculated in tonne-kilometres for the calendar year 2023, but the inspection protocols cover the period from March to February of the following year. The assignment to the respective calendar year can be established by calculating a monthly average value of each fiscal year.

- 04/2022 – 03/2023:
  1.700 kg refill/12 months =
  0.1417 kg/month

- 04/2023 – 03/2024:
  1.805 kg refill/12 months =
  0.1504 kg/month

- 01/2023 – 12/2023:
  0.1417 kg/month x 3 months +
  0.1504 kg/month x 9 months = 1.7788 kg

While the data from the estimate in accordance with Annex I of the ISO are to be regarded as secondary data (default values), the data from the freight forwarder's measurements represent primary data. Although the freight forwarder could not use the data from his measurement 1:1, he was able to calculate the refill quantity based on direct measurements.

The GHG emissions associated with the loss of refrigerant are calculated by multiplying the refill quantity (regardless of whether these are secondary or primary data) with the GHG emission factor of the refrigerant (see Annex A.4), shown below on the basis of the primary data.

- 1.7788 kg R-452a/a x 2,292 kg CO_2e/kg R-452a =
  4,076 kg CO_2e/a

In order to be able to assign the absolute annual leakage to the transport chain element or the TOC, the GHG emissions must still be linked to the annual transport performance of the truck (or TOC). In this example, it is assumed that that the annual TOC activity of the 40 t tractor-trailer is 1,800,000 tkm.

- 4,076 kg CO_2e/a / 1,800,000 tkm/a =
  2.26 g CO_2e/tkm

This GHG emission intensity due to refrigerant leakage must be added to the GHG emission intensity caused by fuel consumption of the TOC.

Refrigerant leakage at hubs

According to a survey conducted in the period 2021 to 2023, 66% of the approximately 850 participating site operators confirmed that refrigerants are refilled annually at logistics hubs: The most common refrigerants used by operators were R-410A and 404A (19% each), R-717 (15%), R-407C (8%), R-134a (6%) and R-448a and R-744 (5% each). According to the study, especially R-717 (ammonia), R-744 (carbon dioxide), R-404A, R-410A and R-1234yf are used in hubs with more than 40,000 m^2 (Dobers and Jarmer 2023).

In the absence of primary data on refrigerant leakage at the hub, an approximation of an average refill of 0.5 g of R-404A per tonne of ambient cargo and 1.2 g of R-404A per tonne of temperature-controlled cargo can be assumed.[8]

[8] Note: Refill quantities reported are based on a small sample of logistics hubs that provide complete data sets on refrigerant type, refill quantity, and throughput at the site (source: GILA project). Further research is needed here to derive representative key figures. In order to take a conservative approach, the refrigerant with the highest emission factor from the above list was chosen, i.e. R-404A.

Example 9: Refrigerant leakage at the logistics hub

The refrigerant R-410A is used in a deep-freeze warehouse, and 15 kg of this refrigerant is refilled during the period under review. In addition, the site consumes 2,000,000 kWh of electricity in the same period. The GHG emissions of the hub for operation (i.e. from refrigerant losses) are thus calculated as follows:

- 15 kg x 2,255.5 kg CO_2e/kg = 33,833 kg CO_2e.

The calculated amount of GHG emissions due to refrigerant losses accounts for a share of 3.3% compared to that of electricity consumption (2,000,000 kWh x 493.96 g CO_2e/kWh = 987,926 kg CO_2e).

4.3 Case examples Part 2

In Section 3.3, the first two steps were carried out for the case examples and the transport chain, the transport chain elements and the associated transport and hub operations were determined. Now follow steps 3 and 4.

Case example A: Transport services in freight transport *(continued from page 25)*

For the further greenhouse gas calculation, the company wants to determine the GHG emission intensities.

Step 3: Assign the TO/HO to TOCs or HOCs

In step 3, the characteristics of the various transport chain elements are examined in more detail and similar transport or hub operations are grouped into transport or hub operation categories in order to facilitate data collection.

The company decides to combine TCE 1 and TCE 5 into one TOC A, as a modern diesel articulated truck is used in both cases. Enquiries with the transport companies carrying out the work show that vehicles with Euro 6 A-C emission standards are used in the pre-carriage and onward carriage. The load of the transported container is known to be 10 t. Since the standard container (TEU) has a capacity of about 20 t, this corresponds to an average load of 50%.

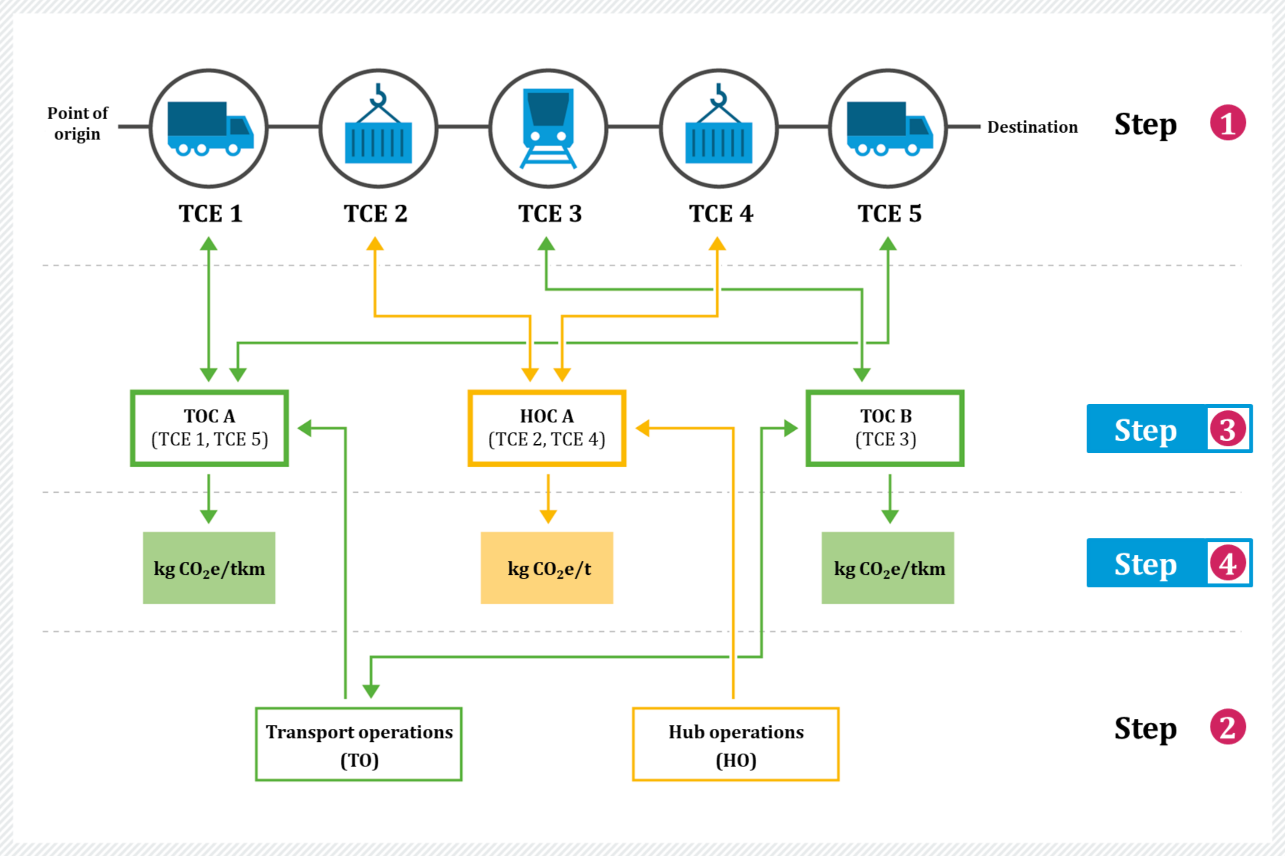
TCE 3 is managed as a separate TOC B and refers to an electrically powered container train with a gross weight of 1,000 t.

