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GUIDE FOR GREENHOUSE GAS EMISSIONS ACCOUNTING FOR LOGISTIC SITES

FOCUS ON TRANSHIPMENT SITES, WAREHOUSES AND DISTRIBUTION CENTRES

FRAUNHOFER VERLAG

GUIDE FOR GREENHOUSE GAS EMISSIONS ACCOUNTING AT LOGISTICS SITES

Focus on transhipment sites, warehouses and distribution centres

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The structure and some illustrations were inspired by the guidance on EN 16258 published by CLECAT (2012) and Spengler & Wilmsmeier (2016).

Content

Abbreviations

CNG	Compressed natural gas
CO_2e	Carbon dioxide equivalents
EF	Emissions factor
GHG	Greenhouse gas
GLEC	Global Logistics Emissions Council
GWP	Global Warming Potential
IPCC	Intergovernmental Panel for Climate Change
LNG	Liquefied natural gas
tkm	Tonne-kilometre
TSC	Transport service category
TTW	Tank to wheel
VAS	Value added services
WTW	Well to wheel
WWT	Well to tank

1
Introduction

Logistics sites play a connecting role within transport chains as shown in the figure below. Here, the term 'logistics sites' refers to all sites that combine different transport legs (within and between modes) or are the starting or end point of transport chains. Instead of 'logistics sites' other terms can also be used, such as logistics nodes, hubs, facilities, centres or depots.

Figure 1:
Sample transport chain maps (source: based on the GLEC Framework)

Examples are terminals at maritime or inland ports, freight and intermodal terminals, cargo terminals at airports, or logistics facilities/ logistics buildings such as warehouses, consolidation centres, distribution centres or cross-docking sites.

Figure 2:
Types of logistics sites

Background and purpose of the guide

Currently, the GLEC Framework (version 1.0) provides a general description of greenhouse gas emissions accounting of logistics chains including transhipment centres. The tool EcoTransIT World also allows inclusion of emissions caused by transhipment centres in the calculation of transport chains (EWI 2017). A step-by-step description of how to calculate greenhouse gas emissions of logistics sites, however, is lacking. Only a sector-specific guideline was published by FEPORT for maritime container terminals at the end of 2017 (FEPORT 2017).

This guide provides **advice on how to carbon audit logistics buildings with a view to performing logistics chains calculation**. The suggested calculation approach will be referred to by the GLEC Framework (version 2.0, in preparation) as well as EcoTransIT World (in preparation). It describes relevant steps as simply as possible so that even those not familiar with the topic will be able to calculate greenhouse gas emissions associated with logistics sites.

The approach provided is generic and can be further specified taking into account relevant characteristics of the site, the goods handled and customers' requirements. Furthermore, operators of logistics sites may want to have indicators reflecting the **environmental performance of the site** at a very detailed process and task level. Although this is definitely a relevant topic, it is not the focus of this guide. However, some general remarks are given in chapter 8.2.

Structure of the guide

The general structure of the guide is shown in Figure 3 and is as follows. **Overarching issues** are addressed in chapter 2 "General principles and terms of GHG emissions accounting" and chapter 3 "Assessment boundaries".

Next, the guide differentiates **two levels of detail for calculating GHG emissions** at logistics sites which is introduced in chapter 4 "Selecting GHG calculation approach". After that, both approaches are described in separate chapters, i.e.:

- Calculating an average emission intensity value for a logistics site (see chapter 5),
- Calculating emission intensity values at activity level (see chapter 6).

These chapters describe which input data is required and how emissions and emission intensity values are calculated.

Once the framework for carbon auditing has been established, the guide provides general remarks on "**Use of calculated emissions and emission intensity values**" in chapter 7. Finally, in chapter 8, **additional guidance** is given in relation to typical accounting and reporting issues as well as the selection of **emissions factors** (see chapter 9). Chapter 10 provides **templates** for data collection for site operators.

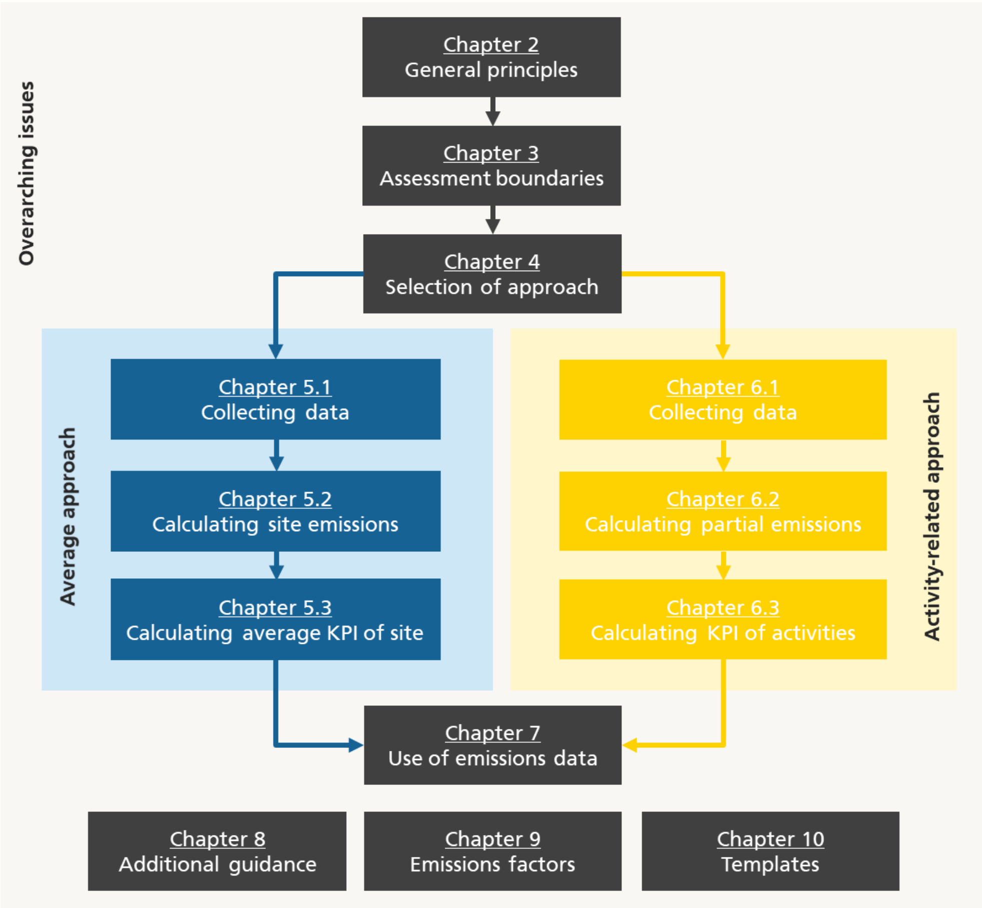


Figure 3:
Structure of the guide

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. These are also relevant to logistics sites and are described briefly in the following.

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.

The Greenhouse Gas Protocol (WRI & WBCSD 2004) uses the term 'scopes'. In the context of emissions of logistics sites, 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. Further details as regards scopes are given in chapter 8.4.

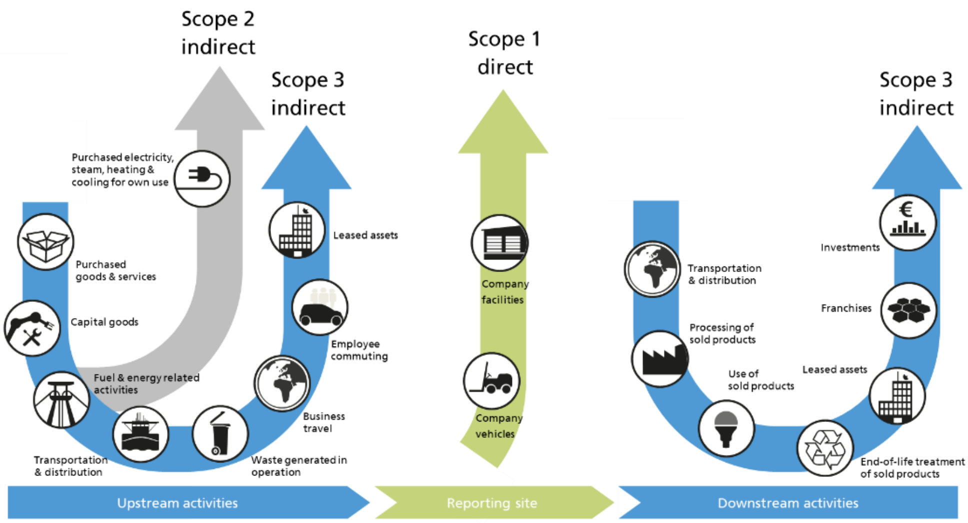


Figure 4: Scopes of emissions accounting (source: basing on WRI & WBCSD 2004)

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. As no appropriate 'translation' of these terms for logistics sites exists, the guide refers to direct and indirect emissions.

Emission factors

Selected direct and indirect emissions of fuels as published in EN 16258 are given in the following table. These factors are also called **emissions factors** and are used for converting the amount of fuel used into the GHG emissions.

Table 1: Emissions factors of fuels (Europe) (source: EN 16258)

Fuel	Direct emissions	Direct + indirect emissions	Unit
Diesel	2.67	3.24	kg CO_2e/l
Diesel with 5% biofuels content	2.54	3.17	kg CO_2e/l
Gasoline	2.42	2.88	kg CO_2e/l

System boundaries & GHG source

The large variety of logistics sites, and an even wider range of corresponding operations and services, makes it necessary to derive clear **system boundaries** for emissions accounting (see chapter 3). This guide defines which activities need to be covered within emissions accounting as they release GHG into the atmosphere (**GHG source**), and those which are out of scope. Practice has shown that this needs to be considered as a continuous process since new issues may arise caused by the variety of logistics sites. This guide covers a core set of activities.

Assessment period of one year

Emissions are 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.

Greenhouse gases

The assessment is to cover all relevant **greenhouse gases** (GHG). Focussing on carbon inventories of logistics services, 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. hydrofluorocarbons (HFCs).

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 Intergovernmental Panel for Climate Change (IPCC): the latest is the 5th Assessment report (IPCC 2013). A selection of GWP values with a 100-year time horizon are given in the following table. When using emissions factors from methodologies (e.g. GLEC Framework, EcoTransIT World), the company should make sure these methodologies use this time horizon.

Table 2: Global warming potential (GWP) for selected GHGs (source: IPCC 2007, IPCC 2013)

Greenhouse gas		100-year GWP values IPCC 2007	100-year GWP values IPCC 2013
Carbon dioxide	CO_2	1	1
Methane	CH_4	25	28
Nitrous oxide	N_2O	298	265
Refrigerant R-134a	CH_2FCF_3	1,430	1,300
Refrigerant R-143a	CH_3CF_3	4,470	4,800

Logistics is organised within networks where vehicles and containers need to be balanced. Empty running of vehicles and **empty handling** of containers and pallets etc. is required. For this reason, the corresponding resource consumption is to be included when calculating average consumption or emissions factors.

Unit of activity = amount of outgoing cargo

Carbon accounting aims to enhance the transparency of GHG emissions caused at a logistics site 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 activity that enables a comparison over the years. In this guide, the **amount of outgoing cargo** in [tonnes] is recommended as it can be applied for most types of logistics sites. Here, '**cargo**' refers to any quantity of goods, 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). Additional guidance on choosing the unit of activity is given in chapter 8.2.

