FRAUNHOFER INSTITUTE FOR MATERIAL FLOW AND LOGISTICS IML

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GUIDE FOR GREENHOUSE GAS EMISSIONS ACCOUNTING AT LOGISTICS HUBS

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Preface

We can state a rising interest of industry and in particular operators of logistics hubs such as warehouses, transhipment sites, distribution centres or terminals in using one internationally aligned methodology to measure and report the sustainability performance of their operations and benchmarking with comparable sites. Starting with addressing the environmental performance and here in particular the energy performance and related greenhouse gas emissions a great step has been established with the publication of the international standard ISO 14083 in March 2023 on "Greenhouse gases – Quantification and reporting of greenhouse gas emissions arising from transport chain operations".

We are happy that logistics hubs are considered as one element of transport chains, and thus, are covered by the scope of the ISO 14083. Almost five years after the publication of the first version of our GUIDE FOR GREENHOUSE GAS EMISSIONS ACCOUNTING AT LOGISTICS SITES (Dobers et al. 2019), it is therefore time to update the guide.

The methodology suggested in the first version was one starting point for developing the ISO 14083:2023. Due to some general requirements defined in the ISO series on greenhouse gas emissions accounting as well as new terms used in the ISO 14083, an update is needed. We hope that this document describes the requirements of the international standard in an illustrative and applicable manner.

For further implementation, please, be aware of the online REff Tool® that supports the data collection and calculation of greenhouse gas emissions and related KPIs as described in this guide. For further information, follow the link https://reff.iml.fhg.de/.

And, please, be also aware of our annual global market studies on "Energy efficiency and GHG emissions of logistics sites". Latest information on how to participate, possible deadlines and webinars on the surveys' results are provided on the webpage of the REff Tool® (https://reff.iml.fhg.de/) as well.

Acknowledgements

This document is the product of several interlinked projects and activities involving the close cooperation and support of various partners over the last few years.

The methodological foundation of the guide was established based on detailed discussions with various logistics service providers in the R&D project "Green Logistics". The project was part of the EffizienzCluster LogistikRuhr, sponsored by the German Federal Ministry of Education and Research (BMBF). Funding code 01IC10L06 (2010-2015). The approach was further developed with the help of experts of the Global Logistics Emissions Council (GLEC) with support of Smart Freight Centre, including co-funding. Additional feedback was received from EcoTransIT World and various companies using the tool.

The first version of the guide (Dobers et al. 2019) was prepared in the framework of the European LEARN Project (Logistics Emissions Accounting and Reduction Network). This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n° 723984.

The Fraunhofer IML was involved in the ISO 14083 development at national (DIN) and international (ISO) level. We were involved in the elaboration of the main content as well as leading the working group with the focus on hubs and related quantification actions, and Annex H on hubs and Annex O on (re)packing processes at logistics hubs. This work was established in the context of the R&D project GILA - German, Italian & Latin American consortium for resource efficient logistics hubs & transport (Fraunhofer IML 2023a), sponsored by the by the German Federal Ministry of Education and Research (BMBF) Funding code 03INT712BA (2020-2023). In the project GILA, we jointly discussed and designed hub related methodological issues with our research partners Politecnico di Milano (Department of Management, Economics and Industrial Engineering), GreenRouter, Arcadis Germany, P3 Logistic Parks and Universidad de los Andes.

In our GILA market studies, numerous companies applied the drafted methodology and provided primary data on around 850 hubs from more than 50 countries.

We cordially thank all those involved for their cooperation and contributions!

Content

Abbreviations

CNG	Compressed natural gas
CO_2e	Carbon dioxide equivalents
EF	Emission factor
ERP	Enterprise resource planning
GHG	Greenhouse gas
GLEC	Global Logistics Emissions Council
GSE	Ground support equipment
GWP	Global Warming Potential
HEEP	Hub equipment energy provision
HEO	Hub equipment operation
HFC	Hydrofluorocarbons
HOC	Hub operation category
HVAC	Heating and air-conditioning
ICT	Information and communications technology
IPCC	Intergovernmental Panel for Climate Change
ISO	International Organisation for Standardization
KPI	Key performance indicator
MHE	Material handling equipment
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
tkm	Tonne-kilometre
TC	Transport chain
TCE	Transport chain element
TEU	Twenty-foot equivalent
TOC	Transport operation category
TTW	Tank to wheel
VAS	Value added services
WMS	Warehouse management systems
WTW	Well to wheel
WTT	Well to tank

1 Introduction

Logistics hubs are locations where freight is handled from one vehicle or transport mode to another before, after or between different elements of a transport chain. They are a vital backbone to supply chains: Logistics hubs are where goods are stored and processed, and where myriad forms of transport intersect. Logistics hubs are often close to population, emphasizing the importance of both the climate and health impacts of their activities. Given their integral role in the booming logistics sector, their impact is only expected to grow in the coming years. Thus, it will be all the more important in the future to align other phases of the life cycle of logistics hubs with sustainability topics in addition to operation. (Dobers et al. 2022)

Logistics hubs are a diverse group of facilities scattered around the globe; their overall environmental impact is not well-understood. The World Economic Forum estimated that warehouse and sorting facilities alone can comprise up to 13% of supply chain emissions. (World Economic Forum 2009) Country-specific evaluations have shown that warehouse emissions account for around 20% of the transport emissions in the United States, while in the UK, it is assumed that they account for 11% to 30%. (McKinnon 2018) Latest research outlined a share of 11% or 5% from national logistics emissions in Germany or Italy respectively. (Dobers et al. 2023b)

A company's use of logistics hubs, and the subsequent emissions arising from operation, will vary based on the modes of transport, refrigeration needs and region besides others. Therefore, the relative impact of emissions from logistics hubs will vary by company and product and should be assessed accordingly in order to create transparency about the performance of logistics hubs in a first step and to understand other overarching interdependencies in following steps. This includes, for example, the continuous evaluation of measures that can reduce the environmental impact of hubs. Early 2023, the International Standard ISO 14083 "Greenhouse gases – Quantification and reporting of greenhouse gas emissions arising from transport chain operations" was published which provides an international consensus on the calculation and reporting of emissions arising from (global) logistics chains. The ISO 14083 replaces the EN 16258:2012 (DIN EN 16258) and includes next to transport operations also processes and related GHG emissions at logistics hubs.

This guide provides **advice on how to carbon audit logistics hubs with a view to performing logistics chains calculation**. Therefore, it outlines requirements and options set by the ISO 14083 as well as clarifies new terms and abbreviations used in the ISO document. However, the stakeholders of logistics hubs such as investors, owners, tenants as well as clients face multiple challenges and trends in the wider context of **sustainability**. This will be shortly addressed in the later parts of this guide.

Structure of the guide

The general structure of the guide is as follows. **Overarching issues** are addressed in chapters 2 to 4 i.e., general principles and terms used in the context of greenhouse gas (GHG) emissions accounting, a more detailed description of logistics hubs, and the assessment boundaries as required by the ISO 14083.

Next, the guide outlines the "**Procedure for GHG emissions calculation**" covering guidance on collecting data, definition of hub operation categories (HOCs) as well as calculating GHG emission intensity values, both without and with allocation (chapter 5). Reporting as required by the ISO 14083 is summarised in chapter 6. This is accompanied with **examples** in chapter 7.

Finally, in chapter 8, **additional guidance** is given in relation to measuring energy consumption, partitioning electricity use at the level of activity clusters, suppliers' electricity mixes and on-site generation as well as average greenhouse gas emission intensity values for logistics hubs.

Navigating through the guide – short cut via key words

2 General principles and terms of GHG emissions accounting

General principles of greenhouse gas (GHG) emissions accounting of transport and logistics chains already exist at the international level (e.g., (ISO 14064-1)) and have been further specified in the ISO 14083 with view to logistics. These are described briefly in the following.

System boundaries & GHG source

The large variety of logistics hubs, and an even wider range of corresponding operations and services, makes it necessary to derive clear **system boundaries** for emissions accounting. The ISO standard defines which processes shall be covered within emissions accounting as they release GHG into the atmosphere (**GHG source**) i.e., also referred to **normative scope**. Furthermore, the ISO outlines optional processes that may be covered (**optional scope**, see relevant informative Annexes) and those processes that shall not be included (out of scope). For logistics hubs the assessment scope can be summarised as follows: Transhipment processes consuming energy or release refrigerants are in the normative scope, comparable warehousing and (re)packing processes are optional. Further details are provided in chapter 4.

Direct and indirect emissions

GHG emissions of logistics chains are mainly caused by the use of energy. **Direct emissions** are caused by burning fuels (e.g., diesel, gas) or leakage of refrigerant gases while **indirect emissions** are emissions associated with the production and supply of the fuels as well as of electricity used and transport packaging needed for e.g., safety measures.

Scope 1 to 3 of GHG Protocol

The Greenhouse Gas Protocol (WRI 2004) uses the terms **scope 1 to 3**. In the context of emissions of logistics hubs operated by a reporting company, Scope 1 emissions correspond to emissions caused by the facility and vehicles on-site, whereas Scope 2 and 3 refer to indirect emissions generated in the course of upstream and downstream activities.

When talking about GHG emissions of fuels used in vehicles, indirect emissions are often referred to as **well-to-tank** (WTT) emissions and direct emissions as **tank-to-wheel** (TTW) emissions. When totalling both, **well-to-wheel** (WTW) emissions are accounted.

Energy provision, operation & packaging life cycle GHG emissions

ISO 14083 introduces additional terms for differentiating GHG emissions, as none of the above approaches have proofed to be fully applicable for logistics chains in general i.e., for all transport modes and hubs. The term **energy provision GHG emissions** refers to the release of greenhouse gases during the production, storage, processing, and distribution of energy carriers for logistics operation i.e., indirect or WTT emissions. Whereas **operation GHG emissions** refers to the release of GHG due to operating hub equipment or vehicles i.e., direct or TTW emissions. In addition, the standard also uses the term **packaging life cycle GHG emissions** that are caused during the life cycle processes of transport packaging used at logistics hubs during (re)packing of goods.

GHG activity & GHG activity data

For calculating GHG emissions of logistics hubs, the relevant activities causing GHG emissions of all processes are monitored, and the relating data is collected (i.e., **GHG activity data**). The **GHG activities** refer to the energy use, leakage of refrigerants and – optional – to the use transport packaging material.

Data type

The quality of the GHG emissions results is determined by the quality of the data sources. **Primary data** refers to values of processes or activities that are based on direct measurements or calculations based on direct measurements. All other data not fulfilling these requirements is categorised as **secondary data** (ISO 14083 sections 3.3.3 and 3.3.4). In practice, all data used in the assessment may be a mixture of both data types. The company should transparently document if (and where) other than measured data is used and which underlying assumptions are applied, see also chapter 6.

Assessment period of up to one year

Emissions are often accounted on an **annual basis** to balance out seasonal effects. This can be either a single calendar year or the relevant inventory year of the reporting company. The ISO 14083 recommends an assessment time period of one year or less (ISO 14083 section 7.1).

GHG emission factors

So called **GHG emission factors** are used for converting e.g., the amount of fuel used into the GHG emissions. These coefficients relate to the individual types of fuels (e.g., diesel, gasoline, biodiesel) or mixtures thereof (e.g., diesel with 7% biofuels content) as well as the related productions processes and supply chains that may strongly differ between regions and over time. The ISO recommends the use of the most current values to ensure comparability of calculations (see ISO 14083 Annex K). Therefore, this guide highlights some recommended sources providing or tools using GHG emission factors relevant for logistics hubs (see section 9.1).

Greenhouse gases

The assessment is to cover all relevant **greenhouse gases** (GHG). Focussing on carbon inventories of logistics hubs, the most commonly included GHGs are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), as well as climate relevant refrigerants e.g., R-410A, R-404A, R-134a, R-448a and R-744 (carbon dioxide). The Intergovernmental Panel on Climate Change publishes a list of GHGs in their assessment reports (IPCC 2023).

Carbon dioxide equivalents (CO_2e) & global warming potential

All accounted GHG emissions are expressed in terms of **carbon dioxide equivalents** (CO_2e). For this, the so-called **global warming potential** (GWP) comes into play. GWP reflects how much a greenhouse gas contributes to global warming over a chosen time horizon, relative to carbon dioxide. These conversion factors are published by the IPCC: the latest is the 6th Assessment report (Smith et al. 2021). A selection of GWP values with a 100-year time horizon are given in Table 12 in section 9.1. When using emission factors from other frameworks or methodologies (e.g., GLEC Framework (SFC 2023), EcoTransIT World 2023), the company should make sure the GWP refer to the same time horizon.

Unit of activity = amount of outgoing cargo

Carbon accounting aims to enhance the transparency of GHG emissions caused at a logistics hub and enable the tracking of emissions as well as reduction measures over time. For this reason, there is a need for a consistent unit of **hub activity** that enables a comparison over the years. The **throughput** measured by the **quantity of freight (outbound)** in [tonnes] is recommended as it can be applied for most types of logistics hubs. The ISO 14083 also allows the use of alternative units for the quantity of freight: For instance, at container terminals the number of containers or TEUs is often used, whereas for roll on/roll off terminals the number of vehicles is more reasonable. Additional alternative units are the number of items (e.g., post and parcel hubus) or m³. at bulk terminals. **Freight** refers to any quantity of goods: i.e., without any packaging (e.g., bulk cargo) or of loose items of unpacked goods, packages (parcels), or unitised goods (e.g., on pallets) including packaging (receptacle, container, wrapping) (DIN EN 14943). Therefore, the quantity of freight shall include the weight of the packaging, that was initially provided by the organization responsible for sending a consignment; it shall exclude any additional transport packaging, pallets or containers used by any other organization (ISO 14083 section 5.5). Additional guidance on choosing the unit of hub activity is given in section 8.2.

Emission intensity = GHG emissions per throughput

GHG emission intensity describes the amount of GHG emissions caused at the logistics hub per throughput. In general, GHG emission intensities are expressed in terms of the amount of GHG emissions per tonne, which is comparable to emission intensities of transport (expressed in the amount of GHG emissions per tonne-kilometre). The metric is used to provide information internally and for clients or shippers to be included in transport chain calculations (see Figure 1) or to use for the purpose of emissions intensity target setting according to Carbon Disclosure Project (CDP) (CDP 2018, C4.1b, page 39f) or for other corporate sustainability reporting (e.g., Corporate Sustainability Reporting Directive CSRD, Global Reporting Initiative GRI).