The two transport chain elements of the hub operations are also combined into HOC A, as in both cases the transhipment takes place at an intermodal terminal.

The following figure visualises the transport chain elements and the assignment to the HOCs/TOCs.

Figure 7

Illustration of steps 3 and 4: Assignment of TOC and TO to the transport chain to be evaluated



Source: own illustration, ifeu/Fraunhofer IML

Step 4: Calculation of GHG emission intensities for TOCs/HOCs

For TOC A (road), TOC B (rail) and HOC A, the company wants to determine the GHG emission intensities in step 4. The various GHG activities are indicated separately from each other and a distinction is made between the energy carriers. Since the transported goods do not have to be cooled, there is no need to account for refrigerant losses. This means that GHG activities are limited to the use of energy carriers, namely diesel for the truck and electricity for the freight train. Thus, no allocation is to be carried out here.

Since the company does not have primary data for HOC A, it decides to use default values (secondary data). It uses the default value of 10.7 kg CO_2e/container transhipment from the GLEC Framework (Smart Freight Centre 2023). Together with a conversion factor of 10 tonnes per container, this results in a factor of 1.07 kg CO_2e per tonne transhipped, which is used for the example.

For both TOCs, the company uses modelled data. For TOC A, a 40-tonne diesel articulated truck of the Euro 6a-c emission standard with a load capacity of 10 tonnes is used. Since the company does not have any information on the complete round trip of the articulated trucks, it uses a default value of 20% for the average share of empty runs. For TOC B, an electric freight train is used. For this a container train with an average load of 48% and a share of empty runs of 20% is used (EcoTransIT World 2023).

The calculation process is only shown here in a highly simplified form. As a result of the calculation with EcoTransIT World, the GHG emission intensity of TOC B (freight train) is 14 g CO_2e/tkm (energy carrier: electricity). For TOC A, the GHG emission intensity is based on the actual distance and accounts for 143 g CO_2e/tkm (total GHG emissions, of which 103 g CO_2e/tkm from operation). The energy carrier is diesel/biodiesel blend with 6.3% biodiesel. By means of the distance adjustment factor, this value must be converted into a GHG emission intensity related to the SFD.

The company uses these GHG emission intensities to calculate the GHG emissions of the TOCs as follows:

- GHG emissions TOC A: 143 g CO_2e/tkm x (525 tkm + 1,050 tkm) = 225.2 kg CO_2e (based on actual distance)

- GHG emissions TOC B: 14 g CO_2e/tkm x 5,000 tkm = 70.0 kg CO_2e

For the conversion to GHG emission intensity of the TOCs, the transport activity based on the shortest feasible distance is now used:

- GHG emission intensity TOC A: 225.2 kg CO_2e / (500 tkm + 1,000 tkm) = 150 g CO_2e/tkm (of which 108 g CO_2e/tkm from operation)

- GHG emission intensity TOC B: 70.0 kg CO_2e / 5,000 tkm = 14 g CO_2e/tkm (of which 0 g CO_2e/tkm from operation)

- GHG emission intensity HOC A: 1,070 g CO_2e/t (of which 384 g CO_2e/t from operation (own calculation based on (Dobers et al. 2023b))

The GHG emission factors used for the energy carriers (including electricity) are documented in Annex A.3.

This example shows how important it is to specify the distance used in each case to understand the results.

Case example B: Passenger transport of an organisation *(continued from page 26)*

Step 3: Assign the TO/HO to TOCs or HOCs

The bus company decides to combine the buses into TOCs based on their fuel type and size. These TOCs also roughly coincide with certain bus lines, as the buses usually run on the same lines. For example, electric buses tend to run on shorter, inner-city routes (TOC B), while diesel standard buses tend to run on less used routes (TOC A). However, partly different types of buses are also in use on one line. For example, one line is served by an articulated bus (TOC A) during the morning's dense commuter traffic, while a standard bus (TOC C) is used at night on the same line.

The company thus considers the following TOCs:

- TOC A: 12 articulated diesel buses Euro 6 a-c + 2 articulated buses Euro 6 d-e (corresponds to TCEs 1 to 14)
- TOC B: 2 articulated electric buses (equivalent to TCEs 15 and 16)
- TOC C: 4 standard diesel buses Euro 6 a-c + 1 standard diesel bus Euro 5 (corresponds to TCEs 17 to 21)

Since the fuel consumption of buses with the same type of drive and the same size hardly differs between the different emission classes, the TOCs include buses with different emission standards.
Euro levels.

Step 4: Calculation of the GHG emission intensity of the TOCs/HOCs

All the data on the buses available to the company are shown in Table 9.

Table 9

Data for Case example B

	Diesel consumption (MJ/km)	Electricity consumption (MJ/km)	Annual mileage per bus	Capacity per bus	Number of buses
TOC A: Articulated diesel bus	14.1	–	55,000 km	90 seats	14
TOC B: Articulated electric bus	–	7.5	50,000 km	90 seats	2
TOC C: Standard diesel bus	10.7	–	52,000 km	60 seats	3

Note: Seats on the bus include both seating and standing.

Source: own calculation, ifeu/Fraunhofer IML

For all buses, the determined uniform average occupancy rate of 18% is used.

Using the GHG emission factors for diesel or electricity (see Appendix A.3), the company can calculate the GHG emissions of the TOCs and their GHG emission intensities.