Activity category

Comparable to Transport Service Categories (TSC) introduced by the GLEC Framework, **activity categories** are used to link annual consumption and emissions information to relevant services provided at the sites and hence may require different resources. The more detail used to define activity categories, the more detailed the data that needs to be collected.

For this reason, it is necessary to decide at the start whether to provide emissions information at:

- An average site level (e.g. GHG emissions per tonne of average cargo transhipped at a site),
- The activity level (e.g. GHG emissions per tonne ambient cargo and per tonne refrigerated cargo transhipped at a site),

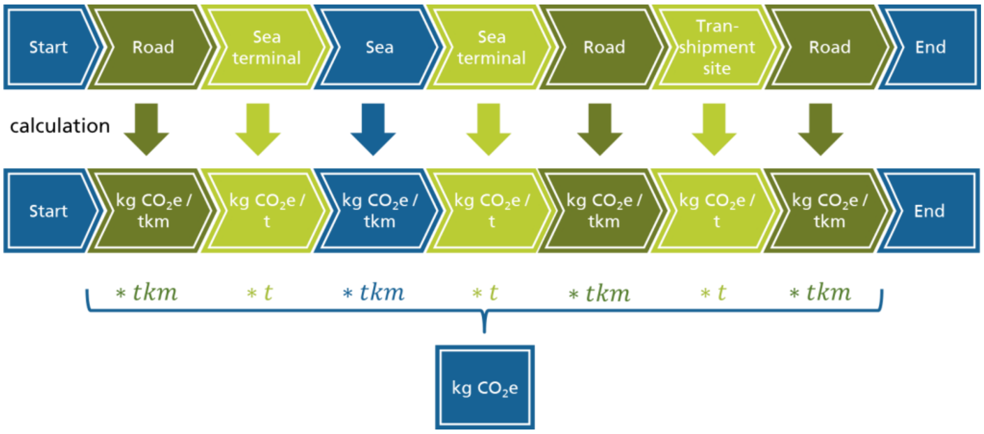
or other levels with even finer granularity, e.g. specific logistics services of the reporting company, such as national/ international shipments, value added services for selected clients.

The most suitable activity categories should be defined by the site operator. It may be reasonable to have a small number of activity categories offering average emissions data for the site type that can be provided/ reported on a regular (annual) basis. However, it may also be interesting to define client-specific categories showing transparently how decisions at different activity levels for clients may influence the emissions of the logistics site or the service. Another option for selected activity categories is to zoom into specific operations of the site for which green measures (e.g. investment in heating or cooling systems) are planned. Further details are given in chapter 8.2.

Emission intensity = GHG emissions per tonne

Emission intensity describes the amount of GHG emissions caused at the logistics site per logistics unit. In general, emission intensities are expressed in terms of GHG emissions per tonne, which is comparable to emission intensities of transport [GHG emissions per tonne-kilometre]. The metric can be used to provide information internally and for clients or shippers to be included in logistics chain calculations (see Figure 5) or to use for the purpose of emissions intensity target setting according to CDP (CDP 2018, C4.1b, page 39f).

Figure 5:
Calculation of GHG emissions along the logistics chain



Data type

The quality of the emissions results is determined by the quality of the data sources. In practice, all data used in the assessment may be a mixture of **measured, calculated or estimated data**. The company should transparently document if (and where) other than measured data is used and which underlying assumptions are applied.

3
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 facilities that are to be included in scope of the emissions accounting. In a second step, it explains which activities are excluded and the reasons for this exclusion.

The assessment boundaries for logistics facilities follow the **operational control** of the reporting company. All sources of GHG emissions are covered that are owned or controlled by the reporting company.

There are numerous names and classification schemes for logistics sites that provide storage, transhipment and other handling services in a supply chain. In this guide, logistics facilities are classified with regard to the presence or absence of three different types of requirements based on their underlying characteristics (following Rüdiger et al. 2016, Arnold et al. 2008, p. 571).

Table 3: Classification scheme for logistics sites

	Requirements regarding		
	Time (stock-keeping)	**Temperature**	**Order picking**
Characteristics	**No storage**, i.e. transhipment	**Ambient** above +8°C	**Without order picking**
	With storage • short-term • medium-term • long-term	**Refrigerated** • fresh (+4°C to +7°C) • sensitive (0°C to +2°C) • pharmaceutical product (+2°C to +8°C) • frozen (< 0°C) in case of food < -18°C	**With order picking**

At **transhipment sites** no stock-keeping is relevant and shipments are transhipped virtually instantly (less than ~24 hours). Typical examples are cross-docking sites as well as distribution centres, delivery sites or micro-depots of CEP service providers. **Warehouses** offer short, medium and/ or long-term storage depending on the market sector.

Both types, transhipment sites as well as warehouses, may be **ambient**, **refrigerated** or mixed sites (i.e. covering ambient and refrigerated areas). Here, refrigerated sites can be further subdivided regarding relevant temperature levels (zones) required for fresh, sensitive or frozen goods.

Order picking and value added service (VAS)

In addition, consignments may leave the logistics site with or without prior **order picking** or order preparation operation. Here, 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. All these activities are covered by the term 'order picking' in the following description in this guide.

3.1 Within assessment boundaries

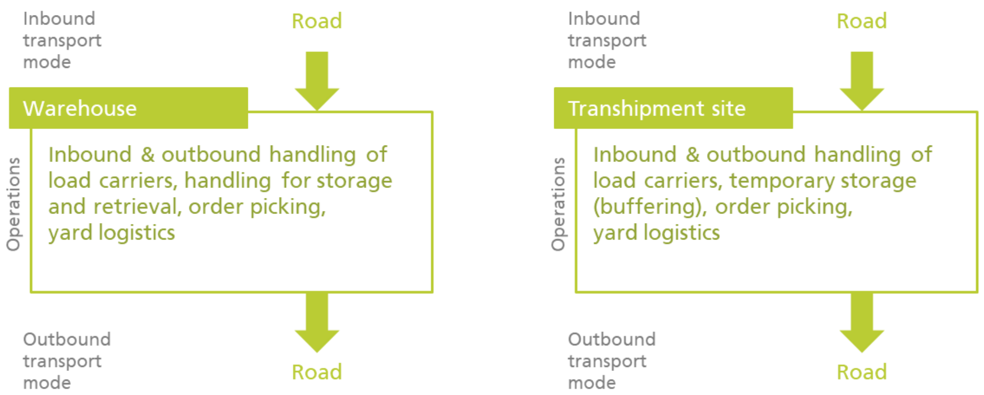
At warehouses and transhipment sites, shipments often arrive and leave via road vehicles or load carriers, e.g. container, swap body (see Figure 6). As long as these are loaded on vehicles also used for inbound or outbound transport, the fuel consumption of these vehicles is out of the scope of the emissions accounting at the site.

Energy use

Dedicated vehicles may move trailers, containers or swap bodies around on-site. For movements confined to the logistics site, the **energy use**, i.e. fuel consumption, of the vehicles is within the scope of the emissions accounting.

Depending on the type of logistics site and its requirements (see Table 3), the following activities are necessary and within assessment boundaries: unloading of shipments, handling for storage and retrieval, cross-docking operations, sorting, order picking and other value added services.

Figure 6: Scope of warehouses and transhipment sites



Typical equipment (see Table 4) used for these operations are industrial trucks, conveyors, fork lifts, high-bay warehouses, rack feeders, lifts or cranes. These may use different fuels (e.g. diesel, petrol, gas) or be electrified operations.

Relevant electricity consumption is also caused by goods refrigeration, lighting (outdoor and indoor), IT infrastructure and offices. Additional but generally minor electricity consumers include weighing equipment, wrapping machines and garbage compactors.

Leakage of refrigerants

An additional GHG source at refrigerated sites can be **refrigerants** leaking out of equipment for temperature-control for logistics areas. Many cold warehouses nowadays use R717 ammonia (NH_3) without any GHG impact when it is leaked. But there are still warehouses using refrigerants that have a climate impact, such as fluorinated refrigerants (R 404A, R 134a), R 22 or CO_2. Air conditioning units at operational offices, for example may also cause refrigerant leakage that usually is less relevant compared to the aforementioned.

Table 4: Equipment used at warehouses and transhipment sites and their GHG sources

Equipment for	Example energy consumer	Diesel/ petrol	Gas*/ hydrogen	Electricity	Heating **	Refrigerants ***
Handling of logistics units: (un)loading, transport on-site, storage	Industrial truck, conveyor, fork lift, high bay warehouse, rack feeder, lift, crane	×	×	×		
Temperature control	Refrigerant device			×		×
	Heating device			×	×	
Lighting	Lighting			×		
Repacking, packing, order picking, sorting	Wrapping machine, sorting machine			×		
Others (basics)	IT systems, offices, garbage compactor, weighing equipment			×	×	

* e.g. LNG (liquefied natural gas), CNG (compressed natural gas)
** e.g. natural gas, heating oil, district heating, geothermal energy, wood chips or pellets
*** e.g. R-134a, R-404A, R-407C, R-410A, R-744, R-717

3.2 Exclusion from the assessment scope

This chapter describes those activities that may be excluded from the assessment scope for the following reasons:

1. They have only minor relevance on targeted emission intensity values of shipments handled at logistics sites
2. Data availability seems difficult at the moment and/ or further research is needed (e.g. packaging material, waste)
3. A combination of both, i.e. high effort is needed to collect data, and there is only a limited impact on the total carbon footprint of the site

Although the following GHG sources are excluded, they are specified upstream scope 3 categories of the GHG protocol (see also chapter 8.4) and are recommended to be covered by corporate reporting.

At warehouses and transhipment sites, the consolidation of shipments as well as changing their physical character by picking, customizing and repacking processes is a relevant task (see also description of order picking and VAS on page 17). Here, operators are responsible for preparation for onward transport and **packaging** (e.g. stretch or shrink foil, cardboard layers, strap band) is used or **waste** (e.g. plastic film, cardboard) produced. Site operators as well as shippers and consignees may influence the type and amount of packaging and the associated environmental impact. This includes:

- 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
- Strategies regarding reusable transport packaging such as pool pallets or containers that require balancing transport within logistics networks

For the time being, GHG emissions associated with the supply and use of packaging material and the recycling of waste produced are excluded from the assessment boundaries when conducting logistics chains calculations. However, it is recommended that these GHG sources should be included in corporate accounting.

Manufacturing and end-of-life/ dismantling of the **building shell** of logistics facilities as well as **materials handling equipment** (covering both stationary and non-stationary equipment such as conveyors and forklifts) are excluded from the assessment boundaries. GHG emissions caused by these processes have only a low impact compared to the overall operational emissions.

Commuting of employees working at the warehouse may have an impact on the total carbon footprint of a site, but would require substantial effort to quantify and may cover personal information. For this reason, it is excluded from the general assessment scope.

However, if a company plans to compare emission intensities of two (or more) sites with different levels of automation, it is recommended that emissions caused by commuting should be covered. At sites with a high level of automation, automated materials handling equipment consume electricity, while sites 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.

To account for emissions generated by **home office** activities and **business travel** of employees, a relatively high effort is needed to collect data, with usually only a limited impact on the total carbon footprint of the warehouse. However, regular long haul business flights by senior site managers, for example, could significantly increase the carbon footprint of a small warehouse. For this reason, it is again recommended that these GHG sources should be included in corporate accounting.

If the reporting company wishes to cover these GHG emissions sources, i.e.

- Packaging material and waste associated with cargo safety measures
- Building shell and materials handling equipment
- Commuting of employees or business travel
- Home office activities

the company should report the results separately from those emissions within the assessment boundaries.