Transport chain, transport chain elements
Hub operation & hub operation category (HOC)

As shown in Figure 1, a **transport chain** is a sequence of elements related to freight from a point of origin to its destination. The relevant **transport chain elements** (TCEs) refer to transport and **hub operations**. The latter of which describes the operation in order to transfer freight through a hub.

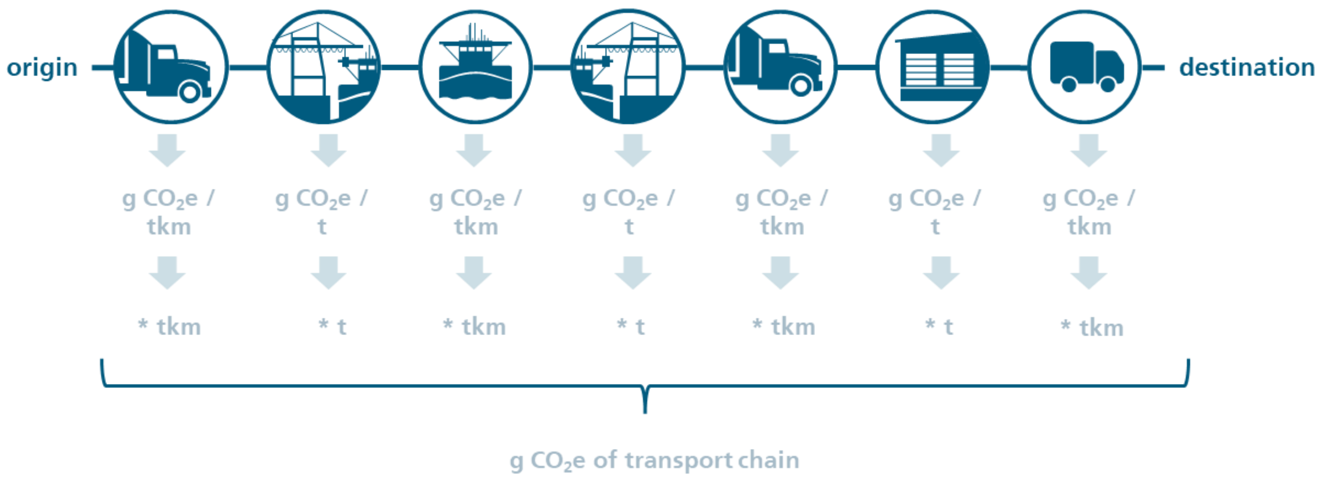

Figure 1: Calculation of GHG emissions along the transport chain

The ISO 14083 uses the term **hub operation category (HOC)**, that is defined as "group of hub operations […] that share similar characteristics" (ISO 14083, p. 2), such as processes, freight type or temperature condition of goods. The smallest coverage of a HOC refers to a full hub operation i.e., a hub operation shall not be split between two HOCs (ISO 14083 section 6.3.3.1). But a hub may perform hub operations that form part of different HOCs. A similar term is used for transport chain elements i.e., transport operation category (TOC), as shown in the following figure.

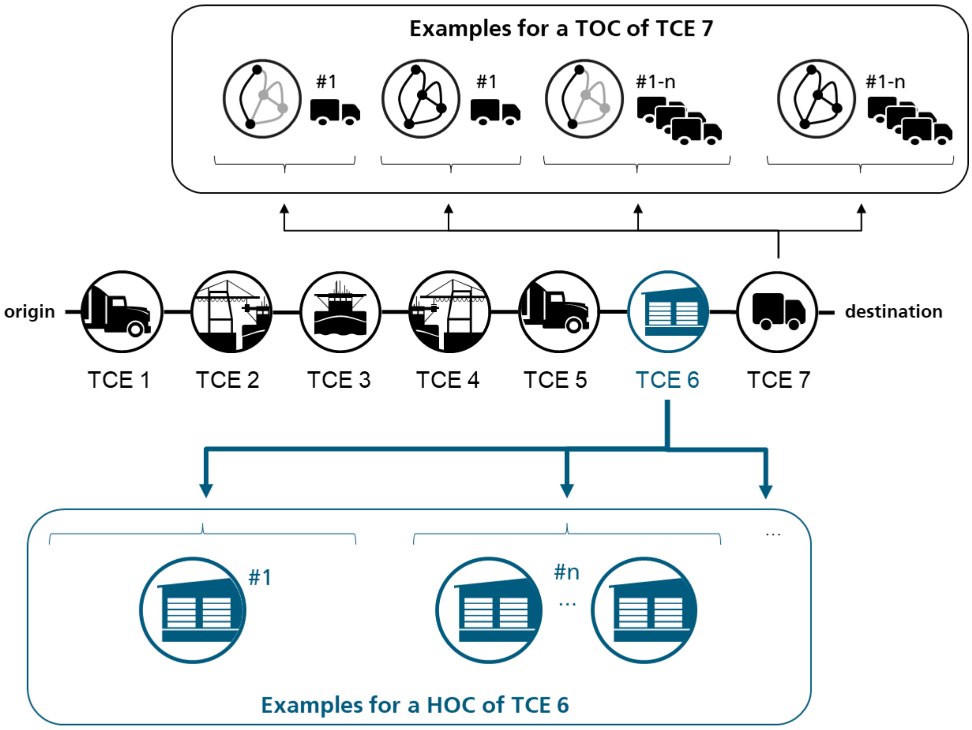

Figure 2: Hub and transport operation categories (source: own illustration based on ISO 14083 Figures 6 and 7)

3
Logistics hubs

There exist a huge variety of logistics hubs, in terms of their role within supply chains, the required and offered activities and processes as well as terms or names they are referred to with. Before outlining the assessment scope, the range of logistics hubs and typical characteristics will be introduced.

Logistics hubs are the nodes, terminals, sites, facilities, centers, and depots that connect transport legs (within and between corresponding transport modes) or are the starting or end point of a transport chain. Examples for logistics hubs are facilities such as warehouses, consolidation/fulfilment centers, distribution centers, cross-docking sites or micro depots/city hubs. The given examples refer to hubs that represent one location.

Differentiation of hubs, terminal, ports

On the other hand, a hub may be an autonomous entity within a larger infrastructural facility of freight transport. This is often the case for terminals at maritime or inland ports (for containerized goods, liquid, or dry bulk), roll on/roll off terminals, freight and intermodal terminals or cargo terminals at airports. Here, several hubs are located at one place and the relevant hub should be considered as individual entity the GHG emissions of which are calculated for. Remark: The ISO-term "hub" may interfere with the common use of "hub" that often is used for referring to a maritime or inland port as a whole.

To manage this variety, a **classification scheme** has been suggested in the previous version of the guide referring to the presence or absence of three types of requirements regarding time (stockkeeping), temperature, and order picking (following Rüdiger et al. 2016 and Arnold et al. 2008 p. 571). This scheme has been used and further elaborated by the ISO 14083 as recommended approach for describing **hub operation categories (HOCs)** (ISO 14083 Annex H). Relevant characteristics are summarized in the Table 1.

Table 1: Characteristics for logistics hubs and HOCs (source: based on ISO 14083 Table H.1)

Processes	Freight types	Temperature condition
• Transhipment only • Combined transhipment and storage • Storage only • Combined freight and passenger transfer	• Average/mixed • Containerized/swap bodies • Palletized • Piece goods/break bulk • Dry bulk • Liquid bulk • Vehicle transfer • other	• Ambient (above +8°C) • Temperature-controlled (heated, fresh (+4°C to +7°C), sensitive (0°C to +2°C), pharmaceutical product (+2°C to +8°C), frozen (< 0°C or in case of food < -18°C))
Others: (Re)packing, inbound/outbound mode(s), technology level of equipment, size, location, age		

Hub operation categories consider different levels of granularity on the one hand e.g., HOC referring to a single hub or specific hub types in the network, and factors that affect the scale, composition and characteristics of the operations carried out on the other (ISO 14083 section 6.3.3.1). Thus, any single hub operation shall always be considered in the context of the overall system in which it takes place.

For example, it is possible to cluster hubs according to different **processes** like transhipment or combined transhipment and storage. This may be further linked to the consideration of specialities in terms of inbound and outbound mode, the technology level of equipment (e.g., electrified, or non-electrified), size or age of the hub. In addition, the **freight type** can also be used to categorize hub operations into HOCs e.g., containerized, palletized, liquid bulk freight. Lastly, a classification can be made with regard to any processes essential for maintaining the **condition** of the freight, which are associated with additional energy or refrigerant use and related emissions e.g., temperature-control, (re)packaging.

Based on this, it is recommended that HOCs are structured on a suitable combination of the influencing factors as listed above. Thus, a hub operation category is the summary of hub operations with similar characteristics in a defined period (up to one year).

4
Assessment boundaries

Compliant with the internationally accepted GHG protocol (WRI & WBCSD 2004), a GHG inventory is to ensure that it appropriately reflects the GHG emissions of the operations and serves the decision-making needs or reporting requirements of users. This chapter outlines the relevant GHG emission sources and activities of logistics hubs that are to be included in scope of the emissions accounting, clearly highlighting normative (i.e., mandatory) and optional issues of the ISO 14083.

Logistics hubs represent individual transport chain elements (TCEs). So, the boundary for assessing emissions from logistics hubs begins when the consignment is unloaded from the inbound vehicle/vessel and ends when the goods are either handed over to the recipient or reloaded onto the outbound vehicle/vessel.

Often logistics hubs enable both, the direct transshipment of goods within few hours or even less as well as buffering or (intermediate) storage of goods. A definition or limitation of dwell time to clearly distinguish between transshipment and storage is not available and difficult since it strongly depends on the relevant industry sector of goods handled. If a company wants to differentiate between the related emissions, allocation of emissions might be necessary (see section 5.4).
In practice, this differentiation is often not necessary. However, with view to the ISO 14083 implementation some companies may face a discussion on how to clearly differentiate. While the consideration of transshipment processes according to ISO 14083 is mandatory, the consideration of storage or (re)packing of cargo is optional. And the latter i.e., coverage is optional, already provides the possibility to avoid too technical discussions: If a company decides to cover any of the optional processes (e.g., warehousing, or (re)packing), this is ISO compliant but shall be noted accordingly.

Generally, the ISO 14083 requires calculation of GHG emissions related to the consumption of energy carriers and leakage of refrigerants. In the following the assessment boundaries for logistics hubs are described in more detail. The ISO 14083 defines the assessment boundaries for hubs in the section 5.2 and Annexes H and O.

Transport and handling of goods by dedicated on-site vehicles and equipment

The operation of all vehicles and equipment, used on-site of the hubs' premise and relevant for the transfer (i.e., unload, move, load) of the goods or shunting manoeuvring vehicles/vessels or trailers, containers, or swap bodies around on-site are to be included in the assessment. This may cover **equipment for yard logistics**, **ground support (GSE)**, **apron** and/or **ramp services** resp. **ramp**

handling as well as **material handling equipment (MHE)**, thus, regardless of whether outdoor or indoors.

If a vehicle or equipment is used between two hubs (e.g., at maritime ports), the energy use has to be allocated as a total to one of the hubs or shared between both hubs as long as both hubs belong to one HOC. The chosen procedure shall be applied consistently e.g., for all processes between the hubs and over time.

- Examples outdoor: cranes, reach stackers, straddle carriers, dedicated onsite trucks, pumps, push or tugboats, shunting or aircraft pushers
- Examples indoor: industrial trucks, automated guided vehicles (AGV) or automated mobile robots (AMR), conveyors, forklifts, rack feeders, shuttle systems, lifts, or cranes

Transport of employees and staff

The vehicles/vessels or equipment that transport employees who steer self-driving vehicles in a roll on/roll off terminal are to be included in the assessment.

- Examples: pilot boats or shuttles

The propulsion energy required for loading the self-driving vehicles, however, is excluded, as illustrated below. Also, the transfer of crew members or drivers of inbound/outbound vehicles/vessels is excluded from hub emissions, as are commuting of employees or staff.

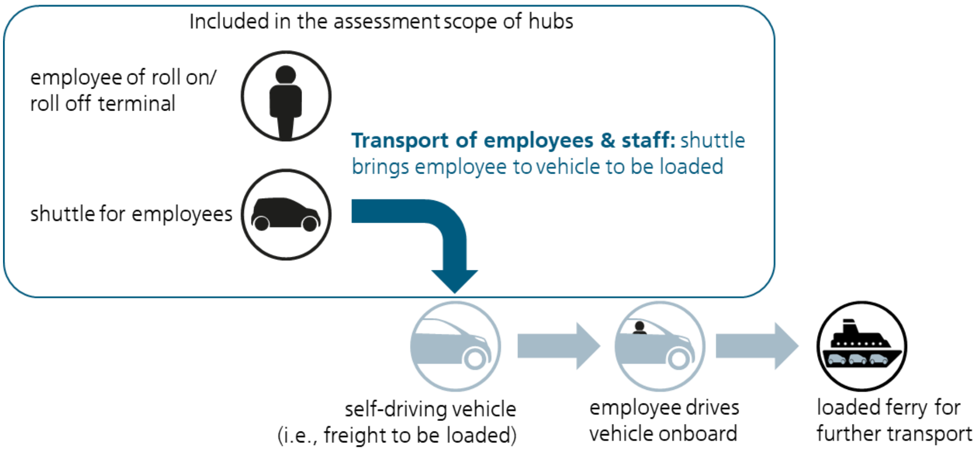

Figure 3: Transport of employees on-site at e.g., roll on/roll off terminals

Building or other infrastructural services

Hub processes shall include the operation of all other facilities, buildings or other infrastructure on-site needed for operating the location.

- Examples: Lighting, heating and air-conditioning (HVAC), temperature control of goods, on-site server rooms, administrative facilities related to freight movement at the hub, yard lighting, diesel generators, heating/cooling of reefers/tanks.