In this case example, the total GHG emissions of a TOC can be calculated as follows:

GHG emissions = consumption x number of vehicles x annual mileage x GHG emission factor

This results in the following values per TOC and year:

- TOC A: 1,018,387 kg CO_2e (of which 766,508 kg CO_2e from operation)
- TOC B: 46,125 kg CO_2e (of which 0 kg CO_2e from operation)

- TOC C: 260,952 kg CO_2e (of which 196,409 kg CO_2e from operation)

Subsequently, the transport activities of the TOCs per year are calculated:

- TOC A: 14 vehicles x 55,000 km/a x 90 passengers x 0.18 = 12,474,000 pkm
- TOC B: 2 vehicles x 50,000 km/a x 90 passengers x 0.18 = 1,620,000 pkm
- TOC C: 5 vehicles x 52,000 km/a x 60 passengers x 0.18 = 2,808,000 pkm

By dividing these GHG emissions by the associated transport activities of the respective TOCs, the GHG emission intensities of the TOCs are determined, which are as follows:

- TOC A: 82 g CO_2e/pkm (of which 61 g CO_2e/pkm from operation)
- TOC B: 28 g CCO_2e/pkm (of which 0 g CO_2e/pkm from operation)
- TOC C: 93 g CO_2e/pkm (of which 70 g CO_2e/pkm from operation)

5 Calculation of GHG emissions of a transport chain

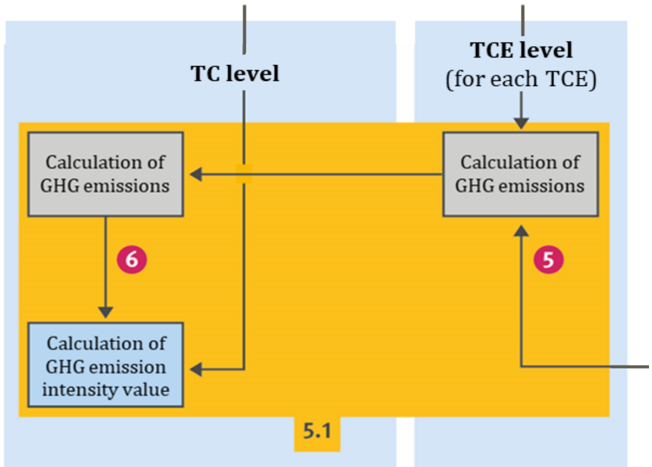
5.1 From GHG emission intensity to GHG emissions of TCEs and TC

In order to get from the GHG emission intensity of the different TOCs or HOCs to the GHG emissions of the TCEs, the transport or hub activity of each TCE is multiplied by the corresponding GHG emission intensity of the respective TOC or HOC. Care must be taken to ensure that – unless the base unit of tonnes or tonne-kilometres has been used – a uniform unit for transport or hub activity or uniform conversion factors (see Annex A.1) are used.

GHG emissions of the TCE =
GHG emission intensity TOC or HOC x
transport or hub activity of the TCE

By adding up all GHG emissions of the TCEs of a transport chain, the total GHG emissions of this transport chain are determined. These can then be converted back into a GHG emission intensity of the transport chain by dividing the GHG emissions of the transport chain by the sum of the transport activity of the transport chain.

$$\text{GHG emissions of TC} = \frac{\sum \text{GHG emissions of the TCEs}}{\sum \text{transport activity of the TCEs}}$$



Hub activities are not taken into account in the calculation of the transport activity of the transport chain, but their associated GHG emissions are still included in the GHG emissions of the transport chain and thus also in the GHG emission intensity of the transport chain.

ISO 14083 also offers the possibility of adding up GHG emissions from different transport chains, e.g. if an organisation wants to report on all its transport processes.

5.2 Case examples Part 3

In the preceding section 4.3, steps 3 and 4 were described for the case examples and it was shown how the associated GHG emission intensities were determined for the transport and hub operations. Now follow steps 5 and 6.

Case example A: Transport services in freight transport *(continued from page 44)*

The previous section 4.3 showed how the associated GHG emission intensities were determined for the transport service in freight transport for the different transport and hub operation categories.

Step 5: Calculation of the GHG emissions of the TCEs
With the help of this information and the transport/hub operations from Section 3.3, the GHG emissions of the individual transport chain elements can now be calculated in step 5 according to the above formula.

- GHG emissions TCE 1: 0.150 kg CO_2e/tkm x 500 tkm = 75.0 kg CO_2e
- GHG emissions TCE 2: 1.07 kg CO_2e/t x 10 t = 10.7 kg CO_2e
- GHG emissions TCE 3: 0.014 kg CO_2e/tkm x 5,000 tkm = 71.9 kg CO_2e
- GHG emissions TCE 4: 1.07 kg CO_2e/t x 10 t = 10.7 kg CO_2e
- GHG emissions TCE 5: 0.150 kg CO_2e/tkm x 1,000 tkm = 150 kg CO_2e

Step 6: Calculation of GHG emissions and GHG emission intensity of the transport chain
In the last step, the company now adds up all GHG emissions of TCEs 1 to 5. In addition, it determines the transport activity of the entire transport chain, which is made up of the sum of the TO of TCEs 1, 3 and 5 and thus amounts to 6,500 tkm.

In order to obtain the GHG emission intensity of the transport chain, the GHG emissions of the transport chain are divided by the transport activity of the transport chain:

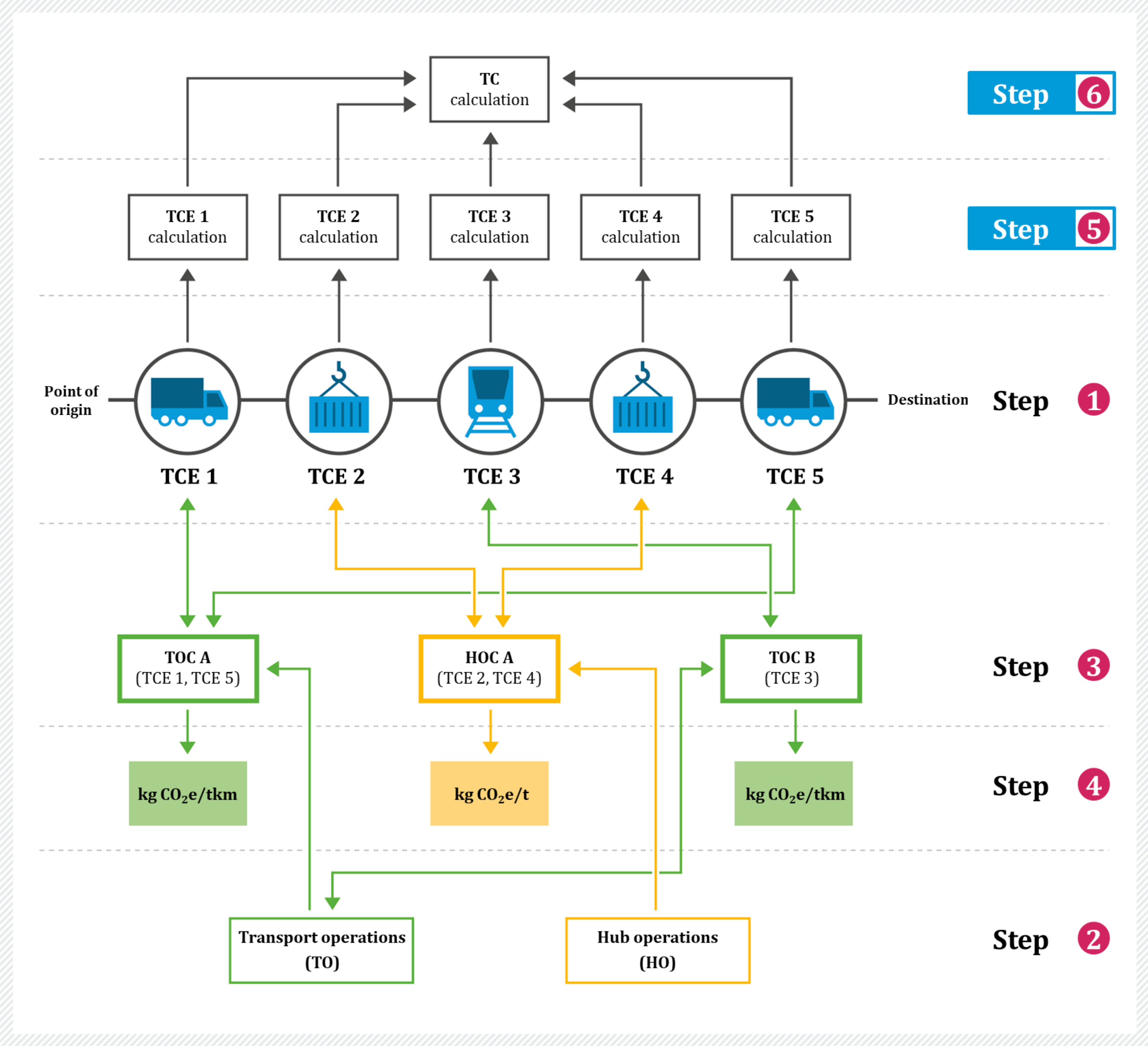
So the process looks like this:

- Total GHG emissions: (75.0 + 10.7 + 71.9 + 10.7 + 150) kg CO_2e = 318.3 kg CO_2e
- GHG emission intensity of TC: 318.3 kg CO_2e / 6,500 tkm = 0.049 kg CO_2e/tkm

It is important to note that the final GHG emission intensity of the entire transport chain also includes the GHG emissions of the intermediate hubs, even if these do not represent a transport process.

Figure 8

Illustration of steps 5 and 6: GHG emissions and GHG emission intensities of the transport chain elements and transport chain



Source: own illustration, ifeu/Fraunhofer IML

Case example B: Passenger transport of an organisation *(continued from page 46)*

Step 5: Calculation of the GHG emissions of the TCEs

In this case example, the GHG emissions of the individual TCEs are not reported (although this is necessary according to ISO), as they are calculated according to the same rules as the TOCs.

Step 6: Calculation of GHG emissions and GHG emission intensity of the transport chain

In order to calculate the GHG emissions of the transport chain(s) (and thus also the organisation's annual GHG emissions from its passenger transport by bus), the GHG emissions of TOC A, TOC B and TOC C can be summed up. The resulting total of 1,325,464 kg CO_2e (of which 962,917 kg CO_2e from operations) can now be divided by the total transport activities of 16,902,000 pkm to obtain the GHG emission intensity of passenger transport. This is 78 g CO_2e/pkm (of which 57 g CO_2e/pkm from operations).

6 Reporting according to ISO 14083

Reporting is an integral part of any GHG emissions calculation in accordance with ISO 14083, which is why ISO 14083 contains requirements for the scope of reporting and specifies what further information must be reported.

Uniform and transparent reporting enables the exchange of information between different partners along a transport chain and supports the further use of calculation results, e.g. in other calculations. It also enables a comparison between different transport chains and organisations. However, it is essential that all relevant framework conditions and assumptions that significantly influence the results are clearly documented. For this purpose, ISO 14083 has formulated clear requirements, which are summarised below.

The report can be established from two different perspectives: at the level of transport or hub services or at the level of an organisation. The reporting organisation can also decide – regardless of the reporting level chosen – whether to produce a single report containing all the necessary information or only a short report, which is supplemented by additional information elsewhere (e.g. reference to the webpage). In the following, therefore, the minimum disclosures (short report) and the additional information will be discussed in more detail. Together, the two make up the ISO-compliant report.

6.1 Short reports

Short report at the level of transport or hub services

In the case of a report at the level of transport or hub services, the information refers to one or more transport chain elements. If the report includes several transport chain elements, they can represent a complete transport chain or only part of it. The following table summarises all the reporting elements of a short report. This should be supplemented by additional information (see Section 6.2).

Short report at the organisational level

The information of a short report at organizational relates either to all transport chains or to a part of them, regardless of whether they are operated or purchased by the organisation itself. The report itself can be divided by organisational structure, such as business units, regions, or subsidiaries. In this case, ISO 14083 recommends that the organisation prepare at least one annual report covering all operations in twelve consecutive months. This report may be supplemented by reports on shorter periods and/or selected journeys and operations.

Table 10

Elements of the short report at the level of transport or hub services

Report elements	Description
Identification of the services covered	Identification of which transport chains or which transport chain elements are covered in the report, based on an exhaustive list of services or indication of the period of time.
Reference to ISO 14083	Reference to ISO 14083:2023
Overall result on GHG emissions and GHG emission intensities	Total sum, i.e. sum of all TCE (1) from operation and energy provision ($G_{T,TC}$) or $g_{T,TC}$ and (2) from operation ($G_{VO,TC}$ or $G_{HEO,TC}$) or ($g_{VO,TC}$ or $g_{HEO,TC}$)*
Transport activity	Total sum, i.e. sum of all transport TCEs
Transport activity distance	Indication of the type used (i.e. SFD or GCD) (per transport mode)
Hub activity	Sum over all hub TCEs
Partial results per transport mode and hub	For each mode and for hub operations (1) Total GHG emissions and transport activity and/or (2) GHG emission intensities
Additional information	Reference to the location where additional information is published

Note: The abbreviations/formula symbols are listed in the glossary.
* GHG emissions from the operation of a vehicle (G_{VO}) are also known as TTW emissions and can be classified as Scope 1 or Scope 3 emissions under the GHG Protocol, depending on who is responsible for the operation and who wants to report the GHG emissions.

Table 11

Elements of the short report at organisational level

Report elements	Description
Identification of the services covered	Indication of which transport chains are covered in the report, if necessary, breakdown according to the organisational structure
Reference to ISO 14083	Reference to ISO 14083:2023
Results on GHG emissions and GHG emission intensities	From operation and energy provision (G_T) or (g_T) 1. across all transport chains 2. across all TCEs of one transport mode and for hub operations Optional: supplemented by corresponding values for GHG emissions from operation
Transport activity distance	Indication of the type used (i.e. SFD or GCD) (per transport mode)
Additional information	Reference to the location where additional information is published

6.2 Additional information as part of the reporting

The short reports are only part of the complete reporting in accordance with ISO 14083. A complete presentation of the results requires additional information that is easily accessible, clearly structured and transparent with regard to data acquisition and calculation. In the following, guiding questions are formulated on the basis of which the reporting organisation can decide whether and which additional information it wants or must publish in order to report in accordance with ISO 14083.