4
Selecting GHG calculation approach

The focal issue of this guide is carbon audits at logistics facilities with a view to carrying out the logistics chains calculation. For this reason, the guide differentiates **two levels of detail for calculating GHG emissions**, which are:

- Calculating an average emission intensity for a logistics site (see chapter 5),
- Calculating emission intensities at activity level (see chapter 6).

These generic approaches can be further detailed with a view to optimizing the management of logistics facilities (see also chapter 8.2), e.g. from the point of view of different temperature zones or from a clients' perspective.

Reasons for one emission intensity value

Why select **one average emission intensity value**? At some logistics sites, all logistics units are similar and are processed in a comparable manner. In this case, it is reasonable to calculate one average emission intensity value (i.e. kg CO_2e per logistics unit) for the site. A second reason may be that more detailed data for calculating partial emissions (see also chapter 6 and 6.3) is not available (yet). For example, the company has only one electricity meter on-site and cannot allocate electricity consumption to relevant activities. Another reason may be that the company simply prefers to calculate an initial emission intensity value to start with.

Assumptions

By doing so, one should be aware of the variety of factors that influence the consumption of activities and processes at logistics sites. Interpretation of the results is limited as many **assumptions** have been made. For instance, no differentiation is made between:

- Types and sizes of logistics units handled at the warehouse, i.e. between sizes of boxes or pallets as well as between heavy or light goods
- The specifics of how each individual unit is moved and stored.
- Ambient and refrigerated cargo
- Types and management of lighting at the facility's areas (e.g. motion sensors in less frequent areas)
- Variability of different order picking requirements and operations

4.1 General remarks on collecting data

Companies operating their own logistics site can easily collect the relevant data of their operations, i.e. consumption and logistics data.

Consumption data

Generally, **consumption data** should be available for any logistics site, 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 site 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 sites, 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 sites are very much aware of the resources purchased and consumed and the warehouse management systems (WMS) offer sufficient information access.

Logistics data

Logistics data that refer to information on handling activities and shipments are usually processed at site 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).

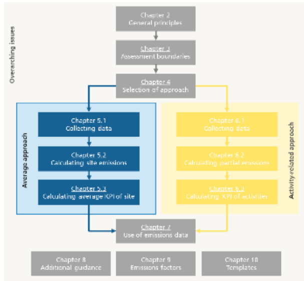
The relevant data a company should collect is summarised in Table 5.

Table 5: Which data sets are relevant for calculating emission intensity values?

Calculation approach	Consumption data		Logistics data
	Energy	Refrigerants[1]	
One average emission intensity value	Total annual fuels and electricity consumption	Total refill of refrigerants	Total throughput
Emission intensity value at activity level	Annual fuels and electricity consumption at activity level	Total refill of refrigerants	Throughput at service level

[1] Only relevant at sites with temperature control, e.g. refrigerated warehouse

5
Calculating an average emission intensity value for a logistics site



This chapter describes all relevant steps for the calculation of one average emission intensity value for a logistics site, i.e.:

1. Collection of consumption and logistics data
2. Calculating total site emissions
3. Calculating the average emission intensity value for the site

If a company chooses to conduct a GHG assessment at activity level, details are given in chapter 6.

5.1 Collecting data

5.1.1 Consumption of fuels and electricity

There is a variety of infrastructure, equipment and activities at logistics sites that require either electricity or fuels. The reporting company records the quantity of electricity and fuels consumed for:

- Driving vehicles and running technical equipment (see also examples in Table 4, p. 19)
- Lighting
- Running the refrigeration or heating system (if relevant)
- IT systems, offices, workshops, generators
- Other items such as weighing station, wrapping machines, garbage compactor etc.

A template for collecting consumption data with the respective typical units is provided below (see Table 6). Here, total consumption per energy source (columns) provides a sufficient level of detail.

Table 6: Data collection on consumption of energy sources

All infrastructure/ equipment	Electricity [kWh]	Diesel [litre]	Petrol [litre]	LNG [kg]	CNG [kg]	Hydrogen [kWh]	Heating[1] [kWh]
…							
Total consumption of site							

[1] e.g. natural gas, heating oil, district heating, geothermal energy, wood chips or pellets

5.1.2 Refill of refrigerants

At temperature-controlled facilities, refrigerants may be refilled after leakages during operation. While ammonia has no relevant climate change impact and is negligible, there are others containing fluorine (e.g. R-134a or R-404A) that are relevant. In this case, the company records the amount of refilled refrigerants per type. A template for data collection is given below.

Table 7: Data collection on refill of refrigerants

Type of refrigerant	[kg]
…	

5.1.3 Logistics data

For calculating one average emission intensity value, the company records the throughput of the site. This refers to the outgoing cargo that is measured in tonnes, which is aligned with the GLEC Framework.

Table 8: Logistics data collection

Logistics data	[tonnes]
Logistics units leaving site	…

If the reporting company usually refers to another unit, e.g. pallets or boxes, this can be used as well. 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.

Note: In the case of logistics sites in the mails and parcels sector, the revised GLEC Framework recommends using one of the EN 16258 tonne-km allocations or else per item, which are typically parcels or letters.

Other relevant base units for deriving KPI’s of logistics sites (e.g. m^2, m^3) are discussed in chapter 8.2.

5.2 Calculating site emissions

Calculating an average emission intensity value for a logistics site

When all consumption data has been collected for the accounting year, the total GHG emissions of the site can be calculated. The total emissions are to be calculated item by item for each energy type or refrigerant type as follows:

Equation 1: Calculation of total emissions of logistics site

$$EM = \sum (Q_i \times EF_i)$$

EM	Emissions of the site [kg CO_2e]
Q_i	Amount used or refilled [kWh, l, kg]
EF_i	Relevant emissions factor [kg CO_2e per unit]
i	Source of emissions, i.e. electricity, fuel type, refrigerant type

Example 1: Calculation of total emissions of a warehouse

At an exemplary French warehouse, only diesel and electricity were used.

Example	Electricity	Diesel
Total consumption of site	700,000 kWh/a	6,000 l/a

The relevant formula is as follows:

$$EM = Q_{diesel} \times EF_{diesel} + Q_{elec} \times EF_{elec-France}$$

With $EF_{diesel} = 3.24 \frac{kg\ CO_2e}{l}$ [EN 16258]; $EF_{elec-France} = 34.8 \frac{g\ CO_2e}{kWh}$ [EEA 2014]

The total emissions are as follows:

$$EM = 6{,}000\ l \times 3.24 \frac{kg\ CO_2e}{l} + 700{,}000\ kWh \times 0.0348 \frac{kg\ CO_2e}{kWh} = \mathbf{43{,}800\ kg\ CO_2e}$$

5.3 Calculating average KPI of site

For the calculation of an average emission intensity value, the following formula applies. The total annual emissions of the site is divided by the annual amount of logistics units leaving the site.

Equation 2: Calculation of average emissions intensity value

$$em_{\emptyset} = \frac{EM}{Q_{units}}$$

$em_{\emptyset}$	Average emission intensity value [kg CO_2e/tonne]
EM	Emissions of site [kg CO_2e]
Q_{units}	Total amount of cargo outbound [tonne]

Example 2 illustrates the calculation of an average emissions intensity value of a warehouse.

Example 2:
Calculation of average emission intensity value of a warehouse

At a refrigerated warehouse (Belgium), the consumption data was collected as shown in the following table. In total the site had a throughput of 90,000 tonnes/a.

Example	Electricity	Diesel	R-410A
Total consumption of site	700,000 kWh/a	6,000 l/a	53 kg/a

The relevant formula is as follows:

$$EM = Q_{diesel} \times EF_{diesel} + Q_{elec} \times EF_{elec-Belgium} + Q_{R-410A} \times EF_{R-410A}$$

With $EF_{diesel} = 3.24 \frac{kg\ CO_2e}{l}$ [EN 16258]; $EF_{elec-\ Belgium} = 221.5 \frac{g\ CO_2e}{kWh}$ [EEA 2014];
$EF_{R-410A} = 2{,}087.5 \frac{kg\ CO_2e}{kg}$ [IPCC 2007]

The total emissions are as follows:

$$EM = 6{,}000\ l \times 3.240 \frac{kg\ CO_2e}{l} + 700{,}000\ kWh \times 0.2215 \frac{kg\ CO_2e}{kWh} + 53\ kg \times 2{,}087.5 \frac{kg\ CO_2e}{kg} = \mathbf{288{,}127.50\ kg\ CO_2e}$$

The average emission intensity accounts for:

$$em_{\emptyset} = \frac{EM}{Q_{units}} = \frac{288{,}127.5\ kg\ CO_2e}{90{,}000\ t} = \mathbf{3.17 \frac{kg\ CO_2e}{t}}$$

The calculated average emission intensity can be used for further emission footprint calculation in logistics chains as shown in the following example.

Example 3:
Use of average emission intensity of a warehouse within a transport chain

For an example transport chain (road, warehouse, road) the following details are given:
50,000 tonnes of cargo are transported from the place of production (start) to wholesale (end) via two road sections (200 km and 50 km). Between the road transportation the cargo is stored in a refrigerated warehouse in Belgium (see example above).

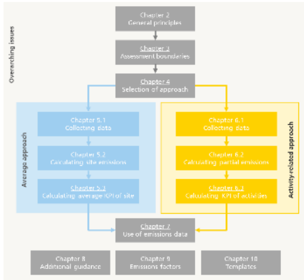
Using an average consumption factor for road transport of $Q_{diesel} = 0.08 \frac{l\ diesel}{tkm}$, an emissions factor for diesel of $EF_{diesel} = 3.24 \frac{kg\ CO_2e}{l}$ [EN 16258] and an average emission intensity of the warehouse of $em_{\emptyset} = 3.17 \frac{kg\ CO_2e}{t}$, the total emissions of the transport chain are calculated as follows:

$$EM = 50{,}000t \times \left[(200\ km + 50\ km) \times 0.08 \frac{l\ diesel}{tkm} \times 3.24 \frac{kg\ CO_2e}{l\ diesel} + 3.17 \frac{kg\ CO_2e}{t}\right] = \mathbf{3{,}398{,}404\ kg\ CO_2e}$$

Of this, transport is responsible for 3,240,000 kg CO_2e and the warehouse for 158,404 kg CO_2e.
As such, storage accounts for 5% of the logistics chain's GHG emissions.

The relevant emission intensity for this transport chain accounts for:

$$em_{\emptyset} = \frac{EM}{Q_{units}} = \frac{3{,}398{,}404\ kg\ CO_2e}{50{,}000\ t} = \mathbf{67.97 \frac{kg\ CO_2e}{t}}$$



6
Calculating emission intensities at activity level

At sites where different activities are offered and where shipments require different operations and resources, such as order picking or refrigeration of goods, it is reasonable to differentiate between two or more activity categories, i.e. picked units or unpicked units for each temperature requirement. Here it is necessary to collect partial consumption data so as to be able to calculate partial emissions as described later in this chapter.

Figure 7 illustrates the various operations a shipment may pass through, based on the classification scheme for logistics sites as introduced in Table 3 (see p. 17). As such, eight different activity categories can be differentiated in total.