Additional equipment/facilities but generally of minor relevance include weighing equipment, workshops, or reception buildings.

While ICT-services provided by on-site infrastructure is to be included into the hub processes, those purchased by external service providers (e.g., by means of cloud services) are specified in ISO 14083 as optional processes.

Inbound and outbound vehicles/vessels

At logistics hubs, consignments often arrive and leave via road vehicles or load carriers e.g., container, swap body. If these are loaded on vehicles also used for inbound or outbound transport, the on-site-operation of these vehicles is out of the scope of the emissions accounting at the hub. These emissions shall be covered by transport TCEs. As are the possible fuelling or charging of vehicles or refill of refrigerants of reefer containers at a hub.

If those vehicles/vessels use energy while temporarily at a hub (e.g., ground power in airports or shore power in ports), the related GHG emissions should be assigned to the transport TCE as well. Alternatively, the emissions may be assigned to a hub TCE, however, this shall be handled "[…] in a consistent manner in order to ensure all GHG emissions are allocated and documented transparently" so that correct interpretation of GHG emission results is enabled.

Energy life cycle

All previously mentioned equipment, vehicles, facilities, and processes cause GHG emissions due to their energy use i.e., the use of different fuels such as diesel, biodiesel, natural gas, district heating or the use of electricity. Regarding the **energy life cycle**, the processes listed in Table 2 shall be covered by the assessment.

Table 2: System boundaries of energy (source: ISO 14083 section 5.2.2)

	Processes included
Solid, liquid, gaseous energy carriers	Production and dismantling of energy source infrastructure, extraction or cultivation of primary energy, chemical processing, transport, and distribution of energy at all steps of the production of the energy carrier used.
Electricity/power	Extraction, processing and transport of primary energy, power generation, power generation infrastructure (e.g., solar panel or wind turbine manufacture), grid losses associated with transmission and distribution of electricity

If diesel is used on-site to generate electricity, caution is needed to not double count the related emissions (i.e., diesel use and electricity-based-on-diesel use) .

Equipment for storage of goods

The ISO 14083 provides the possibility of including the **storage of goods** at hubs, such as warehouses or combined transhipment and storage sites, for short-, medium-, or long-term storage. The approach for warehouses with equipment for stocking, storing and retrieval is comparable to the one of transhipment sites.

Examples: rack feeders, shuttle systems, high-bay warehouses, high density storage systems automated small parts stores, the related equipment for lighting, or temperature-control.

(Re)Packing processes

The quantification of GHG emissions related to (re)packing processes are also outlined as optional processes by the ISO 14083.

At logistics hubs, the consolidation of shipments as well as changing their physical character by picking, customizing and (re)packing processes is a relevant task. The GHG emissions of (re)packing processes refer to the use of energy as well as life-cycle emissions of transport packaging (i.e., production, supply of transport packaging as well as collection, reuse, recycling, and end of life treatment).

Such order picking activities are required to satisfy customers' orders and consist of the collection and compilation of articles in a specified quantity. Supplementary activities may include counting, weighing, packing (e.g., retail promo displays), labelling, confectioning, customizing (e.g., installing software on computer) or adding a cable or plug to electrical appliances) or other value-added services (VAS), to name a number of examples. Here, operators are responsible for preparation for onward transport and transport packaging (e.g., stretch or shrink foil, cardboard layers, strap band) is used or waste may be produced. Hub operators as well as shippers and consignees may influence the type and amount of packaging and the associated environmental impact. This includes:

1. Strategies regarding one-way transport packaging based on primary fossil resources, recyclables and/ or renewable resources causing different types of environmental impact during production, supply and end-of-life
2. Strategies regarding reusable transport packaging such as pool pallets or containers that require balancing transport within logistics networks

Hence, the quantification of GHG emissions related to transport packaging may contribute to enable a hub’s decarbonisation roadmap.

Additional processes not included

A clear description of the assessment boundaries is enabled by the further specification of those processes to be excluded from the GHG emissions quantification. Regarding logistics hubs, ISO 14083 section 5.2.4 refers to processes of construction, service, maintenance or dismantling/scrapping of vehicle/equipment or infrastructure (e.g., yard, real estate). In addition, the production and supply of refrigerants shall also be excluded as are waste production (e.g., in the context of (re)packing), or processes at the administrative (overhead) level of the organisations.

As outlined before, Scope 3 emissions resulting from employee commuting are excluded from the assessment scope defined by the ISO 14083. This is a reasonable simplification for global transport chain discussions. If a company plans to compare emission intensities of two (or more) hubs with different levels of automation, it is reasonable covering those emissions for such an individual exercise/analysis. At hubs with a high level of automation, automated materials handling equipment consume electricity, while hubs with mainly manual processes (i.e., a low level of automation) usually require more (commuting) staff for the same services. Covering emissions caused by employee commuting creates a level playing field. However, reporting emissions related to employee commuting shall be reported separately to ISO 14083 results.

Carbon offsetting

The ISO 14083 specifies that carbon offsetting and GHG emissions trading shall not be considered when quantifying GHG emissions of transport chain operations. (ISO 14083 section 5.2.7) This is shortly covered in section 8.6 on carbon neutral and net zero hubs.

5 Procedure for GHG emissions calculation

5.1 General remarks on collecting data

Companies operating their own logistics hubs can easily collect the relevant data of their operations i.e., GHG activity data and logistics data.

GHG activity data

Generally, **GHG activity data** (e.g., data on energy consumption, refrigerant leakage) should be available for any logistics hub, since this information refers to resources purchased that are of economic relevance to the operators. However, there might be some obstacles to overcome in the early stages of emissions accounting. For example, the data might be collected and stored by different departments or at different locations (e.g., central procurement) within an organisation, not at the hub for which emissions are being calculated. In this case, identification of the relevant department/ contact and access to the relevant information may require more effort. In addition, data may be stored in formats (e.g., scanned invoices) that require manual processing, or the information may not be equivalent to the assessment boundaries at hand (e.g., purchased amount for various hubs, different balance years, etc.). Greater obstacles may arise if the logistics facility is leased, and the cost of energy consumption is included in the rental.

Although the challenges outlined above may apply, most logistics hubs are very much aware of the resources purchased and consumed. The company's warehouse management systems (WMS), Enterprise Resource Planning (ERP) system or alike may offer sufficient information access.

Hub activity data

Data on the hub activity i.e., the throughput of a hub refers to information on handling activities and shipments and are usually processed at hub level and data can be collected from the WMS or even at the equipment level (e.g., activities of a forklift, pallets entering the high bay warehouse).

Data is generally collected **for one year**, as outlined chapter 2 (see assessment period). If data refers to less than one year, extrapolation can be applied.

Primary data on consumption & secondary data

If this data is obtained from a direct measurement or a calculation based on direct measurements, this data is also referred to as **primary data** (ISO 14083 section 3.3.3). Here, "direct" measurement refers to the fact that collected data refers to the hub activity GHG emissions are calculated for. All other data is called **secondary data**, and the ISO further sub-divides it into modelled data and default values. The data types are summarised in the following table.

The measurement or modelling of data does not need to be processed by the reporting organisation. The latter may refer to measured data provided by the subcontractor as well. The ISO 14083 refers to this approach with "Collection of a value from a contracted operator" (ISO 14083 section 7.2.6) who provides GHG emission intensity values that have been established using primary data or a model. An example with regard to hubs is when the contractor (hub operator) provides primary data in the REff Tool® and reports the calculated hub-specific emission intensity values (kg CO_2e per tonne) to the reporting company which can use the emission intensity in its own transport chain calculations.

Table 3: Potential data sources

Data quality	Options	Example
Primary data	Measured data	Direct measurement or a calculation based on direct measurements.
Secondary data	Modelled data	Use of specific consumption factors relating to selected processes e.g., litre of diesel or kWh of electricity per day of technical equipment, which is used to model the hub operation or specific processes.
	Default data	Use of average GHG emission intensity values for defined hub types that are ideally related to the HOC characteristics (see Table 1); they typically refer to throughput or the logistical area (g CO_2e per tonne, per TEU or per m² logistics area indoor).

5.2 Definition of hub operation categories

The ISO 14083 defines the hub operation category with "group of hub operations […] that share similar characteristics […]" (ISO 14083, p. 2). It represents the basis for subsequent GHG quantification and derivation of key performance indicators such as the emission intensity value i.e., GHG emissions per throughput.

The highest level of granularity of a HOC is a single hub as shown in Figure 4. The ISO defines that "[…] a hub operation shall not be split between two HOCs, even if this operation simultaneously benefits different TCEs, […]" (ISO 14083, p. 25) such as TCEs for ambient and temperature-controlled freight. But a hub may perform hub operations that form part of different HOCs. Alternatively, a HOC may cover a number of hubs of a specific hub type with related characteristics as described in chapter 3.

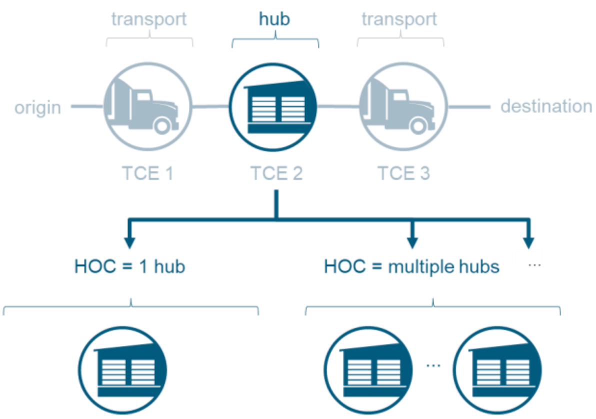

Figure 4: Level of granularity for defining a hub operation category (HOC) (source: based on ISO 14083 Figure 7)

When a hub or a number of hubs of a defined HOC provides different functionalities allocation is needed. Examples are when both ambient and temperature-controlled freight is handled, or containerised and dry bulk freight is handled. Calculating GHG emissions and emission intensity values for HOCs where allocation is needed is described in section 5.4. Before, the calculation procedure without allocation is described. Examples are given in chapter 7.

Procedure for GHG emissions calculation

5.3 Calculating GHG emissions without allocation

This section describes all relevant steps for the calculation of one average emission intensity value for a hub operation category, i.e.:

1. Collection of GHG and hub(s) activity data
2. Calculating total emissions of hub operations
3. Calculating the average emission intensity value for the HOC

5.3.1 Collection of GHG and hub activity data

There is a variety of infrastructure, equipment and activities at logistics hubs that require resources as outlined in chapters 3 and 4. Global market studies performed between 2021 to 2023 (Fraunhofer IML 2023a) provided an overview of currently used resources and sources of GHG emissions at logistics hubs, covering a total sample size of 843 hubs (Figure 5).

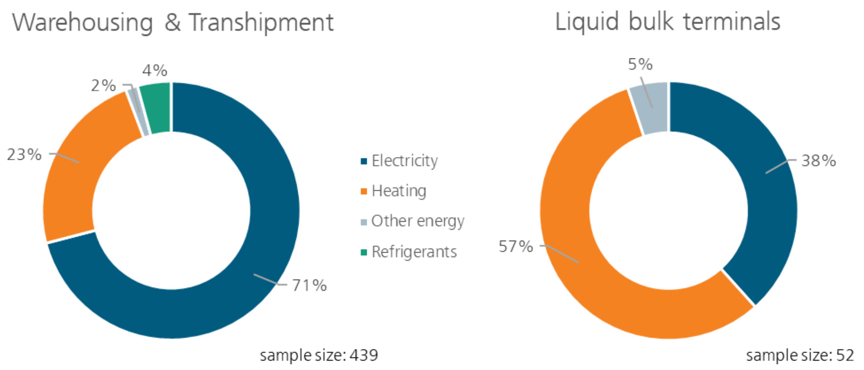

Figure 5: GHG emissions at selected logistics hubs (source: Dobers et al. 2023b)

While the highest share of GHG emissions of warehousing and transhipment hubs are related to electricity use (GHG emissions calculated using the location-based approach), heating emissions are most relevant at liquid bulk terminals. Natural gas is the main heating energy source, liquid bulk terminals also use steam for heating purposes. Energy sources for non-electrified material handling are diesel, biodiesel, LNG, or LPG. The refrigerant types R-410A, R-717 (ammoniac), R-404A, R-134A, R-448a and R-744 are the most frequently used ones as specified by the participating hubs.

For each hub being part of the HOC the reporting company records the relevant **GHG activity data** i.e., the quantity of electricity, fuels and refrigerants consumed for the operation for the assessment period. It is important to collect the data per individual fuel and refrigerant type (favourably using aligned units per type across hubs), since the later calculation of related GHG emissions require individual GHG emission factors.

Typical types of fuels used for heating or material handling are listed below. A list of refrigerant types is provided in Table 12.

- **Heating energy:** Natural gas, biogas, heating oil, district heating, LPG, geothermal energy, wood chips, wood pellets (used in single heating systems or combined heat and power (CHP) or even combined cooling, heat and power (CCHP) systems)

- **Material handling:** electricity, diesel, biodiesel, petrol, ethanol, LPG, LNG, CNG, hydrogen, propane

The data for each fuel and refrigerant type may be realised as a total for the relevant HOC, covering all hubs combined in this HOC. However, for reasons of clarity and for enabling the calculation of hub specific emission intensity values and, thus, the monitoring and internal comparison of similar hubs, it is recommended to list the data for each hub individually.

A template for collecting GHG activity data with the respective typical units is provided in Table 4.

Note:
The consumption of refrigerants can usually be measured by its refill. If refrigerants are refilled into vehicles or load units (e.g., reefer containers), the relevant amount shall be included in the GHG emissions calculation of the transport TCE. As is the consumption of energy (electricity and fuels) for refuelling/recharging vehicles for inbound or outbound transport.

The consumption of fuel blends (e.g., diesel/biodiesel blend) may be collected as one figure per hub if the blend remains the same for all hubs e.g., 7% biodiesel. In this case, the relevant emission factor for this blend needs to be selected later on.

If diesel or other fuels are used to generate electricity (e.g., emergency generators), the fuel consumption is recommended to be used as the basis for calculating emissions to avoid double counting. This may entail, to adjust the hub´s electricity consumption by the electricity generated by diesel or other fuels.