Are all relevant processes included in the calculation?

In principle**, none of the processes**, inputs or outputs **described above** must be omitted. If this is the case, the report must explain this decision and the reasons and consequences for omitting it, supplemented by any **cut-off criteria** used (see also Section 2.1).

When calculating GHG emissions of hub operations, the reporting organisation may be faced with the task of assigning energy consumed by vehicles or vessels temporarily operated in a hub to transport operation (see Table 2). If these are assigned to the hub operations, this must be reported transparently.

ISO 14083 also makes it possible to include **optional processes** in the GHG emissions calculation. This includes, for example, GHG emissions associated with the storage and (re)packaging of goods in logistics hubs, or those generated by the use of information and communication technology (ICT) equipment and external data servers. If these optional aspects have also been calculated, this must be clearly stated in the report. The separate identification (subtraction) of the optional components is not required.

Where was primary data not used?

Only if no primary data is available for an operation, secondary data, i.e. modelled data or default values, may be used in the GHG emission calculation. The use of secondary data must be justified and documented.

Has data been modelled or have default values been used?

When using secondary data, ISO 14083 requires the use of tabular documentation for reporting (see Table 12). The table contains basic influencing parameters of the modelling and may be extended accordingly by additional relevant input parameters if necessary. For each model used, the reporting organisation must complete the table below and make it available upon request.

Table 12

Reporting when using secondary data

Input parameters of modelling and use of deviating default GHG emission intensities

Model type	
Energy based modelling	Yes/No
Activity based modelling	Yes/No

Parameter	Included Yes/No	Additional information If included, state predominant input data type
Vehicle fleet related		
Vehicle class/fleet profile	Yes/No/Not applicable	Primary/modelled/default
Energy consumption profile	Yes/No/Not applicable	Primary/modelled/default
Vehicle configuration	Yes/No/Not applicable	Primary/modelled/default
Body type/empty vehicle mass	Yes/No/Not applicable	Primary/modelled/default
Engine type	Yes/No/Not applicable	Primary/modelled/default
Engine emission class	Yes/No/Not applicable	Primary/modelled/default

Parameter	Included Yes/No	Additional information If included, state predominant input data type
Energy carrier(s) used in vehicle	Yes/No/Not applicable	Primary/modelled/default
Share of energy carrier	Yes/No/Not applicable	Primary/modelled/default
Operational		
Freight type	Yes/No/Not applicable	Primary/modelled/default
Freight requirements (e.g. temperature control, hazardous)	Yes/No/Not applicable	Primary/modelled/default
Use of specific container type	Yes/No/Not applicable	Primary/modelled/default
Load factor or average load expressed in tonnes	Yes/No/Not applicable	Primary/modelled/default
Service type (e.g. full truckload/less than truckload, full container load/ less than container load	Yes/No/Not applicable	Primary/modelled/default
Extent of empty trips	Yes/No/Not applicable	Primary/modelled/default
Journey characteristics		
Routing, including location of intermediate stops	Yes/No/Not applicable	Primary/modelled/default
Route characteristics	Yes/No/Not applicable	Primary/modelled/default
Direct/via location/multiple collection and delivery	Yes/No/Not applicable	Primary/modelled/default
Drive cycle	Yes/No/Not applicable	Primary/modelled/default
Road type/ channel type	Yes/No/Not applicable	Primary/modelled/default
Urban/mixed/long haul	Yes/No/Not applicable	Primary/modelled/default
Frequency of stops	Yes/No/Not applicable	Primary/modelled/default
Speed profile	Yes/No/Not applicable	Primary/modelled/default
Topography	Yes/No/Not applicable	Primary/modelled/default
Geographic region of applicability	Yes/No/Not applicable	Primary/modelled/default
Current/flow rate/head, cross or tail wind and windspeed	Yes/No/Not applicable	Primary/modelled/default
Additional items		
…		

Source: DIN EN ISO 14083, Table 3

If default values are used, their source must be reported. Unless the sources recommended by ISO 14083 in Annex Q have been selected (see Annex A.5 in the guide), the alternative source selection must be justified. When selecting the default values, the best correspondence between the standard classification of GHG emission intensity and the mode-specific characteristics of a TOC or HOC should be achieved. If no clear matching is possible, the selected sources must be documented, as well as the reasons for the selection.

How were emissions allocated, if any?

The reporting must transparently document the selected allocation method (e.g. area-based allocation key, see examples in Section 4.2.2).

Which emission factors were used?

The fuels considered in the GHG emission calculation must be transparently documented together with their GHG emission factors. The respective source must also be listed.

These requirements, which result from Annex J.4 of ISO 14083, can be problematic for reporting organisations if they use licensed GHG emission factors that are not allowed to be published under the licence agreement. In these cases, the authors recommend filling out the table as far as possible and otherwise referring to the external "licensed data". By providing clear, i.e. reproducible, source information, it is possible for those who also hold a licence to reproduce the GHG emission factor.

Table 13

Documentation of the emission factors of fuels and electricity

Fuel type	Lower heating value [MJ/kg]	Density (1) [kg/l]	Operational GHG emissions [g CO_2e/MJ]	Total GHG emissions (2) [g CO_2e/MJ]	Biofuel blend (%energy content)	Source

(1) for liquid fuels; (2) from the operation and energy provision

With regard to biofuels, ISO 14083 recommends that GHG emissions from indirect land use change (iLUC) be reported separately in the report and that the sources used are transparently documented incl. assumptions.

GHG emission factors for energy provision must also include the infrastructure of the energy carriers. If the best available data sources do not contain them, this must be documented. This can be done, for example, in tabular documentation.

In the case of electricity generation, ISO 14083 allows for a separate quantification of GHG emissions from infrastructure. These may be documented separately and included in the report.

If an organisation has also used its own electricity mix for its electricity consumption according to the market-based approach, the GHG results must be documented and reported separately from the calculations with the national electricity mix. If the GHG emission results are to be used for further use in calculations for the Product Carbon Footprint in accordance with ISO 14067, the market-based electricity mix must also be disclosed in the report.

The IPCC's latest publication on global warming potentials (GWP) is – at the time of publication of this guide – the sixth assessment report (Smith et al. 2021). The source used must be documented transparently. The use of deviating GWP (time horizon of 100 years, without climate-carbon feedback) should be explained.

Were alternative units of transport or hub activity used?

ISO 14083 specifies tonnes as the standard unit for transport and hub activities for freight. For some operations, such as mail and parcel operations and containerised freight, the standard allows for an alternative unit. The choice of an alternative unit is to be justified and documented in the report. Examples of conversion factors are given in Annex A.1.