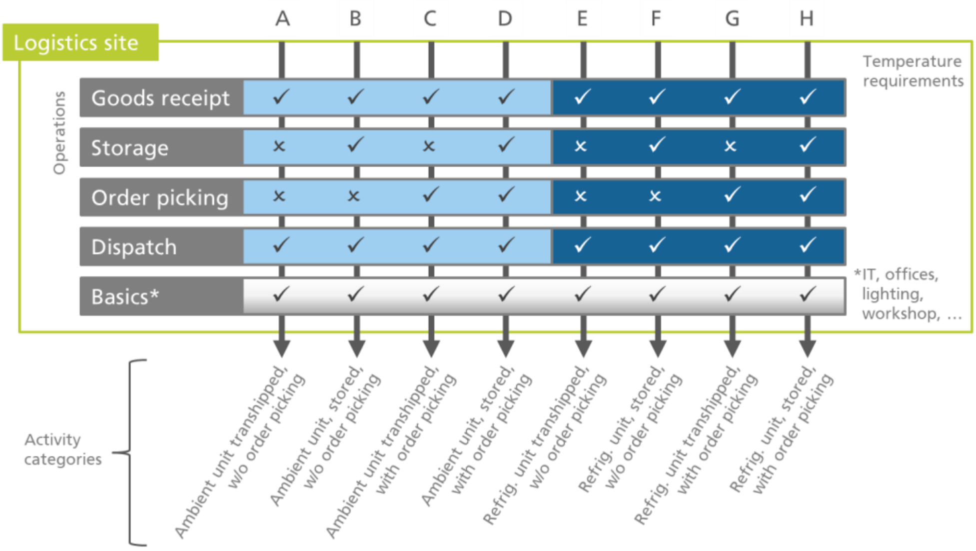


Figure 7:
Differentiation of max. eight activity categories (A to H)

Figure 7 does not cover further specification of short, medium or long-term storage, nor does it cover temperature levels for refrigerated goods (i.e. fresh to frozen). This would add even more possible activity categories.

For sites that offer only one of these activity categories (i.e. only one perpendicular arrow is relevant, e.g. ‘A’ in an ambient cross-docking centre), one average emission intensity value can be calculated for the site as described in the previous chapter. For all other sites (with two or more activity categories), the following procedures will help calculate activity-related emission intensity values.

This chapter describes all relevant steps for conducting a GHG assessment at activity level, i.e.:

1. Collection of partial consumption and logistics data
2. Calculating partial emissions of the site
3. Calculating activity-related emission intensity values for the site

6.1 Collecting data at activity level

Since this approach provides emission intensity values in more detail, i.e. at activity level, more detailed input data has to be collected as compared to the approach described in chapter 5.

There is a variety of infrastructure, equipment and activities at logistics sites that require either electricity or fuels. The reporting company records the quantity of electricity and fuels consumed for:

- Driving vehicles and running technical equipment (see also examples in Table 4, p. 19)
- Lighting
- Running the refrigeration or heating system (if relevant)
- IT systems, offices, workshops, generators
- Others such as weighing station, wrapping machines, garbage compactor etc.

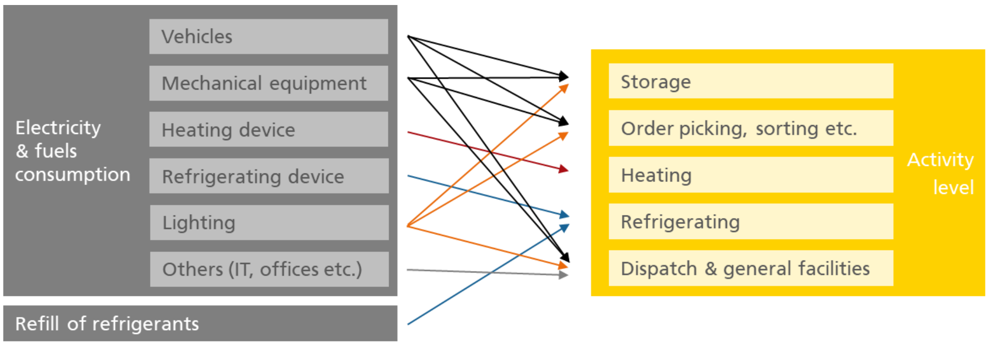
In addition, the company records the amount of refilled refrigerants (in case of refrigerated sites).

Partial consumption of energy

At this point, the challenge is to clearly allocate part of the total annual electricity or fuels consumption to specific activities (see Figure 8), i.e. energy used for

- Running the heating system
- Running the refrigerating system
- Goods storage
- Order picking, sorting or other equivalent services
- Dispatch and general facilities

Figure 8: Schematic allocation of GHG source to activities



At a mixed warehouse, for example ambient as well as refrigerated shipments are handled. Here, 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 blue arrows in Figure 8). Similarly, emissions caused by the use of natural gas for heating needs is only allocated to ambient goods (see red arrow in Figure 8).

In the following, the identification of relevant partial energy consumption depending on the type of logistics facility as well as the collection of the data is described in more detail.

6.1.1 Electricity consumption of lighting

Regarding the electricity consumption of **lighting**, companies often 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 at activity level. 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 9. In this example, 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. Here, the company may allocate $^2/_3$ of the electricity consumption of lighting to transhipment activities, and $^1/_3$ to storage and order picking. Another example is given below (see Example 4).

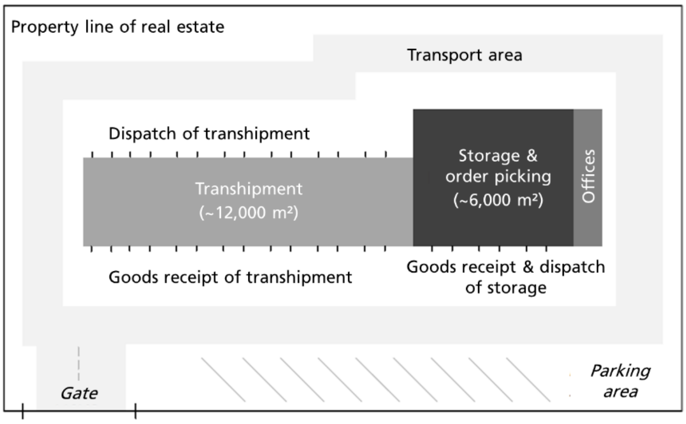


Figure 9:
Example logistics site with relevant functional areas

Example 4:
Share of electricity use for lighting per functional area

A warehouse operator measured an electricity consumption of 450,000 kWh/a for lighting. Furthermore, the operator decided to allocate the total consumption at activity level using the size of the respective functional area. The relevant information is summarized in the table below.

$$electricity\ consumption_{storage} = \frac{3{,}000\ m^2}{9{,}500\ m^2} \times 450{,}000\ kWh = 32\% \times 450{,}000\ kWh = 142{,}105\ kWh$$

Functional area	Allocation via [m²]	Share	Electricity
Storage	3,000 m²	32%	142,105 kWh
Order picking	4,000 m²	42%	189,474 kWh
Dispatch	2,500 m²	26%	118,421 kWh
Total	**9,500 m²**	**100%**	**450,000 kWh**

If no measured electricity consumption is at hand, the operator may collect the total (or area-specific) installed capacity (e.g. by total number of lights and their respective capacity) and multiply this by the average operation time of the lights (see Example 5).

Example 5: Estimating electricity consumption by installed capacity

A warehouse with 4 halls, each consisting of:

- Storage area with 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

- Storage area: $277.2\ kW \times 4{,}420\ h/a = 1{,}225{,}224\ kWh/a$
- Dispatch area: $16.8\ kW \times 4{,}420\ h/a = 74.26\ kWh/a$
- Total site: $294\ kW \times 4{,}420\ h/a = 1{,}299{,}480\ kWh/a$

6.1.2 Energy consumption of materials handling equipment

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

For the calculation of **storage** emissions, the energy consumption of all relevant materials handling equipment used in the storing area (e.g. conveyors, fork lifts) 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 use for lighting the storage area is described in the previous chapter.
Similarly, data relating to energy consumption by **transhipment** activities can be collected.

Order picking activities often are manual or semi-manual, e.g. using fork lifts. Energy consumption (usually electricity) may refer to the use of conveyors, fork lifts or other relevant equipment as well as the lighting of the order picking area (see also Table 4).

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.

A sample template for collecting energy consumption at activity level is provided below. Here, lighting and handling are kept separate, as they are often collected separately. However, this is not required for the later emissions calculation (as described in chapter 6.2f).

Table 9: Example template for data collection on energy consumption (without heating/cooling)

Activity/ functional area		Electricity [kWh]	Diesel [litre]	Petrol [litre]	LNG [kg]	CNG [kg]	Hydrogen [kWh]
Storage	Handling	…					
	Lighting						
Transhipment	Handling						
	Lighting						
Order picking	Handling						
	Lighting						
Goods receipt, dispatch, general facilities (IT, office…)	Lighting						
	others						
Total consumption of site							

Further relevant guidance is given for "Measuring energy consumption at the logistics site" (see chapter 8.1).

6.1.3 Consideration of the temperature requirements of logistics units

As described above, at some sites, both ambient and refrigerated units are handled and the energy use and possible refill of refrigerants need to be allocated at activity level.

For the calculation of **heating** emissions, all relevant fuel types[1] 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 refilled. Again, the operator might need to measure or estimate the electricity consumption of the refrigerating devices.

Templates for collecting consumption data with regards to temperature requirements are provided below (see Table 10 and Table 11).

[1] e.g. natural gas, heating oil, district heating, geothermal energy, wood chips or pellets

Table 10: Data collection for temperature requirements

Infrastructure/ equipment	Electricity [kWh]	Natural gas [kWh]	Heating oil [kWh]	District heating [kWh]	Geothermal energy [kWh]	Wood chips [kWh]	Wood pellets [kWh]
Heating devices	…						
Refrigerating devices							

Table 11: Data collection on refill of refrigerants

Type of refrigerant	[kg]
…	

If all functional areas of a site, i.e. areas for storage, picking or dispatch, require the same temperature control and the consumption and associated emissions can be evenly allocated to all refrigerated or ambient shipments, it is sufficient to record total energy consumption for refrigerating or heating.

However, there are exceptions that require a differentiated approach. One example is if one functional area is only used for a share of all logistics units, e.g. only some of the shipments require order picking and not all unpicked shipments pass the picking area. In this case, the reporting company may decide to allocate the refrigerating energy just to the specific activity processed in this functional area (in the example, this is picking). For this reason, the company collects or estimates the electricity consumption of the refrigerating equipment per functional area. Example 6 describes this approach in more detail.

It may also be relevant to consider, that depending on the climate ambient goods need refrigeration as well (e.g. during summer). This raises complexity within the allocation of energy consumption and it is recommended to consider this only if this is a regular aspect and may have a relevant effect on the carbon intensity factors.

Example 6:
Calculation of activity related electricity consumption for refrigeration, considering functional area specific electricity consumption

A warehouse operator collected the following data relating to electricity consumption of the refrigerating equipment (e.g. estimated by the capacities of respective equipment) and logistics data for relevant logistics units of the functional area.

This includes the total number of refrigerated pallets outbound (for storage and dispatch) and the total number of refrigerated pallets that required order picking, which is 15% of the total pallets outbound.