The reporting company also records the related throughput of the hub(s), which is the **hub activity** and refers to the quantity of freight (outbound). This is generally measured in tonnes; however, alternative units may be used e.g., pallets or boxes. In this case, the company should define a conversion factor (e.g., on average 300 kg/pallet) for finally calculating tonne-based emission intensity values that can be used for transport chain calculations.

Table 4: Collection of GHG activity data and hub activity data

From dd/mm/yyyy **To** dd/mm/yyyy **Hubs of the HOC**	**Electricity [kWh]**	**Diesel [litre]**	**Biodiesel [litre]**	**Natural gas [MJ]**	**R-410A [kg]**	**Other types [unit]**	**Throughput [tonne]**
Hub 1: name							
Hub 2: name							
…							
Total consumption of HOC							

Note:
The ISO 14083 allows for alternative units for hub activities in specific circumstances such as for the post and parcel sector or containerized freight. Here, the quantity of freight may be the number of items or twenty-foot equivalent (TEU) respectively.

Other relevant base units for deriving key performance indicators (KPIs) of logistics hubs (e.g., m² logistical area indoor, m³ cubature of the building) are discussed in section 8.2.

5.3.2 Calculating total emissions of hub operations

When all consumption data has been collected for the assessment year, the total GHG emissions of the HOC (covering one or more hubs) can be calculated. The total emissions are to be calculated item by item for each energy type or refrigerant type as showed in a simplified manner below.

Figure 6: GHG emissions quantification for logistics hubs in accordance with ISO 14083

The ISO 14083 requires the separate reporting of emissions due to energy provision and due to operation, which is the reason why those should be calculated separately right from the beginning:

- calculating GHG emissions due to hub equipment energy provision (HEEP) of HOC, and
- calculating GHG emissions due to hub equipment operation (HEO) of HOC.

Equation 1:
Calculation of total emissions of logistics hub(s) and HOC

$$G_{HEEP,HOC} = \sum_{hub} \sum_{i} (Q_{HOC,A_i} \times \varepsilon_{HEEP,A_i})$$

$$G_{HEO,HOC} = \sum_{hub} \sum_{i} (Q_{HOC,A_i} \times \varepsilon_{HEO,A_i})$$

$$G_{HOC} = G_{HEEP,HOC} + G_{HEO,HOC}$$

G_{HOC}	Total GHG emissions of HOC [kg CO_2e] covering one or more hubs
Q_{HOC,A_i}	Amount used or refilled [kWh, l, kg, m^3]
$\varepsilon_{....,A_i}$	Relevant emission factor [kg CO_2e per unit] for hub equipment energy provision (HEEP) or operation (HEO)
A_i	GHG activity type i.e., electricity, fuel type, refrigerant type

Procedure for GHG emissions calculation

5.3.3 Calculating the average emission intensity value for the HOC

For the calculation of an average emission intensity value of the HOC, the following simplified formula applies.

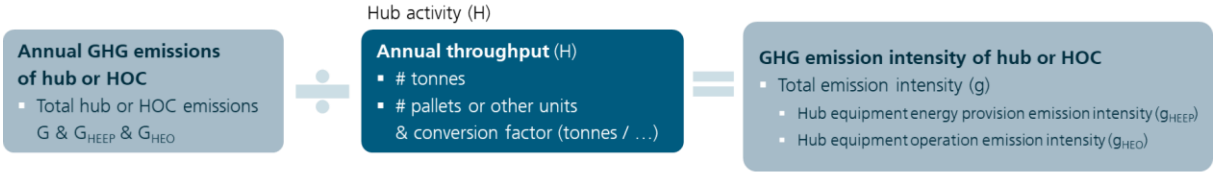

Figure 7: Calculating the emission intensity value for the HOC in accordance with ISO 14083

The total annual emissions of the hub is divided by the annual throughput of the hub.

Equation 2: Calculation of average emissions intensity value

$$g_{HEEP,HOC} = \frac{G_{HEEP,HOC}}{H_{HOC}} \qquad g_{HEO,HOC} = \frac{G_{HEO,HOC}}{H_{HOC}} \qquad g_{HOC} = \frac{G_{HOC}}{H_{HOC}}$$

g_{HOC}	GHG emission intensity value [kg CO_2e/tonne]
G_{HOC}	Total GHG emissions of HOC [kg CO_2e] covering one or more hubs
H_{HOC}	Hub activity (annual throughput) of HOC [tonne]

5.4 Calculating GHG emissions with allocation

Allocation is needed when multiple services are fulfilled by the hub which may have different characteristics.

This section describes all relevant steps for calculating GHG emissions with allocation i.e., the calculation of GHG emissions and emission intensities per relevant group freight:

1. Collection of GHG and hub(s) activity data at the level of groups
2. Calculating total emissions of hub operations
3. Calculating the average emission intensity value for the HOC

5.4.1 Collection of GHG and hub(s) activity data at the level of groups

For each hub being part of the HOC the reporting company records the relevant **GHG activity data** i.e., the quantity of electricity, fuels and refrigerants consumed for the operation for the assessment period. Typical resources used and sources of GHG emissions at logistics hubs have been described in section 5.3.1 (see Figure 5). It is important to collect the data per individual fuel and refrigerant type (favourably using aligned units per type across hubs), since the later calculation of related GHG emissions require individual GHG emission factors.

Since the resources may be used for different groups of entities (e.g., goods requiring different temperature-conditions), the **allocation** i.e., the partitioning, **of GHG emissions** is needed. This is eased by separate data collection of GHG activity data e.g., at equipment level. For reasons of clarity and for enabling the calculation of hub specific emission intensity values and, thus, the monitoring and internal comparison of similar hubs and groups of freight, it is recommended to list the data for each hub individually.

As general guidance, the following separation of GHG activity data may help, dependent on the relevance at the hub(s) at hand:

1. Energy used for
   a. material handling only (indoors and on the yard)
   b. storage (equipment for stocking, storing and retrieval)
   c. order picking
   d. other activities and equipment relevant for all goods, such as ICT, offices, workshops, weighing stations
2. Lighting (if needed and possible for different functional areas)
3. Consideration of the temperature requirements of goods

An indicative template for collecting separate GHG activity data with the respective typical units is provided in Table 5. In the context of allocation, it might be relevant to collect GHG activity data at equipment level and their sum equals the total consumption of the hub.

Note:
The consumption of refrigerants can usually be measured by its refill. If refrigerants are refilled into vehicles or load units (e.g., reefer containers), the relevant amount shall be included in the GHG emissions calculation of the transport TCE. As is the consumption of energy (electricity and fuels) for refuelling/recharging vehicles for inbound or outbound transport.

The consumption of fuel blends (e.g., diesel/biodiesel blend) may be collected as one figure per hub if the blend remains the same for all hubs e.g., 7% biodiesel. In this case, the relevant emission factor for this blend needs to be selected later on.

If diesel or other fuels are used to generate electricity (e.g., emergency generators), the fuel consumption is recommended to be used as the basis for calculating emissions to avoid double counting. This may entail, to adjust the hub´s electricity consumption by the electricity generated by diesel or other fuels.

An indicative template in Table 5 also covers data on the hub activity to be collected. The reporting company records the related throughput of the hub(s), which is the **hub activity** and refers to the quantity of freight (outbound). In the context of allocation, the throughput needs to be collected separately per specific group, their sum equals the total throughput of the hub.

The hub activity is generally measured in tonnes; however, alternative units may be used e.g., pallets or boxes. In this case, the company should define a conversion factor (e.g., on average 300 kg/pallet) for finally calculating tonne-based emission intensity values that can be used for transport chain calculations.

Procedure for GHG emissions calculation

Table 5: Collection of separate GHG activity data and hub activity data for later allocation

From dd/mm/yyyy **To** dd/mm/yyyy **Hubs of the HOC**	**Electricity [kWh]**	**Diesel [litre]**	**Biodiesel [litre]**	**Natural gas [MJ]**	**R-410A [kg]**	**Other types [unit]**	**Throughput [tonne]**
Hub 1: name							
Equipment level 1 (specific group1)							
Equipment level 2 (specific group2)							
Hub 2: name							
Equipment level 1 (specific group1)							
Equipment level 2 (specific group2)							
…							
Total consumption of HOC							

Note:
The ISO 14083 allows for alternative units for hub activities in specific circumstances such as for the post and parcel sector or containerized freight. Here, the quantity of freight may be the number of items or twenty-foot equivalent (TEU) respectively.

Allocation

Wherever possible, allocation should be avoided by more detailed data gathering. Whenever there is no other choice, allocation shall partition GHG emissions considering specific characteristics. While handling ambient and refrigerated freight within a hub, the energy consumption for cooling and the leakage of refrigerants can be partitioned between these two characteristics easily. However, it may be difficult to split electricity and fuel burn for freight and non-freight related activities e.g., at hubs with additional (non-freight related) processes such as general administration, or value-added services. In such cases, logistics hub operators are encouraged to make these calculations based on the best available information and transparently record any potential anomalies when reporting. For logistics hubs that are jointly operated (e.g., multi-tenant hubs with central metering), allocation of emissions should be based on the throughput tonnage by each operator.

Definition of specific group

As a start, the reporting company shall identify the relevant **specific groups** for the defined HOC. This depends on the relevant characteristics as introduced in Table 1 and their combinations.

In the following, guidance is provided how allocation can be realized i.e., which allocation principles can be used for hub processes and GHG activity data collection. The selected allocation principles shall remain constant over time and shall be documented transparently.

Energy consumption of materials handling, storage, and other equipment

Depending on where materials handling equipment is used, its energy consumption can be allocated to the respective functional area or activities such as transhipment and storage.

For the calculation of **storage** emissions, the energy consumption of all relevant materials handling equipment used in the storing area (e.g., conveyors, forklifts) or storage equipment (e.g., high-bay warehouse) is collected. If electricity is also used for running the heating or cooling equipment as well as during order picking or dispatch, only the amount of electricity relevant to storage is considered here. This is generally the total electricity consumption minus electricity used for heating, cooling, order picking and dispatch. The allocation of electricity consumption for lighting the storage area is described below.

Similarly, data relating to energy consumption by **transhipment** activities can be collected.

(Re)Packing and order picking activities often are manual or semi-manual e.g., using forklifts. Energy consumption (usually electricity) may refer to the use of conveyors, forklifts, or other relevant equipment as well as the lighting of the order picking area.

Usually, there are **general processes** used for all shipments, where energy consumption is difficult and/ or time consuming to allocate e.g., goods receipt, dispatch, IT infrastructure or offices. These may be summarized in one general group, the emissions of which are allocated evenly to all shipments.

Electricity consumption of lighting

Regarding the electricity consumption of **lighting**, companies may have access to smart metering systems that offer the annual power consumption at sub-levels (e.g., lighting system). However, the substructure of the metering system may not be applicable to use here. This means that the operator may know the electricity consumption of the total lighting system but not the share of relevant activities such as storing (lighting in storage area) or picking (lighting in picking area).

For this reason, it is often necessary to estimate the electricity consumption of lighting per **functional area**. Here, a functional area is a defined zone of the logistics facility in which specific operations take place, as indicated in Figure 12 (see section 0) . Alternatively, e.g., if no measured electricity consumption is at hand, the operator may collect the total (or area-specific) **installed capacity** (e.g., total number of lights and their respective capacity) and multiply this by the average operation time of the lights (see example in section 7.6).

Procedure for GHG emissions calculation

Consideration of the temperature requirements of goods

At some hubs goods that require different temperature-levels are handled and the energy use and possible refill of refrigerants need to be allocated. A company may differentiate between

1. Goods not requiring any energy use,
2. Goods that need to be heated (seasonally) e.g., to avoid quality loss or keep liquid state,
3. Goods that need to be chilled or even frozen.

For the calculation of heating emissions, all relevant fuel types (e.g., natural gas, district heating, diesel/biodiesel) are to be considered. If electricity is used, the operator might need to measure or estimate the electricity used exclusively for the heating system.

For the calculation of refrigerating emissions, the dedicated electricity consumption is needed, as well as the amount of refrigerants per type refilled. Again, the operator might need to measure or estimate the electricity consumption of the refrigerating devices (e.g., installed capacity multiplied with operation time).

5.4.2 Calculating total emissions of hub operations

When all separate consumption data has been collected for the defined assessment period, the total GHG emissions of the HOC (covering one or more hubs) at the level of the identified specific groups can be calculated. The total emissions are to be calculated item by item for each energy type or refrigerant type as showed in a simplified manner below.

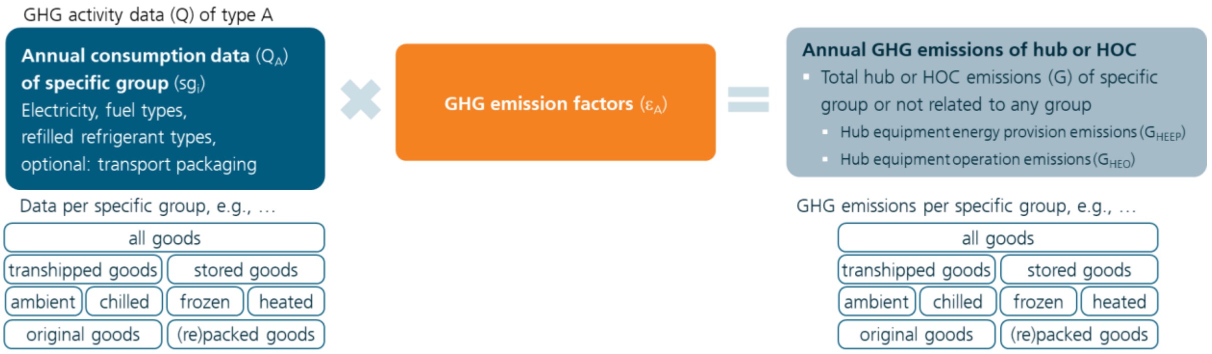

Figure 8: GHG emissions quantification for logistics hubs with allocation in accordance with ISO 14083

The ISO 14083 requires the separate reporting of emissions due to energy provision and due to operation, which is the reason why those should be calculated separately right from the beginning. The principle formulae have been provided in Equation 1. For reasons of clarity and comprehensibility, this differentiation is not duplicated in the following. Moreover, the calculation including allocation is focussed.