Are there any national requirements that deviate from ISO 14083?

Requirements from national and international legislative bodies take precedence over ISO 14083, and if they require the use of a specific quantification methodology and/or the use of specific GHG emission factors, the methodology and sources of the GHG emission factors must be clearly documented in the report.

6.3 Case examples Part 4

Case example A: Transport services in freight transport (continued from page 50)

Reporting for Case example A is carried out at the level of the transport service. For this purpose, a short report in tabular form is first prepared. The necessary additional information is then compiled, which can be published together with the summary report or separately.

Table 14

Short report on the Case example A

Report element	Description
Identification of the services covered	Final transport chain
Reference to ISO 14083	These calculation results were calculated in accordance with ISO 14083:2023.
Overall results on GHG emissions	Total GHG emissions of the transport chain: $G_{T,TC}$ = 318.3 kg CO_2e (of which 296.9 kg CO_2e from road/rail and 21.4 kg CO_2e from the hub) GHG emissions from the operation of the transport chain: $G_{O,TC}$ =170 kg CO_2e (of which 162 kg CO_2e from the road and 8 kg CO_2e from the hub)
Overall results on GHG emission intensities	Total from operation and energy provision: $g_{T,TC}$ = 0.049 kg CO_2e/tkm Total from operation: $g_{O,TC}$ = 0.022 kg CO_2e/tkm
Transport activity of the TC	6,500 tkm (sum of all transport TCEs)
Transport activity distances	Road (TCE 1 and TCE 5): SFD Rail (TCE 3): SFD
Hub activity	20 t (sum of all hub TCEs)
GHG emission intensities by transport mode and hub*	Road (TCE 1, TCE 5): 0.150 kg CO_2e/tkm Rail (TCE 3): 0.014 kg CO_2e/tkm CT terminal (TCE 2, TCE 4): 1.07 kg CO_2e/t
Additional information	subsequent

*The TCE numbers shown are supplemented for illustrative purposes only for this example and are not generally required in reporting.

Additional Information

- Are all relevant processes included in the calculation?
  Yes, which means no further documentation is required.

- At what point were secondary data used instead of primary data?
  Different data categories were used for the individual TCE in the GHG emission calculation, i.e. modelled data for transport in TCE 1, TCE 3 and TCE 5, and default values of transhipment in TCE 2 and TCE 4. The documentation of the model is shown in Table 15. A default value according to GLEC Framework Version 3 was used for handling at the CT terminal.

- An allocation was not required in the case example and therefore does not need to be documented.

- Which GHG emission factors were used?
  GHG emission factors for diesel and electricity were used in the GHG emission calculation. At this point, reference should be made to Annex A.3 of the guide. A default value according to GLEC Framework Version 3 was used for handling at the CT terminal.

Table 15

Reporting for the use of secondary data in Case example A for TCEs 1, 3 and 5

Input parameters of modelling and use of deviating default GHG emission intensities

Parameter	Included Yes/No	Additional information If included, state predominant input data type
Vehicle fleet related		
Vehicle class/fleet profile	Yes (for road)	Modelled
Energy consumption profile	Yes	Modelled
Vehicle configuration	Yes (for road)	Modelled
Body type/empty vehicle mass	Yes (for road)	Modelled
Engine type	Yes (for road)	Primary
Engine emission class	Yes (for road)	Primary
Energy carrier(s) used in vehicle	Yes	Primary
Share of energy carrier	Yes	Primary
Operational		
Freight type	Primary	Primary
Freight requirements (e.g. temperature control, hazardous)	Not applicable (ambient temperature)	Primary
Use of specific container type	Yes	Primary
Load factor or average load expressed in tonnes	Yes	Primary (road) / modelled (rail)

Parameter	Included Yes/No	Additional information If included, state predominant input data type
Service type (e.g. full truckload/less than truckload, full container load/ less than container load	Yes	Primary
Extent of empty trips	Yes	Default
Journey characteristics		
Routing, including location of intermediate stops	Yes	Primary
Route characteristics	Yes	Modelled
Direct/via location/multiple collection and delivery	Yes (direct)	Primary
Drive cycle	Yes (road)	Modelled
Road type/ channel type	Yes (road type) Not applicable (channel type)	Modelled
Urban/mixed/long haul	Yes (road)	Modelled
Frequency of stops	No	
Speed profile	Yes (road)	Modelled
Topography	Yes (road)	Modelled
Geographic region of applicability	Yes	Primary
Current/flow rate/head, cross or tail wind and windspeed	No	
Additional items		
CT terminal	Yes	Default

Case example B: Passenger transport of an organisation *(continued from page 51)*

Reporting for Case example B is established at the level of the organisation. For this purpose, a short tabular report is prepared first. The necessary additional information is then compiled, which can be published together with the summary report or separately.

Table 16

Short report on the Case example B

Report element	Description
Identification of the services covered	All transport chains of the organisation (passenger transport by bus) within one calendar year
Reference to ISO 14083	These calculation results were calculated in accordance with ISO 14083:2023.
Overall results on GHG emissions	Total GHG emissions of the transport chain: $G_{T,TC}$ = 1,371,631 kg CO_2e (of which 1,279,339 kg CO_2e from diesel and 92,292 kg CO_2e from electricity) GHG emissions from the operation of the transport chain: $G_{O,TC}$ =962,917 kg CO_2e (all from diesel)
Overall results on GHG emission intensities	Total of operation and energy provision: $g_{T,TC}$ = 0.080 kg CO_2e/pkm Total from operation: $g_{O,TC}$ = 0.056 kg CO_2e/pkm
Transport activity	17,064,000 pkm (sum of all transport TCEs)
Transport activity distances	SFD
Additional information	subsequent

Additional Information

- Are all relevant processes included in the calculation?

Yes, which means no further documentation is required.

- At what point were secondary data used instead of primary data?
  For the organisation's bus fleet, primary data were available for both transport activity and GHG activities. Thus, no secondary data had to be used.

- An allocation was not required in the case example and therefore does not need to be documented.

- Which GHG emission factors were used?
  GHG emission factors for diesel and electricity were used in the GHG emission calculation. At this point, reference should be made to Annex A.3 of the guide.