Calculating emission intensities at activity level

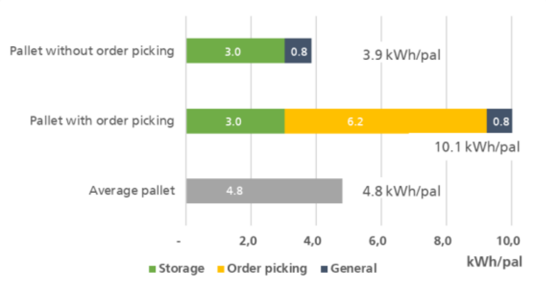
Functional area	Electricity consumption	Logistics unit	kWh / unit
Storage	933,000 kWh/a	308,000 pal. outbound	1,451 kWh/pal. outbound
Order picking	292,000 kWh/a	47,000 pal. picked	2,976 kWh /pal. picked
Dispatch	253,000 kWh/a	308,000 pal. outbound	393 kWh /pal. outb.
Total	**1,478,000 kWh/a**	**308,000 pal. outbound**	**2,299 kWh /pal. outb.**

The activity related electricity consumption for refrigeration per logistics unit is calculated using the following formula:

$$q_{activity} = \frac{Q_{elec,area}}{units_{area}}$$

For the handled pallets, two activity categories can be differentiated:

- Pallet without order picking with 3.9 kWh/pallet
- Pallet with order picking with 10.1 kWh/pallet



On average, i.e. without differentiating between energy consumption specific to functional areas, the electricity consumption for refrigeration accounts for 4.8 kWh/pallet (see diagram).

6.1.4 Logistics data

For calculating emission intensity values, the company records the throughput of the site. In addition to the total amount of cargo leaving the logistics site (throughput), the reporting company may also collect information on the share of logistics units **with or without order picking** or the share of **ambient or refrigerated goods** (depending on the relevant activities at the site) leaving the site.

Table 12: Logistics data collection

Logistics data	[tonnes]
Logistics units leaving site	…
• of this: picked units	
• of this: refrigerated units	

Here, one has:

Equation 3: Annual amount of cargo leaving the site

$$Q_{total} = Q_{amb} + Q_{refr} = Q_{picked} + Q_{unpicked}$$

Q_{total}	Total amount of cargo outbound [tonnes]
Q_{amb}	Amount of ambient cargo outbound [tonnes]
Q_{refr}	Amount of refrigerated cargo outbound [tonnes]
Q_{picked}	Amount of cargo outbound with order picking [tonnes]
$Q_{unpicked}$	Amount of cargo outbound without order picking [tonnes]

If the reporting company usually refers to another unit, e.g. pallets or boxes, this can be used as well. 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.

Note: In the case of logistics sites of the mails and parcels sector, the revised GLEC Framework recommends using one of the EN 16258 tonne-km allocations or per item, which are typically parcels or letters.

Other relevant base units for deriving KPI's of logistics sites (e.g. m^2, m^3, time stored) are discussed in chapter 8.2.

6.2 Calculating partial emissions

When all consumption and logistics data has been collected for the accounting year, GHG emissions can be calculated. The accounting of emission intensity values at activity level requires the calculation of partial emissions, which uses the activity-related consumption data as described in the previous chapter.

A different set of partial emissions needs to be calculated depending on the relevant activity categories at the logistics site assessed. The following table provides an overview of which partial emissions an operator of a selected type of logistics site should probably consider and calculate.

Table 13: Relevant partial emissions of different types of logistics sites

Temperature	Operations	$EM_{tranship}$	$EM_{storage}$	$EM_{picking}$	$EM_{general}$	EM_{heat}	EM_{refr}
Ambient site	Storage only		×	(×)	×	×	
	Transhipment only	×		(×)	×	×	
	Transhipment & storage	×	×	(×)	×	×	
Refrigerated site	Storage only		×	(×)	×		×
	Transhipment only	×		(×)	×		×
	Transhipment & storage	×	×	(×)	×		×
Ambient + refrigerated (mixed) site	Storage only		×	(×)	×	×	×
	Transhipment only	×		(×)	×	×	×
	Transhipment & storage	×	×	(×)	×	×	×

The sum of all partial emissions of the site equals the total annual emissions of the site according to Equation 4. Their calculation is described item by item in more detail in the following chapters.

$$EM = EM_{tranship} + EM_{storage} + EM_{picking} + EM_{general} + EM_{heat} + EM_{refr}$$

EM	Total emissions of the site [kg CO_2e]
$EM_{tranship}$	Transhipment emissions of the site [kg CO_2e]
$EM_{storage}$	Storage emissions of the site [kg CO_2e]
$EM_{picking}$	Picking, sorting etc. emissions of the site [kg CO_2e]
$EM_{general}$	Emissions of general operations of the site [kg CO_2e]
EM_{heat}	Heating emissions of the site [kg CO_2e]
EM_{refr}	Refrigerating emissions of the site [kg CO_2e]

Equation 4: Calculation of total emissions of logistics site

Further relevant guidance is given for:

- Measuring energy consumption at the logistics site (see chapter 8.1)
- Identifying the relevant emissions factor (see chapter 9)
- Calculation of emissions factor with supplier's mix (see chapter 8.3)

6.2.1 Calculation of transhipment emissions

For the calculation of transhipment emissions, all relevant fuel types used are collected, which covers energy used by materials handling equipment as well as electricity for lighting (see also Table 6).

The emissions can be calculated item by item for each fuel type as follows:

Equation 5: Calculation of transhipment emissions

$$EM_{tranship} = \sum (Q_{fuel\ type} \times EF_{fuel\ type})$$

$EM_{tranship}$	Transhipment emissions of the site [kg CO_2e]
$Q_{fuel\ type}$	Amount of fuel used [l, kg, kWh]
$EF_{fuel\ type}$	Relevant emissions factor [kg CO_2e / unit]

6.2.2 Calculation of storage emissions

For the calculation of storage emissions, all relevant fuel types used are collected, which covers energy used by materials handling or storage equipment as well as electricity for lighting (see also Table 6).

The storage emissions can be calculated item by item for each fuel type as follows:

Equation 6: Calculation of storage emissions

$$EM_{storage} = \sum (Q_{fuel\ type} \times EF_{fuel\ type})$$

$EM_{storage}$	Storage emissions of the site [kg CO_2e]
$Q_{fuel\ type}$	Amount of fuel used [l, kg, kWh]
$EF_{fuel\ type}$	Relevant emissions factor [kg CO_2e/unit]

Example 7: Calculation of the annual emissions for storage activities

At an exemplary German warehouse, only electricity was used for storage activities.

Example	Electricity
Total consumption of site	405,000 kWh/a

The relevant formula is as follows: $EM_{storage} = Q_{elec} \times EF_{elec-Germany}$

With $EF_{elec-Germany} = 424.9 \frac{kg\ CO_2e}{kWh}$ [EEA 2014]

The total emissions are as follows:

$$EM_{storage} = 405{,}000\ kWh \times 0.4249 \frac{kg\ CO_2e}{kWh} = \mathbf{172{,}085\ kg\ CO_2e}$$

6.2.3 Calculation of order picking emissions

For the calculation of order picking emissions, all relevant fuel types used are collected, which covers energy used by materials handling equipment as well as electricity for lighting (see also Table 6).

The emissions can be calculated item by item for each fuel type as follows:

$$EM_{picking} = \sum(Q_{fuel\ type} \times EF_{fuel\ type})$$

$EM_{picking}$	Order picking emissions of the site [kg CO_2e]
$Q_{fuel\ type}$	Amount of fuel used [l, kg, kWh]
$EF_{fuel\ type}$	Relevant emissions factor [kg CO_2e / unit]

Equation 7: Calculation of order picking emissions

6.2.4 Calculation of emissions general activities

As described in chapter 6.1.2, some activities can be summed up as general activities, such as goods receipt, dispatch, IT infrastructure or offices.

For the calculation of their emissions, all relevant fuel types (often just electricity) used for these activities are collected (see also Table 6).

The general emissions are to be calculated item by item for each fuel type as follows:

$$EM_{general} = \sum(Q_{fuel\ type} \times EF_{fuel\ type})$$

$EM_{general}$	General emissions of the site [kg CO_2e]
$Q_{fuel\ type}$	Amount of fuel used [l, kg, kWh]
$EF_{fuel\ type}$	Relevant emissions factor [kg CO_2e/unit]

Equation 8: Calculation of emissions by general processes

6.2.5 Calculation of heating emissions

For the calculation of heating emissions, all relevant fuel types are to be considered, this might include heating oil, natural gas, district heating and electricity (see also Table 10).

The heating emissions would be calculated item by item for each fuel type as follows:

Equation 9:
Calculation of heating emissions

$$EM_{heat} = \sum(Q_{fuel\ type} \times EF_{fuel\ type})$$

EM_{heat}	Heating emissions of the site [kg CO_2e]
$Q_{fuel\ type}$	Amount of fuel used [l, kg, kWh]
$EF_{fuel\ type}$	Relevant emissions factor [kg CO_2e/unit]

Example 8:
Calculation of the annual heating emissions of a warehouse

At an example German warehouse, natural gas and heating oil is used.

Example	Natural gas	Heating oil
Total consumption of site	300,000 kWh/a	200,000 kWh/a

The relevant formula is as follows:

$$EM_{heat} = Q_{gas} \times EF_{gas} + Q_{oil} \times EF_{oil}$$

With $EF_{gas} = 0.260\ \frac{kg\ CO_2e}{kWh}$; $EF_{oil} = 0.312\ \frac{kg\ CO_2e}{kWh}$ [ecoinvent (v3.1), LCIA: IPCC 2013]

The heating emissions are as follows:

$$EM_{heat} = 300{,}000\ kWh \times 0.260\ \frac{kg\ CO_2e}{kWh} + 200{,}000\ kWh \times 0.312\ \frac{kg\ CO_2e}{kWh} = \mathbf{140{,}400\ kg\ CO_2e}$$

6.2.6 Calculation of refrigerating emissions

For the calculation of refrigerating emissions, the dedicated electricity consumption as well as the amount of refrigerants refilled are needed (see Table 10 and Table 11).

The refrigerating emissions would be calculated item by item for electricity and refrigerants as follows:

Equation 10:
Calculation of refrigerating emissions

$$EM_{refr} = \sum(Q_i \times EF_i)$$

EM_{refr}	Refrigerating emissions of the site [kg CO_2e]
Q_i	Amount of electricity used for refrigerating or refrigerant type refilled [kWh, kg]
EF_i	Relevant emissions factor [kg CO_2e/unit]

At some sites, it can be necessary to further subdivide refrigerating emissions at activity level, e.g. if the electricity consumption and the refill of refrigerants of the refrigerated storage area is differentiated from other areas of the site. In this case, the reporting company should collect the data separately and calculate the refrigerated storage emissions item by item as follows:

Equation 11: Calculation of refrigerating emissions of storage

$$EM_{refr,storage} = \sum (Q_{i,storage} \times EF_i)$$

$EM_{refr,storage}$	Refrigerating emissions of the storage area [kg CO_2e]
$Q_{i,storage}$	Amount of electricity used for refrigerating or refrigerant type refilled for the storage area [kWh, kg]
EF_i	Relevant emissions factor [kg CO_2e/unit]

Example 9: Calculation of the annual refrigerating emissions of a warehouse

A warehouse operator in Italy refilled an amount of 53 kg of refrigerant R-410A. One can assume that the same amount was emitted into the atmosphere. Furthermore, 470,000 kWh of electricity was used to run the refrigerating system.