Equation 3: Calculation of total emissions of logistics hub(s) and HOC considering allocation

Expressed at the level of GHG activity data

$$G_{HOC} = \sum_{hub} \sum_{i} \left(Q_{HOC,A_i,all} \times \varepsilon_{A_i} + \sum_{1}^{n_{HOC}} (Q_{HOC,A_i,sg_i} \times \varepsilon_{A_i}) \right)$$

and at the level of GHG emissions

$$G_{HOC} = \sum_{hub} (G_{HOC,all} + \sum_{1}^{n_{HOC}} G_{HOC,sg_i})$$

G_{HOC} Total GHG emissions of HOC [kg CO_2e] covering one or more hubs

Q_{HOC,A_i} Amount used or refilled [kWh, l, kg] with either
sg_i for the specific group or
all not related to any specific group

ε_{A_i} Relevant emission factor [kg CO_2e per unit] for GHG activity type

A_i GHG activity type i.e., electricity, fuel type, refrigerant type

n_{HOC} Number of specific groups of the HOC

5.4.3 Calculating the average emission intensity value for the HOC

Procedure for GHG emissions calculation

For the calculation of group-specific emission intensities of the HOC, the following simplified formula applies.

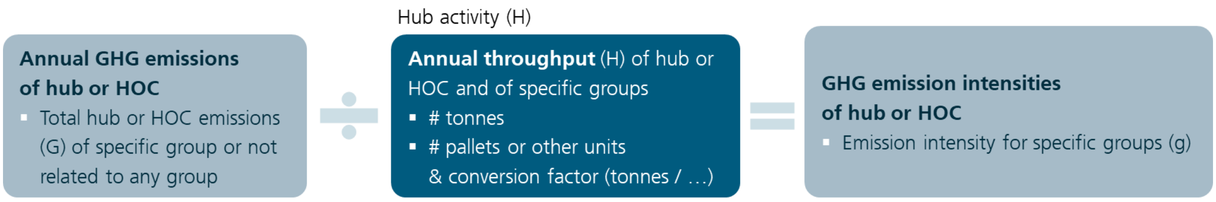

Figure 9: Calculating the group-specific emission intensity value for the HOC in accordance with ISO 14083

Again, the differentiated illustration per activity type (i.e., energy provision or operation) is left out here, see section 5.3.3. The emission intensity per specific group is calculated as follows.

$$g_{HOC,sg_i} = \frac{G_{HOC,all}}{H_{HOC}} + \frac{G_{HOC,sg_i}}{H_{HOC,sg_i}}$$

Equation 4: Calculation of average emissions intensity value of a specific group

g_{HOC,sg_i}	GHG emission intensity value [kg CO_2e/tonne] of specific group i
G_{HOC}	Total GHG emissions of HOC [kg CO_2e] covering one or more hubs with either sg_i for the specific group or all not related to any specific group
H_{HOC}	Hub activity (annual throughput) of HOC [tonne] or of the specific group

6
Reporting GHG emissions and intensity values

The calculation of GHG emissions and intensities of hubs enables different options for internal and external use as shown in the following.

First, the information can be used to provide information for clients and/ or shippers to be included in transport chain calculations. For this purpose, the calculated GHG emission intensities are multiplied by the total amount of shipments relevant for the respective transport chain element and added together with relevant transport emissions as shown in Figure 1 (see page 14) and in the example in section 0). As such use is focussed by ISO 14083, the ISO requirements regarding documentation and reporting are further described in section 0.

Moreover, the total emissions as well as the emission intensities of a hub can be internally monitored to analyse the hub's performance over the years. The allocation of the emissions to operational units, processes, sectors, or locations, for example, helps identify main sources of emissions and possible areas of improvement.

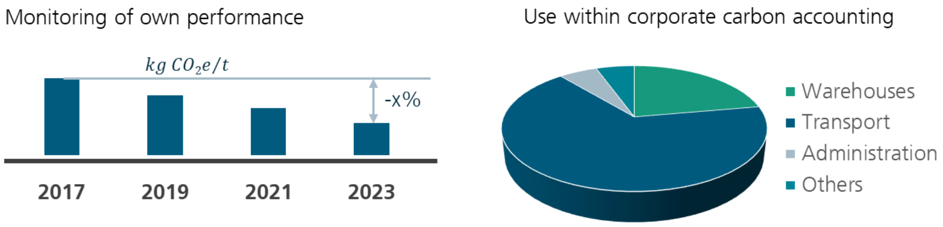

Figure 10: Monitoring of own performance and use in corporate balance sheets

To achieve this, it is important to transparently document the emissions as well as underlying assumptions. For this reason, a general framework for documentation is provided in section 6.2.

6.1 Reporting according to ISO 14083

The following outlines reporting requirements set by ISO 14083 focussing hubs. For reporting focussing transport or complete transport chains, please see ISO 14083 chapter 13.

The report may refer to two different perspectives:

1. **Organizational level**[1]
   The reported information may relate to all transport chains or parts of them the company operated or purchased and can be split into relevant organizational structures, such as geographical regions of locations, business units.

2. **Hub service level**
   The reported information may relate to single or a set of transport chain elements (TCEs), and thus to a single hub, various hubs grouped in a hub operation category (HOC) or to various HOCs.

In general, the report shall transparently outline the hub operations the information refers to as well as the calculated total greenhouse gas emissions and emission intensities.

Table 6: Framework for ISO 14083 reporting on hubs incl. refence to ISO letter value (based on ISO 14083, p. 46)

ISO	Report information as required by ISO	Application and proposed information
a)	**Identification of TCE(s) covered by the report**	[Name, location] - [country] for all hubs From [dd/mm/yyyy] to [dd/mm/yyyy]
b)	**Reference to the ISO 14083**	These calculation results have been established in accordance with ISO 1403:2023.
c)	**Total GHG emissions** i.e., operation plus energy provision	G_T = ___________________ kg CO_2e i.e., the sum of all hubs as specified in a)
d)	**Total GHG emission intensity** i.e., operation plus energy provision	g_T = ___________________ kg CO_2e/tonne
e)	**Reference to the location where supporting information is available**	e.g., webpage or download link
g)	**Hub activity** i.e., the sum of all hubs as specified in a)	H = ___________________ tonne
h)	**Operational GHG emissions** i.e., the sum of all hubs as specified in a)	$G_{HEO,T}$ = ___________________ kg CO_2e
i)	**Operational GHG emission intensity** i.e., for all hubs as specified in a)	g_{HEO} = ___________________ kg CO_2e/tonne

[1] This level is not further discussed in the following as of less relevance when just focussing hub operations only.

Remarks to ISO 14083 letter values (see ISO 14083, p. 46):

f) Not relevant, as transport activity and type of distance not applicable for hubs

i) The emission intensities may also be expressed in GHG emissions per alternative unit such as item or TEU, if relevant.

j) ISO 14083 also requests the provision of information at the level of each mode of transport and for hub operations i.e., total GHG, transport activity and/or GHG emission intensities and transport activity distance, where appropriate. When applying the report structure with the focus on hubs only, this information is already specified by (i).

Supporting information

Aiming at transparency and a clear understanding of the provided reports by the targeted users, supporting information is requested by ISO 14083 (ISO 14083, p. 47).

This shall be easily accessible (information on access is provided by letter value (e)) and refers to the ISO document (as described by (b)).

Are all relevant processes or are any optional processes included?

Whenever the calculation method deviates from the normative scope and requirements, this shall be clearly stated. In the area of hubs this specifically refers to **omitted GHG sources**, such as energy carriers or refrigerants. If any cut-off criteria have been applied, this has to be clearly stated.

In case additional GHG emissions are considered, this has to be documented as well: Firstly, this may occur, if the reporting organisation decided to include GHG emissions caused by vehicles/vessels while temporarily at a hub (e.g., ground power in airports or shore power in ports) into the hub TCE (instead of transport TCE). Secondly, this is the case if GHG emissions of optional processes are quantified in the combination with the hubs operations, such as storage and/or (re)packing.

Which hubs are included in defined HOCs?

Information on the applied **level of granularity** for defining a hub operation category (as described in section 5.2) supports transparency in related GHG emission results as well. Describe the characteristics selected, as indicated by Table 10.

To what extent do the GHG emissions results base on primary data?

Since the standard aims at a high share of primary data used for GHG emissions calculation, the use of secondary data has to be clearly stated and justified. This can be realised by outlining the **share of primary and secondary data** (the latter split into modelled and default data). This can be expressed by e.g., the total amount or the relevant shares of GHG emissions calculated based on the data categories. With view to modelling GHG emissions, the ISO refers to a tabular documentation of the model, which however mainly comes into play for transport modelling. The use of models for hub GHG quantification is less relevant and therefore not further specified here.

Use of alternative units than tonne?

In specific sectors, alternative unites for measuring throughput of a hub is reasonable and allowed by ISO 14083. In this case, the reporting organisation shall justify and transparently outline the use of an alternative unit for hub activities.

Which allocation approach has been applied?

When calculating GHG emissions with allocation (see section 5.4) the applied allocation approach shall be outlined in the report (e.g., on the basis of functional areas as used in the example in section 0).

Which emission factors have been used?

Provide information on the applied **emission factors** in the calculations. ISO 14083 covers normative requirements (see Annex J of standard) on its scope as well as it provides a list of relevant GHG emission factors and sources in an informative Annex K. When using external tools for calculating hub GHG emissions and emission intensities (e.g., REff Tool® hosted by Fraunhofer IML), the required information on applied emission factors should be clearly stated or be provided by the tool provider upon request. The following table can be used for documentation.

Table 7: Documentation of applied emission factors of fuels

Fuel type	Lower heating value [MJ/kg]	Density(1) [kg/l]	GHG emission (operational) [g CO_2e/MJ]	GHG emission total(2) [g CO_2e/MJ]	biofuel blend(3) [% energy content]	Source

(1) for liquid fuels; (2) operational and from energy provision, (3) if applicable

In case of **biofuels**, ISO 14083 recommends to separately report of indirect land use change (iLUC) GHG emissions along with clear, accompanying documentation of the sources and assumptions used.

GHG emission factors shall include production and dismantling of **energy source infrastructure**. If best available GHG emission factors do not realise this requirement, this shall be noted in the reporting.

With view to **electricity generation**, the GHG emissions arising from the related infrastructure may be quantified, documented, and reported separately. If the reporting organisation has used their own electricity mix using the market-based approach, the results shall be documented and reported separately from those calculated with the location-based approach. If the results are intended to be included in a product carbon footprint in accordance with the ISO 14067, then the reporting organisation shall report the relevant market-based electricity mix in addition.

Reporting GHG emissions and intensity values

And, finally, the report shall outline if any other than the latest **GWP 100 values** are used, which are currently published by IPCC in the sixth assessment report (Smith et al. 2021).

Does national legislation mandate different emission factors?

In some countries national legislation may require or recommend the use specific GHG emission factors, either within mandatory or voluntary GHG emissions reporting. Then, the use of these sources shall be clearly documented.

6.2 Internal documentation framework for monitoring a hub's performance

The following refers to internal monitoring tasks (Figure 10), for example. The internal documentation framework should cover additional information to Table 6 and Table 7 specifically at the hub level, such as:

1. Total annual GHG emissions of each hub
2. Partial emissions at the level of GHG sources or even sub-processes (e.g., lighting, temperature control)
3. Relevant throughput of each hub
4. Electricity mix of supplier[1]
5. Additional results on calculations based on other emission factors (e.g., electricity mix of supplier)[1]
6. Implemented measures impacting GHG emissions and their date of implementation

Table 8: Exemplary documentation framework for internal monitoring

Specification of hub	[Name, location] - [country]	
Total annual emissions	#.## t CO_2e	
Transhipment emissions	#.## t CO_2e	
Storage emissions	#.## t CO_2e	
Heating emissions	#.## t CO_2e	
Refrigeration emissions	#.## t CO_2e	
Lighting emissions	#.## t CO_2e	and/or #.## kWh
Total throughput	#,### [tonnes]	
Electricity: supplier mix (market-based mix)[1]	#.### g CO_2e/kWh	
Total emissions (calculated with supplier's mix)[1]	#.### t CO_2e	
Average emission intensity with supplier's mix	#.## kg CO_2e/tonne	
Implemented measures impacting GHG emissions	measure XY	since dd/mm/yyyy

[1] see also section 8.3

7
Examples

The following calculation examples are intended to illustrate the calculation steps and selected challenges that may arise.

The examples start from the basic use case where access to relevant GHG activity data (e.g., electricity use, fuel consumption) is assumed, so that the average emission intensity value can be calculated: HOC with one hub and one average emission intensity value (see section 7.1). In addition, an example is provided for a HOC covering two hubs (see section 7.2).

In section 7.3 an example with allocation is shown: HOC with one hub and two emission intensity values. This is accompanied with two examples on a typical concept for allocation (see section 7.4) and the partitioning of electricity consumption based on functional areas (see section 0).

However, it is not always possible to access all relevant primary data. Therefore, on example describes an approach to fill these data gaps in case of electricity consumption related to lighting (see section 7.6). Finally, the use of the calculated values in the transport chain context is shown (see section 0).

7.1 Calculation GHG emissions and emission intensity without allocation

At an ambient hub located in France only diesel and electricity are used. This hub is used as HOC.