References

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A Appendix

A.1. Relevant conversion factors

- 1 kWh = 3.6 MJ

Starting value, unless specific values are available:

- 1 TEU = 10 t (Smart Freight Centre 2024)
- 1 pallet = 300 kg (Dobers and Jarmer 2023)
- Table 3: Distances and distance adjustment factors
- Table 5: Passenger equivalents of Ro-Pax ferries and trains

A.2. TOC characteristics of the different modes of transport

TOC characteristics for air transport according to ISO 14083 Table A.1

- Journey length: "short (e.g. < 1,500 km)" OR "long (> 1,500 km)"
- Plane configuration: "Passenger aircraft without cargo" OR "Dedicated freight aircraft" OR "Passenger aircraft with belly freight"

TOC characteristics for freight on inland waterway vessels according to ISO 14083 Table C.1

- Freight type: "Dry bulk" OR "Liquid bulk" OR "Containerised" OR "Mass-limited, general freight" OR "Volume-limited, general freight"
- Vessel size category: "< 50 m" OR "50 m to 80 m" OR "80 m to 110 m" OR "110 m to 135 m" OR "> 135 m"
- Vessel configuration: "Individual vessel" OR "Pushed convoy"
- Condition: "Ambient " OR "Temperature controlled"
- Waterway type: "Canal" OR "River" OR "Lake"

TOC characteristics for passengers on inland waterway vessels according to ISO 14083 Table C.2

- Vessel operation type: "River cruise" OR "Ro-Pax river ferry" OR "Waterbus" OR "Water taxi"
- Vessel size category: “Varies by vessel type”
- Condition: "Transport only" OR "Transport plus other services (restaurant, accommodation, etc.)"
- Waterway type: "Canal" OR "River" OR "Lake"

TOC characteristics for rail freight transport according to ISO 14083 Table E.1

- Operation type: "Long-distance freight transport: block train" OR "Long-distance freight transport: single wagon" OR " Long-distance freight transport: intermodal wagon” OR “Short-distance freight transport (feeder transport)"
- Freight type: "Average/mixed" OR "Containerised/swap bodies" OR "Dry bulk" OR "Liquid bulk" OR "Vehicle transport" OR "Semi-trailers" OR "Other"
- Condition: "Ambient" OR "Temperature-controlled"
- Propulsion: "Electric motor: fixed electricity supply system (catenary, third rail)" OR "Electric motor: on train battery energy storage" OR "Electric motor: fuel cell energy storage" OR "Combustion engine" OR "Other"

TOC characteristics for rail passenger transport according to ISO 14083 Table E.2

- Train operation type: "Long-distance passenger trains" OR "Short-distance passenger trains" OR "Urban passenger: suburban trains" OR "Urban passenger: tram (streetcar)" OR "Urban passenger: underground (subway, metro)"

- Passenger experience: "Night trains (slow trains)" OR "Vehicle trains (slow trains)" OR "Luxury trains (slow trains)" OR "High-speed trains" OR "Other"
- Propulsion: "Electric motor: fixed electricity supply system (catenary, third rail)" OR "Electric motor: on train battery energy storage" OR "Electric motor: fuel cell energy storage" OR "Combustion engine" OR "Other"

TOC characteristics for road freight transport according to ISO 14083 Table F.1

- Freight type: "Dry bulk" OR "Liquid bulk" OR "Containerised" OR "Palletised" OR "Mass-limited, general cargo (heavy cargo)" OR "Volume-limited, general cargo (light cargo)" OR "Vehicle transport"
- Condition: "Ambient " OR " temperature-controlled"
- Journey type: "Point-to-point (long haul)" OR "Collection and delivery"
- Contract type: "Shared transport" OR "Dedicated contract (charter)"

TOC characteristics for road passenger transport according to ISO 14083 Table F.2

- Means of transport: "Shared public transport (e.g. bus, coach, trolleybus)" OR "Shared private transport (taxi)" OR "Private transport (e.g. own car, bicycle, scooter, motorbike)"
- Journey type: "Urban" OR "Suburban" OR "Regional" OR "Long-distance" OR "Dedicated lines (e.g. school bus)"
- Level of passenger loading: "Discrete number of individuals (1, 2, 3, etc.)" OR "Average occupancy rate"

TOC characteristics for cargo on seagoing vessels in accordance with ISO 14083 Table G.1

- Vessel type: "Bulk carrier" OR "Chemical tanker" OR "General cargo" OR "Ro-Ro (roll-on roll-off freight)" OR "Liquefied gas tanker" OR "Oil tanker" OR "Other liquid tanker" OR "Container" OR "Vehicle carrier"
- Freight condition: "Ambient" OR "Temperature-controlled" OR "Mixed ambient and temperature-controlled"
- Service type: "Scheduled (by origin and destination pairs)" OR "Tramp"

TOC characteristics for passengers on seagoing vessels according to ISO 14083 Table G.2

- Vessel type: "Passenger ferry" OR "Cruise ship"
- Vessel size: "Varies by vessel type (more information in ISO 14083 Table G.4)
- Service type: "Scheduled (by origin and destination pairs)" OR "Chartered"

TOC characteristics for mixed passenger and cargo on seagoing vessels in accordance with ISO 14083 Table G.3

- Vessel type: "Ro-Pax ferry (mixture of roll-on roll-off freight and passengers)"
- Vessel size: "Varies by vessel type" (more information in ISO 14083 Table G.4)
- Service type: "Scheduled (by origin and destination pairs)" OR "Chartered"

A.3. GHG emission factors of common energy carriers

As part of the work on this guideline, it was not possible to carry out our own analyses for GHG emission factors of energy carriers. However, the factors listed in the informative annex to ISO 14083 are considered obsolete according to recent findings on increased methane emissions from oil and natural gas extraction. For this reason, the GHG emission factors of the most common European energy carriers have been analysed here based on the work for the EcoTransIT World Tool (EcoTransIT World 2023). These factors were also used for the calculations in the case examples.

Table 17

GHG emission factors of European energy carriers

Energy carrier	Lower heating value [g CO_2e/MJ]	Density (kg/l)	GHG emissions operation [g CO_2e/MJ]	GHG emissions energy provision (g CO_2e/MJ)	Total GHG emissions [g CO_2e/MJ]
Gasoline	42.5	0.743	74.96 (of which 74.82 from CO_2)	24.01	98.97
Ethanol (40 % corn, 35 % sugar-beet, 25 % wheat)	27.0	0.780	0.14 (of which 0 from CO_2)	47.90	48.03
Diesel	42.8	0.832	75.26 (of which 74.10 from CO_2)	22.56	97.82
Diesel with 6.3 % biodiesel	42.4	0.836	70.6	23.22	93.8
Biodiesel (50 % rapeseed, 40 % used cooking oil, 10 % soy)	37.0	0.892	1.16 (of which 0 from CO_2)	34.22	35.38
HVO (50 % rapeseed, 50 % used cooking oil)	44.0	0.770	1.16 (of which 0 from CO_2)	28.56	29.72
CNG (SI truck)	49.2	–	56.08 (of which 55.14 from CO_2)	21.04	77.12
Bio-CNG (40 % corn, 40 % manure, 20 % organic waste) (Truck with gasoline engine)	50.0	–	0.93 (of which 0 from CO_2)	24.72	25.65
LNG (SI truck)	49.1		57.35 (of which 56.42 from CO_2)	25.77	83.12
LNG sea ship (SI engine, dual-fuel, medium speed)	49.1	–	74.10 (of which 56.42 from CO_2)	25.77	99.87
Kerosene	43.0	0.800	74.15 (of which 73.49 from CO_2)	20.00	94.13
Heavy fuel Oil (HFO) (2.7 % S-content)	41.2	0.970	77.06 (of which 75.73 from CO_2)	16.89	93.95
Very low sulphur fuel oil (VLSFO) (0.5 % S-content)	41.3	0.975	78.87 (of which 77.54 from CO_2)	20.84	99.85
Ultra-low sulphur fuel oil (ULSFO) (0.1 % S content)	41.1	0.939	78.87 (of which 77.54 from CO_2)	20.43	99.30
Consumption mix DE 2021 (Medium voltage)	–	–	0	123	123
Consumption mix DE 2021 (at train pantograph)	–	–	0	131	131

* In this column, the CO_2 emissions from operation are also given, since they are only influenced by the energy carrier and not by its use.