Example	Electricity	R-410A
Total consumption of site	470,000 kWh/a	53 kg/a

The relevant formula is as follows:

$$EM_{refr} = Q_{elec} \times EF_{elec-Italy} + Q_{R-410A} \times EF_{R-410A}$$

With $EF_{elec-Italy} = 229.2 \frac{g\ CO_2e}{kWh}$ [EEA 2014]; $EF_{R-410A} = 2{,}087.5 \frac{kg\ CO_2e}{kg}$ [IPCC 2007]

The total emissions are as follows:

$$EM_{refr} = 470{,}000\ kWh \times 0.2292 \frac{kg\ CO_2e}{kWh} + 53\ kg \times 2{,}087.5 \frac{kg\ CO_2e}{kg} = \mathbf{218{,}361.50\ kg\ CO_2e}$$

6.3 Calculating activity-related emission intensities

At sites where different activity categories are offered and where shipments require different processes and resources, such as order picking or refrigerating of shipments, it is reasonable to differentiate between emissions intensity factors, i.e. emissions per picked tonne or emissions per unpicked tonne for each temperature requirement. For this, it is necessary to calculate partial emissions as described above.

Table 14 lists the recommended activity categories depending on the type of site and operations offered. Following this scheme, operators of sites with only one activity category (highlighted in light blue) can calculate one average emissions intensity value for their sites as described in chapter 5. Operators of all other site types may follow activity-related procedures as described in the following.

Table 14: Types of warehouses and transhipment sites and their recommended activity categories

		Requirements						Activity categories								
	Site type	No storage	With storage	Ambient	Refrigerated	No order picking	With order picking	Ambient unit transhipped, w/o order picking	Ambient unit, stored, w/o order picking	Ambient unit transhipped, with order picking	Ambient unit, stored, with order picking	Refrigerated unit transhipped, w/o order picking	Refrigerated unit, stored, w/o order picking	Refrigerated unit transhipped, with order picking	Refrigerated unit, stored, with order picking	Further details in chapter
Transhipment	1	×		×		×		×								5
	2	×			×	×						×				5
	3	×		×	×	×		×				×				6.3.1
	4	×		×			×			×						5
	5	×			×		×							×		5
	6	×		×	×		×			×				×		6.3.1
	7	×		×		×	×	×		×						6.3.3
	8	×			×	×	×					×		×		6.3.3
	9	×		×	×	×	×	×		×		×		×		6.3.4
Storage	10		×	×		×			×							5
	11		×		×	×							×			5
	12		×	×	×	×			×				×			6.3.1
	13		×	×			×				×					5
	14		×		×		×								×	5
	15		×	×	×		×				×				×	6.3.1
	16		×	×		×	×		×		×					6.3.3
	17		×		×	×	×						×		×	6.3.3
	18		×	×	×	×	×		×		×		×		×	6.3.4
Transhipment + storage	19	×	×	×		×		×	×							6.3.2
	20	×	×		×	×						×	×			6.3.2
	21	×	×	×	×	×		×	×			×	×			6.3.5
	22	×	×	×			×			×	×					6.3.2
	23	×	×		×		×							×	×	6.3.2
	24	×	×	×	×		×			×	×			×	×	6.3.5
	25	×	×	×		×	×	×	×	×	×					6.3.5
	26	×	×		×	×	×					×	×	×	×	6.3.5
	27	×	×	×	×	×	×	×	×	×	×	×	×	×	×	-

6.3.1 Consideration of temperature requirements of logistics units

Calculating emission intensities at activity level

At the logistics sites with mixed temperature requirements, both ambient and refrigerated units are handled. If all other processes are equivalent or no further differentiation is chosen (i.e. site types 3, 6, 12 or 15 in Table 14), two activity categories are relevant, i.e. handling of ambient and handling refrigerated units. The respective emission intensities to consider are:

1. GHG emissions per tonne ambient unit
2. GHG emissions per tonne refrigerated unit

Figure 10 provides an overview on the allocation procedure for this.

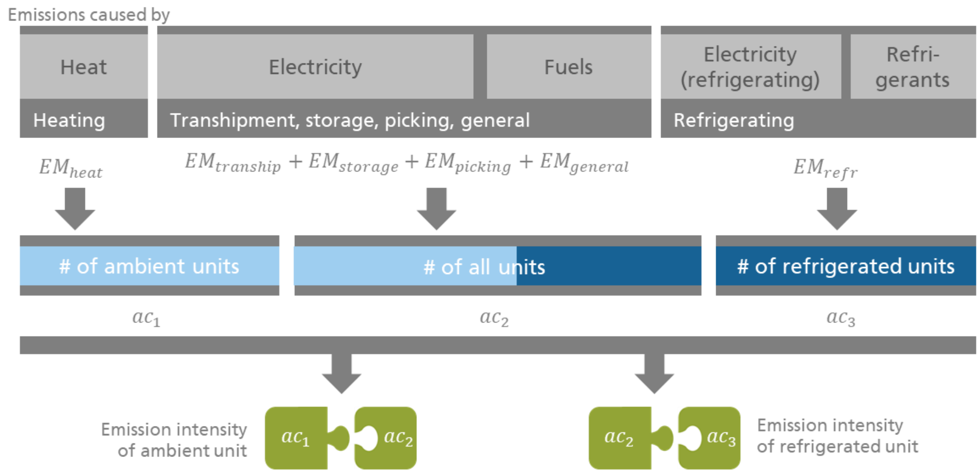


Figure 10: Allocation procedure for activity-related emission intensities per ambient and refrigerated unit

The following partial emissions need to be calculated beforehand. This step is described in the chapters referred to in the table.

Table 15: Relevant partial emissions for calculating emission intensities per ambient and refrigerated unit

Partial emission	Parameter	Chapter
Heating emissions	EM_{heat}	6.2.5
Refrigerating emissions	EM_{refr}	6.2.6
All other emissions	$EM_{tranship}$	6.2.1
	$EM_{storage}$	6.2.2
	$EM_{picking}$	6.2.3
	$EM_{general}$	6.2.4

Here, all other emissions cover emissions caused by storage, transhipment, order picking or general processes, depending on the activities of the site. They can be calculated as follows:

$$EM_{rest} = EM_{tranship} + EM_{storage} + EM_{picking} + EM_{general} = EM_{total} - EM_{heat} - EM_{refr}.$$

Furthermore, the company needs to specify the total amount of ambient units outbound ($Q_{units,amb}$) and refrigerated units outbound ($Q_{units,refr}$); with $Q_{units,total} = Q_{units,amb} + Q_{units,refr}$.

These partial emissions are used to derive allocation coefficients as follows:

Equation 12: Calculation of allocation coefficients for calculating emission intensities per tonne ambient and refrigerated unit

Heating of units	$ac_1 = \frac{EM_{heat}}{Q_{units,amb}}$
Handling of units	$ac_2 = \frac{EM_{rest}}{Q_{units,amb}+Q_{units,refr}}$
Refrigerating of units	$ac_3 = \frac{EM_{refr}}{Q_{units,refr}}$
ac_1	Allocation coefficient for heating of units [kg CO_2e/tonne]
ac_2	Allocation coefficient for all other processes at the site [kg CO_2e/tonne]
ac_3	Allocation coefficient for refrigerating of units [kg CO_2e/tonne]
$EM_{partial}$	Partial emissions [kg CO_2e] i.e. heating, rest or refrigerating
$Q_{units,amb}$	Amount of ambient cargo outbound [tonne]
$Q_{units,refr}$	Amount of refrigerated cargo outbound [tonne]

As a final step, the resulting emissions intensities are calculated as follows:

Equation 13: Calculation of emissions intensities per ambient and refrigerated unit

For ambient units	$em_{amb} = ac_1 + ac_2$
For refrigerated units	$em_{refr} = ac_2 + ac_3$
em	Emissions intensities for ambient or refrigerated unit [kg CO_2e/tonne]
ac_1	Allocation coefficient for heating of units [kg CO_2e/tonne]
ac_2	Allocation coefficient for all other processes at the site [kg CO_2e/tonne]
ac_3	Allocation coefficient for refrigerating units [kg CO_2e/tonne]

Calculating emission intensities at activity level

Example 10: Allocation of emissions at mixed site (Site type 12, see Table 14)

At a mixed warehouse 220,000 tonnes of ambient goods ($Q_{units,amb}$) and 23,000 tonnes of refrigerated goods ($Q_{units,refr}$) are handled. No order picking takes place. Based on annual consumption data, the following partial emissions can be calculated as listed below.

EM_{heat}	$EM_{storage}$	$EM_{general}$	EM_{refr}
$140{,}400\ kg\ CO_2e$	$262{,}440\ kg\ CO_2e$	$87{,}480\ kg\ CO_2e$	$247{,}763\ kg\ CO_2e$

The allocation coefficients are as follows:

$$ac_1 = \frac{EM_{heat}}{Q_{units,amb}} = \frac{140{,}400\ kg\ CO_2}{220{,}000\ t} = 0.64\ \frac{kg\ CO_2e}{t}$$

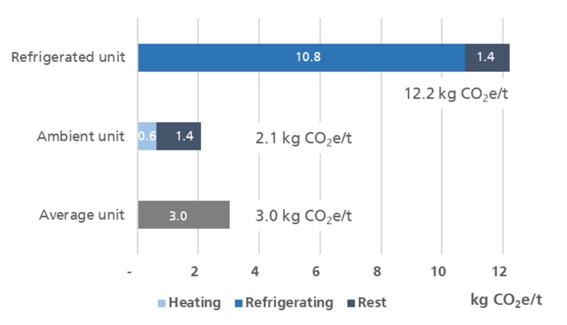
$$ac_2 = \frac{EM_{storage}+EM_{general}}{Q_{units,amb}+Q_{units,refr}} = \frac{262{,}440\ kg\ CO_2e+87{,}480\ kg\ CO_2e}{220{,}000\ t+23{,}000\ t} = 1.44\ \frac{kg\ CO_2e}{t}$$

$$ac_3 = \frac{EM_{refr}}{Q_{units,refr}} = \frac{247{,}763\ kg\ CO_2e}{23{,}000\ t} = 10.77\ \frac{kg\ CO_2e}{t}$$

The resulting emission intensities can be calculated as follows:

$$em_{amb} = ac_1 + ac_2 = 0.64\ \frac{kg\ CO_2e}{t} + 1.44\ \frac{kg\ CO_2e}{t} = \mathbf{2.08}\ \frac{\mathbf{kg\ CO_2e}}{\mathbf{t}}$$

$$em_{refr} = ac_2 + ac_3 = 1.44\ \frac{kg\ CO_2e}{t} + 10.77\ \frac{kg\ CO_2e}{t} = \mathbf{12.21}\ \frac{\mathbf{kg\ CO_2e}}{\mathbf{t}}$$



The average emission intensity is calculated as follows:

$$em_{av} = \frac{EM_{heat}+EM_{storage}+EM_{general}+EM_{refr}}{Q_{units,amb}+Q_{units,refr}} = \frac{738{,}083\ kg\ CO_2e}{243{,}000\ t} = \mathbf{3.04}\ \frac{\mathbf{kg\ CO_2e}}{\mathbf{t}}$$

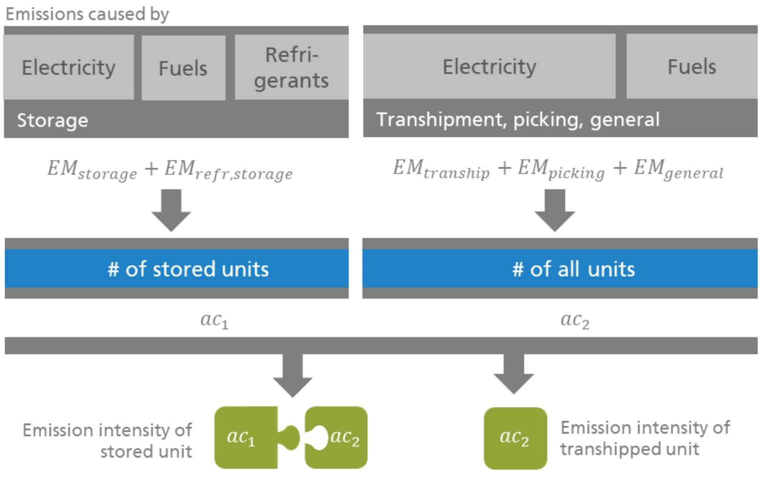
6.3.2 Differentiation between transhipped and stored units

At logistics sites with mixed requirements regarding stock-keeping, both transhipped and stored units cause different amounts of emissions. It is assumed that all processes other than storage are equivalent or no further differentiation is chosen (i.e. site types 19, 20, 22 or 23 in Table 14), so two activity categories are relevant, i.e. to storage or the transhipped units. The respective emission intensities are:

1. GHG emissions per tonne transhipped unit
2. GHG emissions per tonne stored unit

Figure 11 provides an overview on the allocation procedure for this. The following description refers to a refrigerated logistics sites. Ambient sites follow equivalent procedures.