From 01.01.2022 **To** 31.12.2022 **Hubs of the HOC**	**Electricity (elec) [kWh]**	**Diesel [litre]**	**Throughput [tonne]**
Hub 1: French hub	700,000	6,000	90,000
Total consumption of HOC	**700,000**	**6,000**	**90,000**

Relevant emission factors and parameters are:

$\varepsilon_{elec,France}$	$25\ g\ CO_2e/MJ$	(EWI 2023, p. 126)
$\varepsilon_{HEO,diesel,Europe}$	$2{,}639\ g\ CO_2e/l$	Calculated based on
$\varepsilon_{HEEP,diesel,Europe}$	$801\ g\ CO_2e/l$	(SFC 2023)

The relevant formula is as follows:

$$G_{HOC} = Q_{HOC,elec} \times \varepsilon_{elec} + Q_{HOC,diesel} \times \varepsilon_{diesel}$$

GHG emissions related to energy provision:

$$G_{HEEP,HOC} = 700{,}000\ kWh \times 3.6 \frac{MJ}{kWh} \times 25 \frac{g\ CO_2e}{MJ} + 6{,}000\ l \times 801 \frac{g\ CO_2e}{l} = 67{,}807\ kg\ CO_2e$$

GHG emissions related to operation:

$$G_{HEO,HOC} = 6{,}000\ l \times 2{,}639 \frac{g\ CO_2e}{l} = 15{,}832\ kg\ CO_2e$$

The total emissions of the HOC are as follows:

$$G_{HOC} = 67{,}807\ kg\ CO_2e + 15{,}832\ kg\ CO_2e = 83{,}639\ kg\ CO_2e$$

The average emission intensity accounts for:

$$g_{HEEP,HOC} = \frac{G_{HEEP,HOC}}{H_{HOC}} = \frac{67{,}807 kg\ CO_2e}{90{,}000\ tonnes} = 0.75\ kg\ CO_2e/tonne$$

$$g_{HEO,HOC} = \frac{G_{HEO,HOC}}{H_{HOC}} = \frac{15{,}832\ kg\ CO_2e}{90{,}000\ tonnes} = 0.18\ kg\ CO_2e/tonne$$

$$g_{HOC} = \frac{G_{HOC}}{H_{HOC}} = \frac{67{,}807\ kg\ CO_2e}{90{,}000\ tonnes} = 0.93\ kg\ CO_2e/tonne$$

7.2 Calculation of GHG emission intensity of a HOC consisting of multiple hubs

Examples

The second example refers to the GHG emissions quantification of a HOC that consists of two comparable hubs in Italy. At both hubs palletised ambient freight is handled.

From 01.01.2023 **To** 31.12.2023 **Hubs of the HOC**	**Electricity (elec)** **[kWh]**	**Diesel** **[litre]**	**Natural gas (ng) for heating** **[kWh]**	**District heating (dh)** **[kWh]**	**LNG** **[kg]**	**Throughput** **[tonne]**
Hub 1 - Italy	130,000	3,467	52,000		3,200	74,000
Hub 2 - Italy	142,000	7,334		37,000	2,300	69,000
Total consumption of HOC	**272,000**	**10,801**	**52,000**	**37,000**	**5,500**	**143,000**

Relevant emission factors are listed in the reporting chapter (see Table 11 on page 48).

The relevant formula is as follows:

$$G_{HOC} = Q_{HOC,elec} \times \varepsilon_{elec} + Q_{HOC,diesel} \times \varepsilon_{diesel} + Q_{HOC,ng} \times \varepsilon_{ng} + Q_{HOC,dh} \times \varepsilon_{dh} + Q_{HOC,LNG} \times \varepsilon_{LNG}$$

GHG emissions related to energy provision:

$$G_{HEEP,HOC} = 272{,}000\ kWh \times 439 \frac{g\ CO_2e}{kWh} + 10{,}801\ l \times 801 \frac{g\ CO_2e}{l} + 52{,}000\ kWh \times 65 \frac{g\ CO_2e}{kWh} + 37{,}000\ kWh \times 382 \frac{g\ CO_2e}{kWh} + 5{,}500\ kg \times 1{,}210 \frac{g\ CO_2e}{kg} = 152{,}276\ kg\ CO_2e$$

GHG emissions related to operation:

$$G_{HEO,HOC} = 10{,}801\ l \times 2{,}639 \frac{g\ CO_2e}{l} + 52{,}000\ kWh \times 198 \frac{g\ CO_2e}{kWh} + 5{,}500\ kg \times 2{,}843 \frac{g\ CO_2e}{kg} = 54{,}446\ kg\ CO_2e$$

The total emissions of the HOC are as follows:

$$G_{HOC} = 152{,}276\ kg\ CO_2e\ + 54{,}446\ kg\ CO_2e = 206{,}722\ kg\ CO_2e$$

The average emission intensity accounts for:

$$g_{HEEP,HOC} = \frac{G_{HEEP,HOC}}{H_{HOC}} = \frac{152{,}276 kg\ CO_2e}{143{,}000\ tonnes} = 1.06\ kg\ CO_2e/tonne$$

$$g_{HEO,HOC} = \frac{G_{HEO,HOC}}{H_{HOC}} = \frac{54{,}446\ kg\ CO_2e}{143{,}000\ tonnes} = 0.38\ kg\ CO_2e/tonne$$

$$g_{HOC} = \frac{G_{HOC}}{H_{HOC}} = \frac{206{,}722\ kg\ CO_2e}{143{,}000\ tonnes} = 1.45\ kg\ CO_2e/tonne$$

Exemplary report of this example

Table 9: Short report on example

Report information as required by ISO	Example application
Identification of TCE(s) covered by the report	From [01/01/2023] to [31/12/2023] Hub 1 - Italy and Hub 2 - Italy
Reference to the ISO 14083	These calculation results have been established in accordance with ISO 1403:2023.
Total GHG emissions	$G_T = 206{,}722\ kg\ CO_2e$
Total GHG emission intensity	$g_T = 1.45\ kg\ CO_2e/tonne$
Reference to the location where supporting information is available	See further below
Hub activity	$H = 143{,}000\ tonne$
Operational GHG emissions	$G_{HEO} = 54.446\ kg\ CO_2e$
Operational GHG emission intensity	$0.38\ kg\ CO_2e/tonne$

Table 10: Exemplary documentation of HOC granularity basing on Table 1

Characteristics	Example: Applied in hub operation category
Name of HOC	Mixed transhipment sites in Italy
Number of hubs or list of hubs covered	Hub 1 & Hub 2 – both Italy
Hub activity	Freight only
Processes	Transhipment only
Freight type, temperature level	Palletized, ambient

All GHG emissions of the HOC are calculated with primary data (100%).

Table 11: Documentation of applied emission factors of fuels in example

Fuel type (regional focus)	Lower heating value [MJ/kg]	Density(1) [kg/l]	GHG emission (operational) [g CO_2e/MJ]	GHG emission total(2) [g CO_2e/MJ]	Source
Electricity (Italy)	-	-	0	122	(EWI 2023)
Natural gas for heating (Europe)	-	-	55.07	73.06	ecoinvent 3.9.1 cut-off, IPCC 2021
District heating (Europe)	-	-	0	106.12	
Diesel (Europe)	42,80	0.832	74.10	96.60	(SFC 2023)
LNG (Europe)	49.10	-	57.90	82.55	(SFC 2023)

Note to emission factor of electricity: the applied values refer to national production not consumption mix.

7.3 Calculation GHG emissions and emission intensity with allocation

At a hub located in France, both ambient and chilled goods are handled. This hub is used as HOC. These two different types of goods represent the specific groups defined for allocation. Diesel and electricity are used as well as the refrigerant R-410A refilled. The electricity consumption for chilling goods could not be measured separately, therefore allocation is needed. Here, the partitioning of electricity consumption is realised by using average shares as elaborated in the GILA project (Fraunhofer IML 2023a) as well as functional areas, as described in more detail in section 0. The total electricity consumption is 2,800,000 kWh.

Using an average share of 31% for cooling equipment, 868,000 kWh can be attributed to the cooling. In addition, 32% of the total electricity consumption is attributed to lighting i.e., 896,000 kWh. Own measurements at the hub outlined that the cooled area accounts for 10% of the total area indoors. Thus, 89,600 kWh for lighting the cooled area can be derived. In total, 957,600 kWh is allocated to the chilling of goods.

From 01.01.2022 **To** 31.12.2022 **Hubs of the HOC**	**Electricity [kWh]**	**Diesel [litre]**	**R-410A [kg]**	**Throughput [tonne]**
Hub 1: French hub				
Chilling	957,600		5.00	50,000
All other equipment	1,842,400	1,000		20,000
Total consumption of HOC	**2,800,000**	**6,000**		**70,000**

Relevant emission factors and parameters are:

$\varepsilon_{elec,France}$	$25\ g\ CO_2e/MJ$	(EWI 2023, p. 126)
$\varepsilon_{HEO,diesel,Europe}$	$2{,}639\ g\ CO_2e/l$	Calculated based on
$\varepsilon_{HEEP,diesel,Europe}$	$801\ g\ CO_2e/l$	(SFC 2023)
ε_{R-410A}	$2{,}226\ g\ CO_2e/g$	see Table 12

The relevant formula is as follows:

$$G_{HOC} = Q_{HOC,elec} \times \varepsilon_{elec} + Q_{HOC,diesel} \times \varepsilon_{diesel} + Q_{HOC,R-410A} \times \varepsilon_{R-410A}$$

GHG emissions related to energy provision:

$$G_{HEEP,HOC,all} = 1{,}842{,}400\ kWh \times 3.6 \frac{MJ}{kWh} \times 25 \frac{g\ CO_2e}{MJ} + 1{,}000\ \mathrm{l} \times 801 \frac{g\ CO_2e}{l} = 166{,}617\ kg\ CO_2e$$

$$G_{HEEP,HOC,chilled} = 957{,}600\ kWh \times 3.6 \frac{MJ}{kWh} \times 25 \frac{g\ CO_2e}{MJ} = 86{,}184\ kg\ CO_2e$$

$$G_{HEEP,HOC} = 166{,}617\ \ kg\ CO_2e + 86{,}184\ kg\ CO_2e = 252{,}801\ kg\ CO_2e$$

GHG emissions related to operation:

$$G_{HEO,HOC,all} = 1{,}000\ \mathrm{l} \times 2{,}639 \frac{g\ CO_2e}{l} = 2{,}639\ kg\ CO_2e$$

$$G_{HEO,HOC,chilled} = 5\ \mathrm{kg} \times 2{,}226 \frac{g\ CO_2e}{g} = 11{,}128\ kg\ CO_2e$$

$$G_{HEO,HOC} = 2{,}639\ kg\ CO_2e + 11{,}128\ kg\ CO_2e = 13{,}766\ kg\ CO_2e$$

The total emissions of the HOC are as follows:

$$G_{HOC} = 252{,}801\ kg\ CO_2e\ + 13{,}766\ kg\ CO_2e = 266{,}567\ kg\ CO_2e$$

Two emission intensities need to be accounted for:

$$g_{HEEP,HOC,ambient} = \frac{G_{HEEP,HOC,all}}{H_{HOC,all}} = \frac{166{,}617\ kg\ CO_2e}{70{,}000\ tonnes} = 2.38\ kg\ CO_2e/tonne$$

$$g_{HEEP,HOC,chilled} = \frac{G_{HEEP,HOC,all}}{H_{HOC,all}} + \frac{G_{HEEP,HOC,chilled}}{H_{HOC,chilled}} = \frac{166{,}617\ kg\ CO_2e}{70{,}000\ tonnes} + \frac{86{,}184\ kg\ CO_2e}{50{,}000\ tonnes} = 4.10\ kg\ CO_2e/tonne$$

$$g_{HEO,HOC,ambient} = \frac{G_{HEO,HOC,all}}{H_{HOC,all}} = \frac{2{,}639\ kg\ CO_2e}{70{,}000\ tonnes} = 0.04\ kg\ CO_2e$$

$$g_{HEO,HOC,chilled} = \frac{G_{HEO,HOC,all}}{H_{HOC,all}} + \frac{G_{HEO,HOC,chilled}}{H_{HOC,chilled}} = \frac{2{,}639\ kg\ CO_2e}{70{,}000\ tonnes} + \frac{11{,}128\ kg\ CO_2e}{50{,}000\ tonnes} = 0.26\ kg\ CO_2e/tonne$$

Thus, the following energy intensities are calculated for ambient goods and chilled goods, respectively:

$$g_{HOC,ambient} = 2.42\ kg\ CO_2e/tonne \qquad g_{HOC,chilled} = 4.36\ kg\ CO_2e/tonne$$

7.4 Concept for allocation

Examples

As described earlier, allocation is needed when multiple services are fulfilled by the hub which may have different characteristics. This means, reporting companies may face the challenge to clearly allocate part of the total annual electricity or fuels consumption to specific activities (see Figure 11) i.e., energy used for

- Transhipment
- Storage and/or (re)packing
- Running the heating system
- Running the refrigerating system

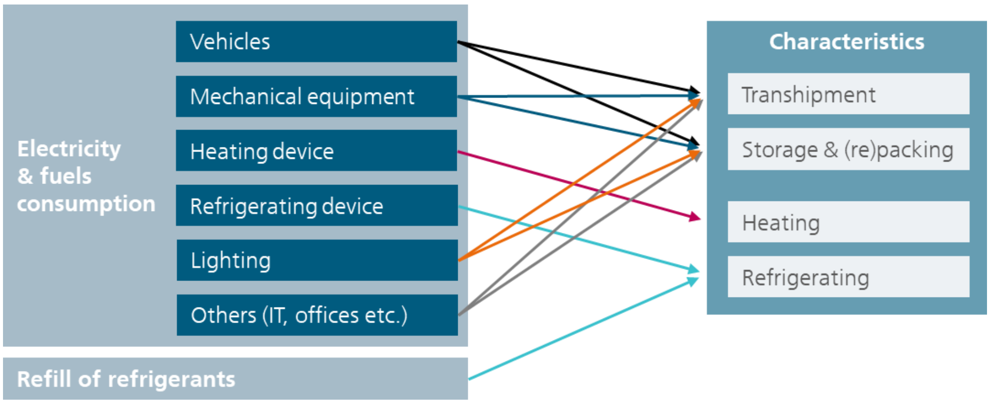

Figure 11: Schematic allocation of GHG source to activities

A typical example is a hub with multiple temperature levels of goods some of which are just transhipped, some of which are additionally stored and (re)packed. Here, fuels and electricity used for e.g., vehicles or material handling equipment needs to be allocated between transhipped and stored goods. Also, the electricity use for lighting needs to be split, an example is given in section 0. The electricity used for the refrigerating device and associated emissions will not be allocated to ambient shipments, but to refrigerated ones only. The same holds true for emissions caused by leaked refrigerants, which have to be refilled (see light blue arrows in Figure 11). Similarly, emissions caused by the use of natural gas for heating needs is only allocated to ambient goods (see red arrow in Figure 11).