Source: own calculations, ifeu Institute for EcoTransIT World and GHG emissions energy supply from ecoinvent 3.9.1 for gasoline, diesel, kerosene and HFO

Notes on the table:

- GHG emissions from operation comprise of CO_2 emissions from operation and non-CO_2-GHG emission from operations. Since non-CO_2-GHG emissions depend not only on the fuel type but also on the intended use, the (fossil) CO_2 emissions are also shown separately here as information.
- To calculate the non-CO_2-GHG emissions from operation, a specific vehicle configuration was selected, i.e. a gasoline LNF (light commercial vehicle) N1-III Euro 6ab, a diesel tractor-trailer40 t Euro 6a-c, a CNG or LNG tractor-trailer 40 t Euro 6a-c (with gasoline engine), an aircraft for kerosene and a seagoing vessel for HFO/USLFO/VLSFO.
- The high non-CO_2-GHG emissions of the LNG seagoing vessel result from the relatively high methane slip of the gasoline engine used. At medium speed, they amount to 3.1 mass-percent of the fuel used (Fuel EU maritime 2021).

Table 18

Focus on heating at hubs: GHG emission factors of European energy carriers

Energy carrier	Lower calorific value [MJ/kg]	Density [kg/l]	GHG emissions operation [g CO_2e/MJ]	GHG emissions energy provision [g CO_2e/MJ]	Total GHG emissions [g CO_2e/MJ]
Process steam (1) (4 atm, 140 °C)	2.74	–	0	110.42	110.42
District heating (2)	–	–	0	106.12	106.12
Natural gas at boiler <100 kW	Not specified	–	55.07	17.99	73.06
Biogas at boiler <100 kW	Not specified	–	0.19	13.73	13.92
Light fuel oil in boiler of 100 kW	Not specified	–	78.93	22.33	101.26
Wood pellets furnace 300 kW	Not specified	–	1.02	11.34	12.36
Wood chips furnace 50 kW	18.3	–	1.53	4.48	6.01

(1) market for heat, from steam, in chemical industry (RER);
(2) own calculation, Fraunhofer IML based on District heating (46 % natural gas, 54 % hard coal) (Europe without Switzerland)

Note: values in the table may differ from the original German version of the guide which contained some errors. Values in the table above have been checked and revised.

Source: ecoinvent 3.9.1 cut-off, IPCC 2021

A.4. GHG emission factors of common refrigerants

ISO 14083 recommends using the current GWP values published by the IPCC with a time horizon of 100 years. This is the 6th Assessment Report (Smith et al. 2021) at the time of publication of this guide, but it is not yet widely applied in tools and reports. For this reason, the following table shows the GWP values from the current, sixth (AR6) and the previous, fifth (AR5) assessment report. The GWP values of mixtures are calculated accordingly with the specified parts.

Table 19

Exemplary emission factors for refrigerants (in g CO_2e per g refrigerant type)

Refrigerant type	Description	IPCC 2013 AR5	IPCC 2021 AR6
R-717	NH3, Ammonia	–	–
R-600a	C4H10, Isobutane	3.0	0.01
R-1234yf	C3H2F4 // CF3CF=CH2, 2,3,3,3- Tetrafluoro propene	1.0	0.5
R-744	CO2, Carbon dioxide	1.0	1.0
R-1234ze(E)	C3H2F4 // trans-CF3CH=CHF, (E)-1,3,3,3,-Tetrafluorpropen	1.0	1.4
R-32	CH2F2, Difluoromethane	677.0	771.0
R-448a	Mixture, own calculation: 26 % R-32, 26 % R-125, 20% R-1234yf, 21 % R-134a, 7 % R-1234ze(E)	1,273.5	1,494.4
R-449A	Mixture, own calculation: 25,7 % R-134a, 25,3 % R-1234yf, 24,7 % R-125, 24,3 % R-32	1,281.9	1,504.5
R-134a	CH2FCF3, 1,1,1,2-Tetrafluorethane	1,300.0	1,530.0
R-407C	Mixture, own calculation: 23 % R-32, 25 % R-125, 52 % R-134a	1,624.2	1,907.9
R-22	CHClF2, Chlorodifluoromethane	1,760.0	1,960.0
R-410A	Mixture, own calculation: 50 % R-32, 50 % R-125	1,923.5	2,255.5
R-407A	Mixture, own calculation: 20 % R-32, 40 % R-125, 40 % R-134a	1,923.4	2,262.2
R-542a	Mixture, own calculation: 11 % R-32, 59 % R-125, 30 % R-1234yf	1,945.1	2,291.6
R-404A	Mixture, own calculation: 44 % R-125, 4 % R-134a, 52 % R-143a	3,942.8	4,728.0
R-507	Mixture, own calculation: 50 % R-125, 50 % R-143a	3,985.0	4,775.0
R-507A	Mixture, own calculation: 50 % R-125, 50 % R-143a	3,985.0	4,775.0
R-115	CClF2CF3, Chloropentafluoroethane	7,670.0	9,600.0

Further emission factors can be found in the guidelines for logistics hubs (Dobers and Jarmer 2023).

Note: values in the table may differ from the original German version of the guide which contained some errors. Values in the table above have been checked and revised.

Source: own calculations, Fraunhofer IML based on (Myhre et al. 2013) and (Smith et al. 2021).

A.5. GHG emission intensities (transport/hubs) and their sources

ISO 14083 refers to a selection of sources for default values for GHG emission intensities in Annex Q. The order does not represent a preference.

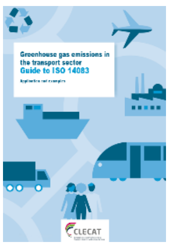
- GLEC Framework Version 2.0 (Smart Freight Centre 2019)
  Note: An updated version 3.1 has been published since October 2024 (Smart Freight Centre 2024).

- REff Tool®: GHG assessment tool for logistics sites (Dobers et al. 2023c)

- France: Base Caron® database (ADEME 2023)

- Japan: (Energy Conservation Centre Japan 2023)

- United Kingdom (UK Government 2022)



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