Figure 11: Allocation procedure for activity-related emission intensities per transhipped or stored unit (refrigerated site)



The following partial emissions need to be calculated beforehand. This step is described in the chapters referred to in the table.

Table 16: Relevant partial emissions for calculating emission intensities per transhipped and stored unit

Partial emission	Parameter	Chapter
Storage emissions	$EM_{storage}$	6.2.2
Refrigerating emissions of storage	$EM_{refr,storage}$	6.2.6
All other emissions	$EM_{tranship}$	6.2.1
	$EM_{picking}$	6.2.3
	$EM_{general}$	6.2.4

Here, all other emissions cover emissions caused by transhipment, order picking or general processes, depending on the activities of the site, and can be calculated as follows:

$$EM_{rest} = EM_{tranship} + EM_{picking} + EM_{general} = EM_{total} - EM_{storage} - EM_{refr,storage}.$$

Furthermore, the company needs to specify the total amount of stored units outbound ($Q_{units,storage}$) and transhipped units outbound ($Q_{units,tranship}$); with $Q_{units,total} = Q_{units,storage} + Q_{units,tranship}$.

These partial emissions are used to derive allocation coefficients as follows:

Equation 14: Calculation of allocation coefficients for calculating emission intensities per tonne stored and transhipped unit

Storage of units	$ac_1 = \frac{EM_{storage} + EM_{refr,storage}}{Q_{units,storage}}$
Handling of units	$ac_2 = \frac{EM_{rest}}{Q_{units,storage} + Q_{units,tranship}}$
ac_1	Allocation coefficient for storing units [kg CO_2e/tonne]
ac_2	Allocation coefficient for all other processes at the site [kg CO_2e/tonne]
$EM_{partial}$	Partial emissions [kg CO_2e] i.e. storage or rest
$Q_{units,storage}$	Amount of stored cargo outbound [tonne]
$Q_{units,tranship}$	Amount of transhipped cargo outbound [tonne]

As a final step, the resulting emissions intensities are calculated as follows:

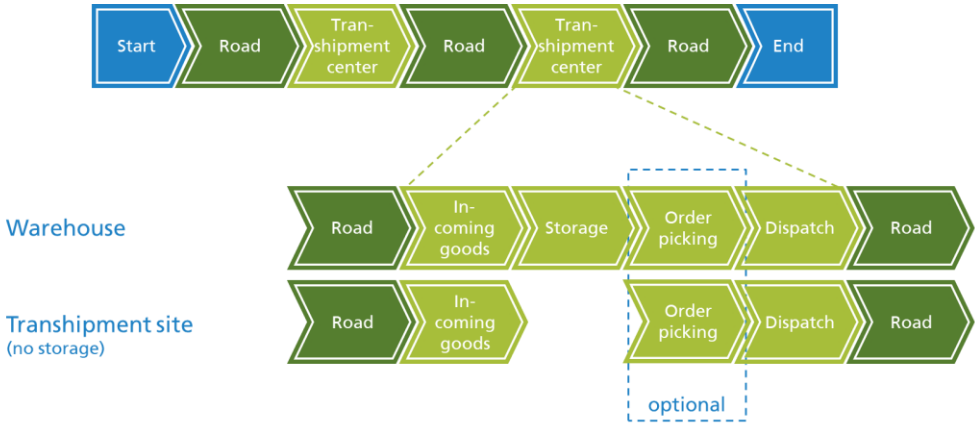
Equation 15: Calculation of emissions intensities per stored and transhipped unit

For stored units	$em_{storage} = ac_1 + ac_2$
For transhipped units	$em_{tranship} = ac_2$
em	Emissions intensities for stored or transhipped unit [kg CO_2e/tonne]
ac_1	Allocation coefficient for storing units [kg CO_2e/tonne]
ac_2	Allocation coefficient for all other processes at the site [kg CO_2e/tonne]

6.3.3 Differentiation between picked and unpicked units

At sites with one temperature requirement (i.e. ambient only, refrigerated only), some of the shipments may require different operations from others, e.g. as regards order picking (i.e. transhipment sites type no. 7 and 8 or warehouse type no. 16 and 17 in Table 14). For this reason, two activity categories are relevant, i.e. shipments with and shipments without order picking, which is illustrated in the following figure.

Figure 12:
Exemplary process chains at logistics sites with order picking



The respective emissions intensities are as follows:

1. GHG emissions per unpicked (original) unit
2. GHG emissions per picked unit

Figure 13 to Figure 16 provide an overview on the allocation procedure at four different logistics sites.

Figure 13:
Allocation procedure for activity-related emission intensities for ambient transhipment sites (site type no. 7)

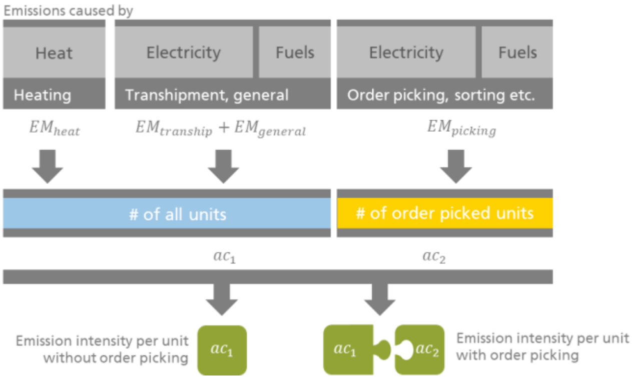
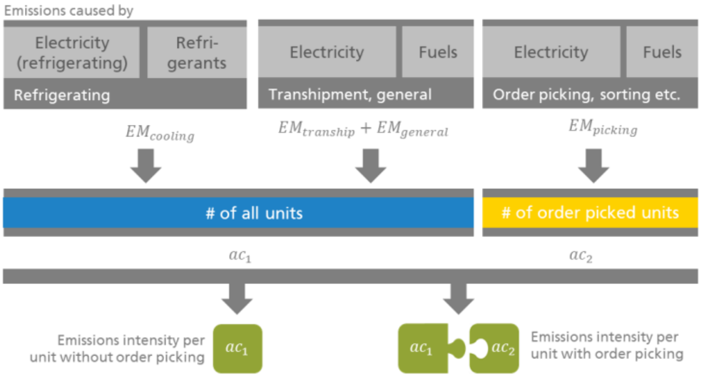


Figure 14:
Allocation procedure for activity-related emission intensities for refrigerated transhipment sites (site type no. 8)



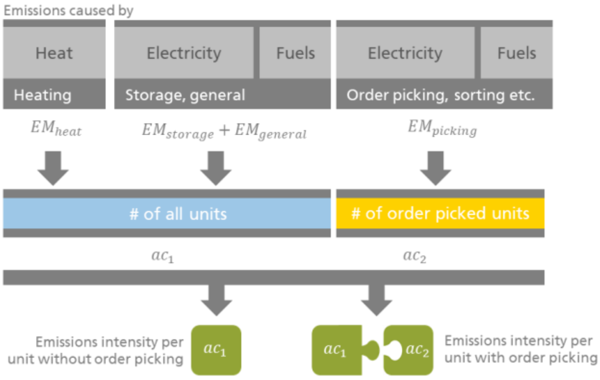


Figure 15: Allocation procedure for activity-related emission intensities for ambient warehouses (site type no. 16)

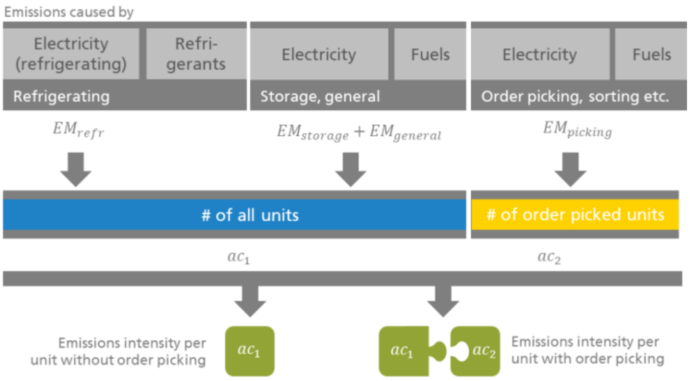


Figure 16: Allocation procedure for activity-related emission intensities for refrigerated warehouses (site type no. 17)

The following partial emissions need to be calculated beforehand. The relevant calculation procedures are described in the chapters referred to in the table.

Table 17: Relevant partial emissions for calculating emission intensities per ambient and refrigerated unit

Partial emission	Parameter	Chapter
Order picking emissions	$EM_{picking}$	6.2.3
Heating emissions (only at ambient sites)	EM_{heat}	6.2.5
Refrigerating emissions (only at refrigerated sites)	EM_{refr}	6.2.6
All other emissions	$EM_{tranship}$	6.2.1
	$EM_{storage}$	6.2.2
	$EM_{general}$	6.2.4

Furthermore, the company needs to specify the total amount of units outbound ($Q_{units,total}$) and picked units outbound ($Q_{units,picked}$); with $Q_{units,total} = Q_{units,picked} + Q_{units,unpicked}$

These amounts are then used to derive allocation coefficients as follows.