7.5 Partitioning of electricity consumption using functional areas

In this example, the reporting company wants to split the total electricity consumption of the facility between goods that are only transhipped and those, that are additionally stored and picked. This shall be realised by the use of functional areas. The facility is subdivided into two main functional areas, i.e. (1) transhipment area of ~12,000 m², and (2) combined storage and picking area of ~6,000 m², as illustrated in Figure 12. Basing on this, the company may allocate $^2/_3$ of the electricity consumption of lighting to transhipment activities, and $^1/_3$ to storage and order picking.

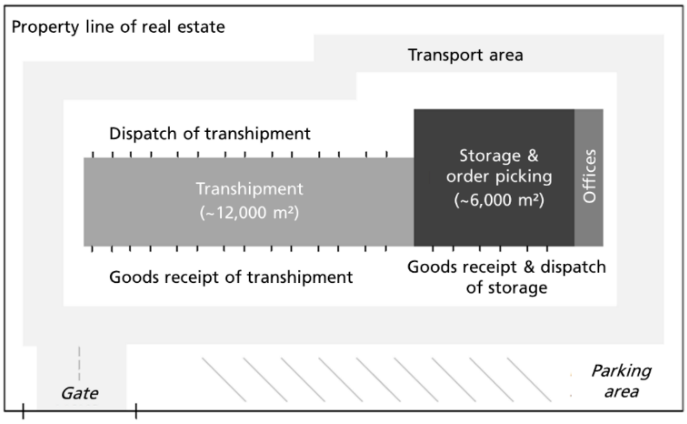

Figure 12: Example logistics hubs with relevant functional areas

7.6 Estimation of electricity consumption related to lighting

If no measured electricity consumption related to lighting is at hand, the operator may use an estimate (i.e., modelled data) basing on the installed capacity and operation time.

For example, a hub with 4 halls consists each of:

- 11 corridors with a light strip with 63 bulbs of 100 W
- Delivery and dispatch area with 42 lamps at 100 W

Installed capacity: $4 \times (11 \times 6{,}300\ W + 4{,}200\ W) = 294\ kW$

Operating time: $17 \frac{hours}{day} \times 5 \frac{days}{week} \times 52 \frac{weeks}{year} = 4{,}420\ h/a$

Electricity consumption: $Q_{elec,light} = 294\ kW \times 4{,}420 \frac{h}{a} = 1{,}299{,}480\ kWh/a$

7.7 Use of emission intensity in transport chain calculation

Examples

If a company wants to calculate a full transport chain, emission intensities for the different transport chain elements need to be identified and their emission intensities combined: expressed for transport in [kg CO_2e per tonne-kilometre] and for hubs in [kg CO_2e per tonne].

For example, 50,000 tonnes of goods are transported via road and a transhipment facility to its destination, see Figure 13.

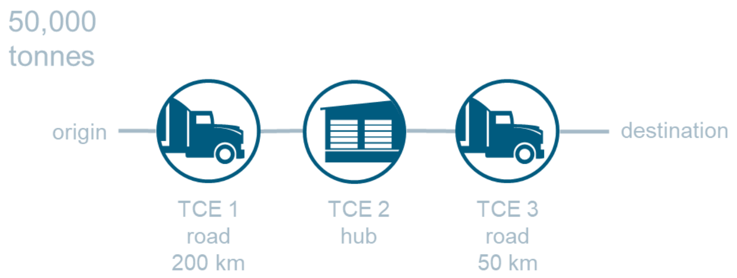

Figure 13: Example transport chain

Using an average emission intensity value for a rigid truck (26-34 t gross vehicle weight) of $g_{truck} = 116\ g\ CO_2e/tkm$ (SFC 2023 Table 8) and an emission intensity value of the hub of $g_{hub} = 929\ g\ CO_2e/t$ (see example in section 7.1), the total emissions of the transport chain are calculated as follows:

$$G_{TCE1} = g_{truck} \times 50{,}000\ tonnes \times 200\ km = 1{,}160{,}000\ kg\ CO_2e$$

$$G_{TCE2} = g_{hub} \times 50{,}000\ tonnes = 46{,}466\ kg\ CO_2e$$

$$G_{TCE3} = g_{truck} \times 50{,}000\ tonnes \times 50\ km = 290{,}000\ kg\ CO_2e$$

With a total quantity of emissions and emission intensity:

$$G_{TC} = \sum_i G_{TCE,i} = 1{,}496{,}466\ kg\ CO_2e/a$$

$$g_{TC} = \frac{\sum_i G_{TCE,i}}{\sum_i T_{TCE,i}} = \frac{1{,}496{,}466\ kgCO_2e/a}{12{,}500{,}00\ tkm} = 119.72\ g\ CO_2e/tkm$$

8
Additional guidance

8.1 Measuring energy consumption at the logistics hub

Information on fuel consumed and purchased (diesel, gasoline, gas) can be found in fuel receipts, the metering system of the internal fuel station, on-board units of vehicles and other invoices. Information on electricity consumed may be collected using (smart) meters at the hub or by the electricity supplier. The latter may also be able to provide information on the relevant electricity mix (see section 8.3). Detailed information on energy consumption may already be covered by the company's energy audit following EN 16247 (see e.g., DIN EN 16247-1 to DIN EN 16247-4) .

The data collection may be realized in two different ways:

1. The operator has access to the total quantities of consumed energy carriers for all energy consuming processes and equipment at the hub for the whole reporting year

2. The operator uses samples if all data required is not available

A representative sample can be used for deriving a specific consumption factor for energy carriers relating to selected processes e.g., litre of diesel or kWh per day of technical equipment, which is extrapolated for one year. Such extrapolated data used for GHG emission calculation is referred to as **modelled data** by ISO 14083.

However, when using samples there are some quality issues to consider in order to obtain reliable input data for emissions accounting:

- Mode of hub operation in the sampling period is representative of the year e.g., as regards shift operation (e.g., 1 to 3 shifts per day), weekly days of operation (e.g., 5 to 7 days per week) or seasons.
- If average data is transferred to another hub of the company, this hub has to offer
    - A comparable mode of operation (e.g., same number of shifts per day and operation days)
    - Equivalent characteristics as outlined in Table 1 (i.e., transhipment, storage, (re)packing) and temperature conditions
    - Equivalent equipment used (e.g., degree of process automation, comparable light technologies (LED or older))

If these prerequisites cannot be fulfilled, the company may use a conservative extrapolation factor to address this inaccuracy: e.g., the hub at hand is 25% more GHG intense (i.e., 25% more emissions per tonne) than the average hub. Document (internally) the assumptions as transparent as possible for future repetitions and or comparisons.

8.2 Partitioning of electricity consumption at logistics real estates

When partitioning of electricity consumption is needed, the following research results of the GILA project may help. The outlined shares are initial values only, and research will be continued in coming annual market studies (see REff Tool®).

The figures refer to a sample size of 192 hubs and have been further sub-divided in

- sites for ambient goods only (n=109),
- sites for cooled or frozen goods (n=35) as well as
- sites with multiple-temperature areas (n=48).

On average, 18% of the electricity consumption can be allocated to material handling equipment, 27% to lighting indoors, and 32% for the temperature control of goods.

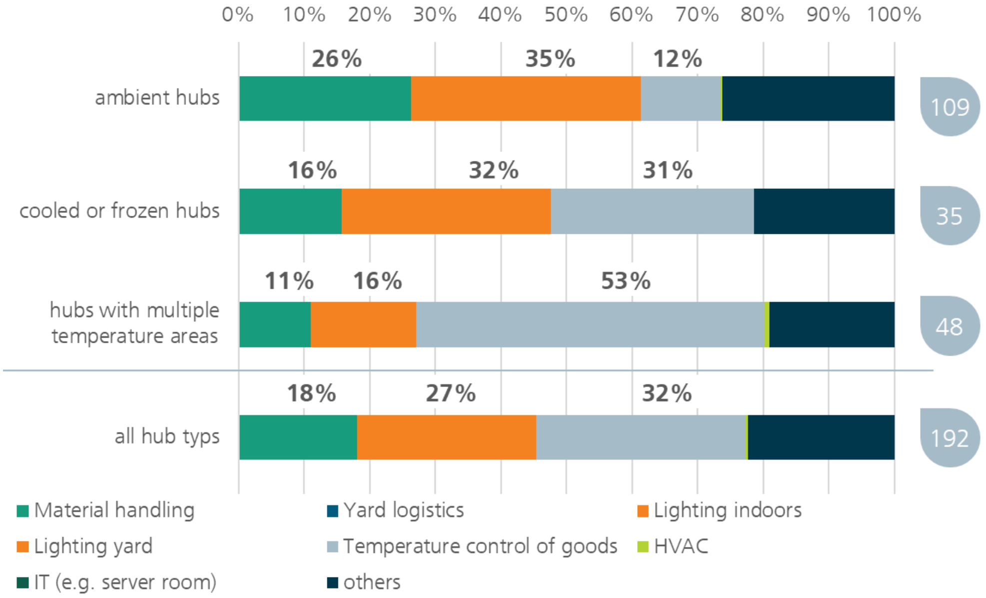

Figure 14: Allocation of electricity to defined activity clusters (source: Dobers et al. 2023b)

8.3 Calculation of emission factor with supplier's mix

Some companies purchase particular electricity products to support renewable electricity generation (green rates) and thus reduce the environmental impact of their electricity consumption. The emission factor representing the amount of GHG emissions per kilowatt-hours varies with the varying share of energy types used for electricity generation. For correct interpretation of the results, it is therefore important to specify the underlying electricity factor used for GHG accounting. ISO 14083 requires the use of location-based approach for electricity i.e., the national mix of the relevant country. All GHG emissions based on calculations using another emission factor, such as the supplier mix (market-based approach), shall be reported separately from those referencing ISO 14083 results.

Additional guidance

The example shown in Figure 15 indicates how much the choice of emission factors may influence the total result of a hub. The example refers to a medium-sized European container terminal located in the Netherlands. The ISO 14083 requires the use of the national electricity grid factor, which is 477 g CO_2e per kWh (EWI 2023) in this Dutch example. If the operator chose the use of an EU-28 average value (0.362 kg CO_2e/kWh [ETW 2023]), this would result in a declaration of 24% less emissions from the terminal. Considering the supplier's green rate and using the corresponding emission factor of only 0.150 kg CO_2e/kWh would reduce the declared total result by another 59%

Figure 15: How much does the choice of emission factors influence the result?

8.4 How to consider on-site production of electricity

When calculating GHG emissions, it is essential to consider which energy carriers are purchased and used for operating the hub. At some hubs own electricity is produced on-site.

One reason for this is e.g., establishing resilience regarding electricity supply as the operators regularly face blackouts of the national grid. As backup power supply system, diesel generators are available, so that a share of the hub's total diesel consumption may be due to the on-site electricity production (i.e., in addition to the diesel consumption of e.g., on-site vehicles). In this case, the reporting organisation should apply the emission factor for diesel to calculate the GHG emissions related to diesel consumption. Furthermore, it is important to use the amount of purchased electricity to avoid double counting of emissions, that means not e.g., the measured electricity consumption at the level of equipment as this may also cover diesel-based electricity.

Another reason of on-site electricity production is the aim at increasing the share of renewable energy. Thus, many real estate owners have installed e.g., PV panels for on-site electricity. To calculate GHG emissions aligned with the ISO 14083, this internally generated electricity may only be considered if the electricity is used for hub processes only i.e., on-site only and not for charging inbound/outbound vehicles. No electricity shall be exported i.e., sold to third parties by means of contractual instruments. If internally generated electricity is covered, the selected emission factors have to meet the requirements set by the ISO 14083 such as the inclusion of infrastructure (manufacturing, construction, operation and disposal). Thus, the emission factor cannot equal zero GHG emissions.

8.5 Key performance indicators for logistics hubs

The ISO 14083 metric for the emission intensity of logistics sites is kg CO_2e emissions per tonne throughput (alternatives outlined in chapter 5). This is motivated by the objective to provide a performance indicator that can be used within logistics chain calculations.

However, depending on the type of hub and the activities provided by the operator, this indicator does not reflect the full picture. It is beyond the scope of this guide to provide a comprehensive description of which key performance indicators are most appropriate for the environmental performance of a logistics hub. Nevertheless, some thoughts addressing this question are summarised in the following and further research and development activities are ongoing.

An alternative to weight-based indicators is the use of

- **volume-based indicators** i.e., kg CO_2e emissions per m^3 cargo outbound,
- **consignment-based indicators** i.e., kg CO_2e emission per pallet or parcel outbound.

Among other things, this reflects the fact that light/ voluminous goods may need the same activities and as such consume the same amount of energy as heavy goods e.g., pallets of toilet paper compared to pallets of beverages. In this case, the weight-based allocation results in an underestimated or overestimated emissions intensity for the respective pallet. Here, further research is required e.g., on the question as to whether emissions of selected logistics sites correlate better with a weight or volume metric. Figure 16 provides the principal procedure covering a 'detour' e.g., using pallet-based indicators. In the final step, the pallet-based indicators are converted to weight-based carbon intensity values that can then be used for logistics chain calculations.

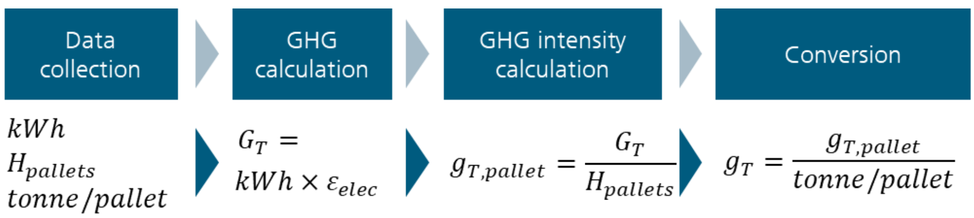

Figure 16: Procedure using pallet-based indicators

Furthermore, temperature-controlled sites may require additional alternatives to show improvement in the warehouse's environmental performance. The temperature level of inbound goods as well as their dwell time in a warehouse may affect the electricity use of temperature-controlled warehouses.

Additional guidance

Here, allocation may follow to show cost allocation principles or use

- **square-based indicators** i.e., kg CO_2e emissions per m^2 of floor space,
- **cubic content-based indicators** i.e., kg CO_2e emissions per m^3 of warehouse.

Other metrics may cover **full-time equivalents** (FTE) employee, **operational hours** of the warehouse or transhipment centre, or unit revenue.

The guide addresses the perspective of operators of logistics hubs. However, corporate accounting may ask for a higher level of aggregation e.g., key performance indicators for logistics hubs within one region or a country. Therefore, the company may want to use hub-specific indicators to derive average indicators for the same type of logistics hubs i.e., with the same operations, temperature and picking requirements, as shown below. This may also adopt the approach of establishing hub operation categories as described in section 5.2.

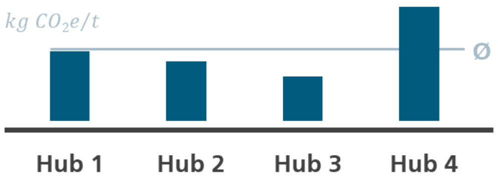

Figure 17: Higher level of aggregation for average emission intensity values within e.g., a region

8.6 Carbon neutral and net zero hubs

In the context of GHG emissions and carbon footprints a rising number of companies target (or some even claim) being "carbon neutral", "net zero" or "zero carbon".

Therefore, we would like to shortly introduce some terms in this context using the recently published ISO 14068-1:2023.

Carbon neutral logistics hubs realise, that its carbon footprint of a specified period (e.g., one year) has been reduced and the remaining GHG emissions are counterbalanced by **offsetting**. The carbon footprint and its reduction may be a result of GHG emission reduction and GHG removal enhancement. In case all technically and economically feasible GHG emission reduction measures have been implemented, unabated GHG emissions may be called **residual GHG emissions** (see Figure 18). Offsetting is the counterbalance of the carbon footprint by retiring a carbon credit(s) which in turn have to meet specific requirements set by ISO 14068-1 and correspond to tradeable certificates on avoided, reduced, or removed GHG emissions.

"For organizations, **net zero GHG emissions** is commonly considered as the condition in which emissions have been reduced such that only residual emissions remain, and offsetting is restricted to removal credits only." (ISO 14068-1, p. 11)

This means, that today most logistics hubs may claim rather being carbon neutral than net zero as usually not all feasible measures have been implemented yet.

In addition, ISO 14068-1 introduced a GHG management hierarchy for carbon neutrality prioritising reduction measures and removal enhancement within the value chain over offsetting.

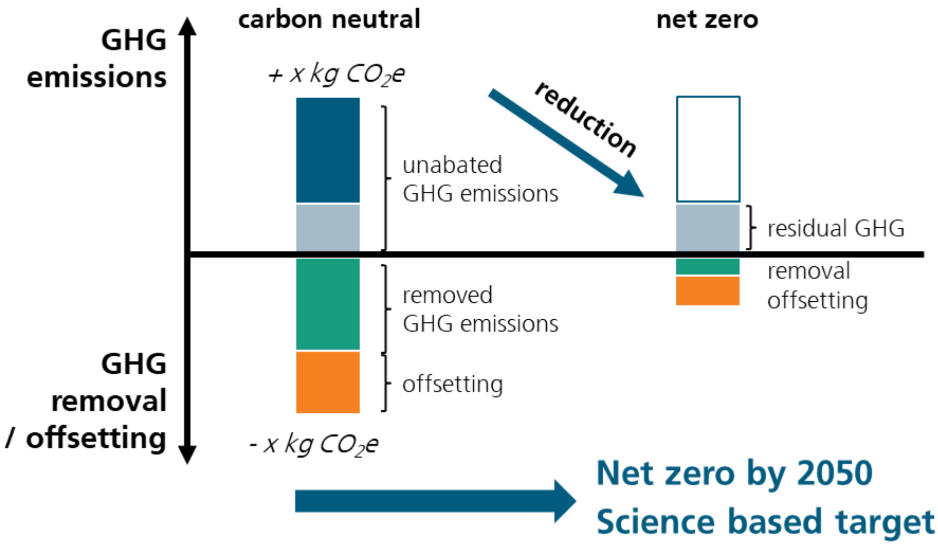

Figure 18: Illustration (simplified) of carbon neutral and net zero condition (source: own illustration basing on ISO 14068-1:2023)

GHG emissions may be reduced by a number of strategies and measures. Following the ASIF model (Schipper et al. 2000 in TRT et al. n.d.), we have clustered them as follows:

(1) Changes in **A**ctivities: avoiding processes or resource consumption,
(2) **S**tructural adjustment by introducing new technologies
(3) Raising **I**ntensity: increasing efficiency in the processes with view to used energy as well as other resources
(4) Substitution of **F**uels, materials, and refrigerants to reduce carbon intensity: e.g., renewable fuels, renewable or secondary materials, low-GWP refrigerants

Further information on possible decarbonisation measures are provided in e.g., (Dobers et al. 2023b), (Perotti et al. 2023) or (Perotti et al. 2024 (planned)).

9
Emission factors and default values

9.1 GHG emission factors

Emission factors for **electricity** depend on the underlying electricity mix and have changed considerably in some countries in the past few years. Also, emission factors for other **fuels** such as diesel with varying regional supply chains and renewable content change over time. It is beyond the scope of this guide to provide an updated list. For this reason, it is recommended that the emission factors provided by the GLEC Framework (SFC 2023) in its current version should be used and the sources of emission factors used should be documented transparently. Other reliable sources for emission factors (partly covered by the GLEC Framework) are (Fröhlich et al. 2023), (SFC & ifeu 2023), or the methodology report published by EcoTransIT World (e.g., ETW 2023 or annual updates).

At the time of updating this report, the European Commission frames a regulation on the accounting of GHG emissions of transport services including the discussion of developing and publishing a European database on emission factors publicly available and aligned across the various stakeholders involved (European Commission 2023).

Operational emissions caused by leakage of **refrigerants** are published by the Intergovernmental Panel on Climate Change (IPCC) and are summarized in the table below. Note: The first column with emission factors [g CO_2e/g] refers to GWP 100 published by IPCC in (Myhre et al. 2013), the second those published by IPCC in (Smith et al. 2021). All emission factors refer to operational (direct) emissions i.e., no indirect emissions associated with the production and supply of refrigerants are included. Thus, those can be used for GHG emissions calculation compliant to ISO 14083.

Table 12: GWP 100 values for refrigerants

Type	Chemical formula	Alternative name	[g CO_2e/g] (Myhre et al. 2013)	[g CO_2e/g] (Smith et al. 2021)
R-12	CF2Cl2 // CCl2F2	Dichlorodifluoromethane	10,200.0	12,500.0
R-22	CHClF2	Chlorodifluoromethane	1,760.0	1,960.0
R-23	CHF3	Fluoroform	12,400.0	14,600.0
R-32	CH2F2	Difluoromethane	677.0	711.0
R-115	CClF2CF3	Chloropentafluoroethane	7,670.0	9,600.0
R-124	C2HF4Cl // CHClFCF3	1-Chlor-1,2,2,2-tetrafluorethane	527.0	597.0
R-125	CHF2CF3	Pentafluoroethane	3,170.0	3,740.0
R-134a	CH2FCF3	1,1,1,2-Tetrafluorethane	1,300.0	1,530.0
R-142b	C2H3F2Cl	1-Chlor-1,1-difluorethane	1,980.0	2,300.0
R-143a	CH3CF3	1,1,1-Trifluorethane	4,800.0	5,810.0
R-152a	C2H4F2 // CH3CHF2	1,1-Difluorethane	138.0	164.0
R-218	C3F8	Octafluorpropane	8,900.0	9,290.0
R-290	C3H8	Propane	3.0	0.02
R-401A	Mixture, own calculation: 53% R-22, 13% R-152A, 34% R-124		1,129.9	1,263.1
R-402A	Mixture, own calculation: 60% R-125, 2% R-290, 38% R-22		2,570.9	2,988.8
R-404A	Mixture ,own calculation: 44% R-125, 4% R-134a, 52% R-143a		3,942.8	4,728.0
R-407A	Mixture, own calculation: 20% R-32, 40% R-125, 40% R-134a		1,923.4	2,250.2
R-407C	Mixture, own calculation: 23% R-32, 25% R-125, 52% R-134a		1,624.2	1,894.1
R-407F	Mixture, own calculation: 30% R-32, 30% R-125, 40% R-134a		1,674.1	1,947.3
R-408A	Mixture, own calculation: 7% R-125, 46% R-143a, 47% R-22		3,257.1	3,855.6
R-409A	Mixture, own calculation: 60% R-22, 25% R-124, 15% R-142b		1,484.8	1,670.3
R-410A	Mixture, own calculation: 50% R-32, 50% R-125		1,923.5	2,225.5
R-413A	Mixture, own calculation: 88% R-134a, 9% R-218, 3% R-600a		1,945.1	2,182.5
R-417A	Mixture, own calculation: 46.6% R-125, 50% R-134a, 3.4% R-600		2,127.4	2,507.8
R-417C	Mixture, own calculation: 19.5% R-125, 78.8% R-134a, 1.7% R-600		1,642.6	1,934.9

Type	Chemical formula	Alternative name	[g CO_2e/g] (Myhre et al. 2013)	[g CO_2e/g] (Smith et al. 2021)
R-422A	Mixture, own calculation: 85.1% R-125, 11.5% R-134A, 3.4% R-600a		2,847.3	3,358.7
R-422D	Mixture, own calculation: 65.1% R-125, 31.5% R-134a, 3.4% R-600a		2,473.3	2,916.7
R-448a	Mixture, own calculation: 26% R-32, 26% R-125, 20% R-1234yf, 21% R-134a, 7% R-1234ze(E)		1,273.5	1,478.8
R-449A	Mixture, own calculation: 25.7% R-134a, 25.3% R-1234yf, 24.7% R-125, 24.3% R-32		1,281.9	1,489.9
R-450A	Mixture, own calculation: 42% R-134a, 58% R-1234ze(E)		546.6	643.4
R-452a	Mixture, own calculation: 11% R-32, 59% R-125, 30% R-1234yf		1,945.1	2,285.0
R-502	Mixture, own calculation: 48.8% R-22, 51.2% R-115		4,785.9	5,871.7
R-504	Mixture, own calculation: 48.2% R-32, 51.8% R-115		4,299.4	5,315.5
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-509A	Mixture, own calculation: 44% R-22, 56% R-218		5,758.4	6,064.8
R-513A	Mixture, own calculation: 44% R-134a, 56% R-1234yf		572.6	673.5
R-600	C4H10	n-Butane	4.0	0,01
R-600a	C4H10	Isobutane	3.0	0,01
R-717	NH3	Ammonia	-	-
R-744	CO2	Carbon dioxide	1.0	1,0
R-1234ze(E)	C3H2F4 // trans-CF3CH=CHF	(E)-1,3,3,3,-Tetrafluorpropene	1.0	1,4
R-1234yf	C3H2F4 // CF3CF=CH2	2,3,3,3-Tetrafluorpropene	1.0	0,5
ISCEON89	Mixture, own calculation: 86% R-125, 9% R-218, 5% R-290		3,527.2	4,052.5
FX100(R-427A)	Mixture, own calculation: 50% R-134a, 25% R-125, 15% R-32, 10% R-143a		2,024.1	2,387.7

9.2 Default values for logistics hubs

Still a developing area, default values for logistics hubs have been historically difficult to come by. Furthermore, logistics hubs are extremely diverse in their nature. Container terminals are clearly very different from transshipment hubs, but even within each category of logistics hubs there is diversity (Dobers et al. 2022). Fraunhofer IML has advanced the understanding of average logistics hub emission intensity values through extensive industry research and data collection with the help of the REff Tool® (Fraunhofer IML 2023b).

Annual market studies

Basing on market studies performed between 2021 and 2023, a set of default values for transshipment sites, warehouses and terminals considering besides ambient freight handling also temperature-controlled handling has been published and provided in table below (Dobers et al. 2022, Dobers et al. 2023a). These initial values are matter of ongoing research and annual updates are planned – the market studies will be continued, see latest info at https://reff.iml.fhg.de/. For these values, electricity, heating energy, or other fuels and refrigerants are already converted to GHG emissions (kg CO_2e) using corresponding national or regional emission factors where available and are aggregated on a global level. While data on terminals origin from various regions worldwide, the focus for warehouses and transshipment sites is Europe so far.

Table 13: Average emission intensity values per tonne throughput (source: Dobers et al. 2023a)

	Ambient		Mixed	
Transhipment	0.6 kg CO_2e / t	(56)	2.2 kg CO_2e / t	(6)
Storage + transhipment	2.1 kg CO_2e / t	(58)	4.0 kg CO_2e / t	(9)
Warehouse	17.5 kg CO_2e / t	(49)	33.0 kg CO_2e / t	(3)
Liquid bulk terminals	3.1 kg CO_2e / t	(22)	8.1 kg CO_2e / t	(29)

Table 14: Average emission intensity values per container throughput (source: Wilmsmeier & Spaggiari in (Dobers et al. 2022))

	Ambient		Mixed	
Container terminal	10.70 kg CO_2e / TEU	(15)	12.57 kg CO_2e / TEU	(15)

Table 15: Average emission intensity values per square meter logistics area indoors (source: Dobers et al. 2023a)

	Ambient		Mixed	
Transhipment	16.7 kg CO_2e / m²	(61)	19.5 kg CO_2e / m²	(7)
Storage + transhipment	28.0 kg CO_2e / m²	(124)	64.4 kg CO_2e / m²	(43)
Warehouse	23.6 kg CO_2e / m²	(138)	22.8 kg CO_2e / m2	(21)
	Chilled		**Frozen**	
Storage + transhipment	68.0 kg CO_2e / m²	(12)	103.3 kg CO_2e / m²	(9)

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