Ambient warehouse or transhipment site

Equation 16: Calculation of allocation coefficients for calculating emission intensities per picked or unpicked unit at ambient site

Handling of units for transhipment site (ts)	$ac_{1,ts} = \frac{EM_{heat}+EM_{tranship}+EM_{general}}{Q_{units,total}}$
Handling of units for warehouse (wh)	$ac_{1,wh} = \frac{EM_{heat}+EM_{storage}+EM_{general}}{Q_{units,total}}$
Picking of units	$ac_2 = \frac{EM_{picking}}{Q_{units,picked}}$
$ac_{1,ts\ or\ wh}$	Allocation coefficient for handling of units [kg CO_2e/tonne] for transhipment site (ts) or warehouse (wh)
ac_2	Allocation coefficient for picking of units [kg CO_2e/tonne]
$EM_{partial}$	Partial emissions [kg CO_2e] i.e. heating, transhipment, storage, general or picking
$Q_{units,total}$	Total amount of cargo outbound [tonne]
$Q_{units,picked}$	Amount of picked cargo outbound [tonne]

Refrigerated warehouse or transhipment site

Equation 17: Calculation of allocation coefficients for calculating emission intensities per picked or unpicked unit at refrigerated site

Handling of units for transhipment site (ts)	$ac_{1,ts} = \frac{EM_{refr}+EM_{tranship}+EM_{general}}{Q_{units,total}}$
Handling of units for warehouse (wh)	$ac_{1,wh} = \frac{EM_{refr}+EM_{storage}+EM_{general}}{Q_{units,total}}$
Picking of units	$ac_2 = \frac{EM_{picking}}{Q_{units,picked}}$
$ac_{1,ts\ or\ wh}$	Allocation coefficient for handling of units [kg CO_2e/tonne] for transhipment site (ts) or warehouse (wh)
ac_2	Allocation coefficient for picking of units [kg CO_2e/tonne]
$EM_{partial}$	Partial emissions [kg CO_2e] i.e. refrigeration, transhipment, storage, general or picking
$Q_{units,total}$	Total amount of cargo outbound [tonne]
$Q_{units,picked}$	Amount of picked cargo outbound [tonne]

Calculating emission intensities at activity level

As a final step that applies to both ambient and refrigerated sites, the resulting emissions intensities are calculated as follows:

Equation 18: Calculation of emissions intensities per unpicked and picked unit

For unpicked units	$em_{unpicked} = ac_{1,ts\ or\ wh}$
For picked units	$em_{picked} = ac_{1,ts\ or\ wh} + ac_2$
em	Emissions intensities for unpicked or picked unit [kg CO_2e/tonne]
$ac_{1,ts\ or\ wh}$	Allocation coefficient for handling of units [kg CO_2e/tonne] for transhipment site (ts) or warehouse (wh)
ac_2	Allocation coefficient for picking of units [kg CO_2e/tonne]

Example 11: Allocation of emissions at an ambient warehouse

At an ambient warehouse 243,000 tonnes are handled in total ($Q_{units,total}$), of which 81,000 tonnes require order picking ($Q_{units,picked}$). Based on annual consumption data, the following partial emissions can be calculated as listed below.

EM_{heat}	$EM_{storage}$	$EM_{picking}$	$EM_{general}$
$140{,}400\ kg\ CO_2e$	$262{,}440\ kg\ CO_2e$	$72{,}760\ kg\ CO_2e$	$87{,}480\ kg\ CO_2e$

The allocation coefficients are as follows:

$$ac_1 = \frac{EM_{heat}+EM_{storage}+EM_{general}}{Q_{units,total}} = \frac{140{,}400\ kg\ CO_2e + 262{,}440\ kg\ CO_2e + 87{,}480\ kg\ CO_2e}{243{,}000\ t} = 2.02\ \frac{kg\ CO_2e}{t}$$

$$ac_2 = \frac{EM_{picking}}{Q_{units,picked}} = \frac{72{,}760\ kg\ CO_2e}{81{,}000\ t} = 0.90\ \frac{kg\ CO_2e}{t}$$

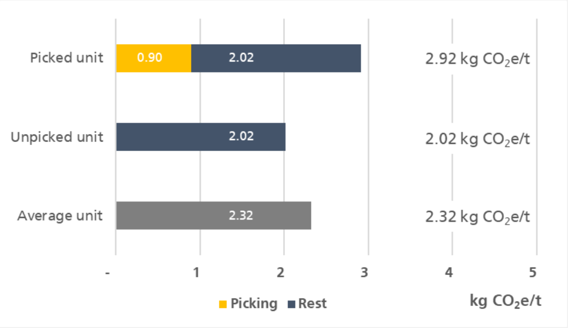
The resulting emission intensities can be calculated as follows:

$$em_{unpicked} = ac_1 = \mathbf{2.02}\ \frac{\mathbf{kg\ CO_2e}}{\mathbf{t}}$$

$$em_{picked} = ac_1 + ac_2 = 2.02\ \frac{kg\ CO_2e}{t} + 0.90\ \frac{kg\ CO_2e}{t} = \mathbf{2.92}\ \frac{\mathbf{kg\ CO_2e}}{\mathbf{t}}$$

The average emission intensity is calculated as follows:

$$em_{av} = \frac{EM_{heat}+EM_{storage}+EM_{general}+EM_{picking}}{Q_{units,total}} = \frac{563{,}080\ kg\ CO_2e}{243{,}000\ t} = \mathbf{2.32}\ \frac{\mathbf{kg\ CO_2e}}{\mathbf{t}}$$



6.3.4 Differentiation of temperature and picking requirements

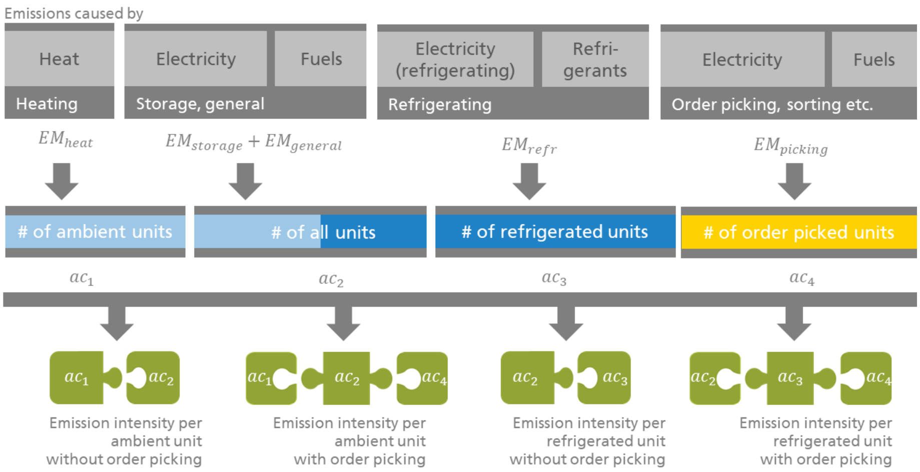
At a mixed site, both ambient and refrigerated units are handled. In addition to this, some of the shipments may require different operations from others, e.g. as regards order picking (i.e. sites type no. 9 and 18 in Table 14). For this reason, four activity categories are relevant, i.e. ambient or refrigerated shipments with order picking as well as ambient or refrigerated shipments without order picking.

The emission intensities are as follows:

1. GHG emissions per ambient unpicked (original) unit
2. GHG emissions per ambient picked unit
3. GHG emissions per refrigerated unpicked (original) unit
4. GHG emissions per refrigerated picked unit

Figure 17 provides an overview on the allocation procedure at a mixed warehouse (site type no. 18). With regard to a mixed transhipment site (site type no. 9), the partial emissions for storage ($EM_{storage}$) can be replaced on a one-on-one basis by $EM_{tranship}$ and the rest of the formula remains the same.

Figure 17: Allocation procedure for activity-related emission intensities for site type no. 18



The following partial emissions need to be calculated beforehand. The relevant steps are described in the chapters referred to in the table.

Table 18: Relevant partial emissions for calculating emission intensities per ambient and refrigerated unit with or without order picking

Partial emission	Parameter	Chapter
Order picking emissions	$EM_{picking}$	6.2.3
Heating emissions	EM_{heat}	6.2.5
Refrigerating emissions	EM_{refr}	6.2.6
All other emission	$EM_{tranship}$	6.2.1
	$EM_{storage}$	6.2.2
	$EM_{general}$	6.2.3

Furthermore, the company needs to specify the total amount of ambient units outbound ($Q_{units,amb}$) and refrigerated units outbound ($Q_{units,refr}$) as well as the amount of units outbound with order picking; with
$Q_{units,total} = Q_{units,amb} + Q_{units,refr} = Q_{units,picked} + Q_{units,unpicked}$

These are used to derive allocation coefficients as follows:

Equation 19: Calculation of allocation coefficients for calculating emission intensities per picked or unpicked unit

Heating of units	$ac_1 = \frac{EM_{heat}}{Q_{units,amb}}$
Handling of units for transhipment site (ts)	$ac_{2,ts} = \frac{EM_{tranship}+EM_{general}}{Q_{units,amb}+Q_{units,refr}}$
Handling of units for warehouse (wh)	$ac_{2,wh} = \frac{EM_{storage}+EM_{general}}{Q_{units,amb}+Q_{units,refr}}$
Refrigerating of units	$ac_3 = \frac{EM_{refr}}{Q_{units,refr}}$
Picking of units	$ac_4 = \frac{EM_{picking}}{Q_{units,picked}}$

ac_1	Allocation coefficient for heating of units [kg CO_2e/tonne]
$ac_{2,wh\ or\ ts}$	Allocation coefficient for handling of units [kg CO_2e/tonne] at transhipment site (ts) or warehouse (wh)
ac_3	Allocation coefficient for refrigerating of units [kg CO_2e/tonne]
ac_4	Allocation coefficient for picking of units [kg CO_2e/tonne]
$EM_{partial}$	Partial emissions [kg CO_2e] i.e. heating, transhipment, storage, picking, general or refrigerating
$Q_{units,amb}$	Amount of ambient cargo outbound [tonne]
$Q_{units,refr}$	Amount of refrigerated cargo outbound [tonne]
$Q_{units,picked}$	Amount of picked cargo outbound [tonne]

As a final step, the resulting emission intensity values are calculated as follows:

Equation 20: Calculation of emission intensity values per unpicked and picked unit at mixed sites

For ambient units without order picking	$em_{amb,unpicked} = ac_1 + ac_{2,ts\ or\ wh}$
For ambient units with order picking	$em_{amb,picked} = ac_1 + ac_{2,ts\ or\ wh} + ac_4$
For refrigerated units without order picking	$em_{refr,unpicked} = ac_{2,ts\ or\ wh} + ac_3$
For refrigerated units with order picking	$em_{refr,picked} = ac_{2,ts\ or\ wh} + ac_3 + ac_4$
em	Emission intensities for ambient or refrigerated unit without or with order picking [kg CO_2e/tonne]
ac_1	Allocation coefficient for heating of units [kg CO_2e/tonne]
ac_2	Allocation coefficient for handling of units [kg CO_2e/tonne]
ac_3	Allocation coefficient for refrigerating of units [kg CO_2e/tonne]
ac_4	Allocation coefficient for picking of units [kg CO_2e/tonne]

Example 12: Allocation of emissions at mixed site

At a mixed warehouse 243,000 tonnes are handled in total ($Q_{units,total}$), of which 81,000 tonnes require order picking ($Q_{units,picked}$) and 23,000 tonnes require refrigeration ($Q_{units,refr}$). Based on annual consumption data, the following partial emissions can be calculated as listed below.

EM_{heat}	$EM_{storage}$	$EM_{picking}$	$EM_{general}$	EM_{refr}
$140{,}400\ kg\ CO_2e$	$262{,}440\ kg\ CO_2e$	$72{,}760\ kg\ CO_2e$	$87{,}480\ kg\ CO_2e$	$247{,}763\ kg\ CO_2e$

The allocation coefficients are as follows:

$$ac_1 = \frac{EM_{heat}}{Q_{units,amb}} = \frac{140{,}400\ kg\ CO_2}{220{,}000\ t} = 0.64\ \frac{kg\ CO_2e}{t}$$

$$ac_2 = \frac{EM_{storage}+EM_{general}}{Q_{units,amb}+Q_{units,refr}} = \frac{262{,}440\ kg\ CO_2e+87{,}480\ kg\ CO_2e}{220{,}000\ t+23{,}000\ t} = 1.44\frac{kg\ CO_2e}{t}$$

$$ac_3 = \frac{EM_{refr}}{Q_{units,refr}} = \frac{247{,}763\ kg\ CO_2e}{23{,}000\ t} = 10.77\frac{kg\ CO_2e}{t}$$

$$ac_4 = \frac{EM_{picking}}{Q_{units,picked}} = \frac{72{,}760\ kg\ CO_2e}{81{,}000\ t} = 0.90\frac{kg\ CO_2e}{t}$$

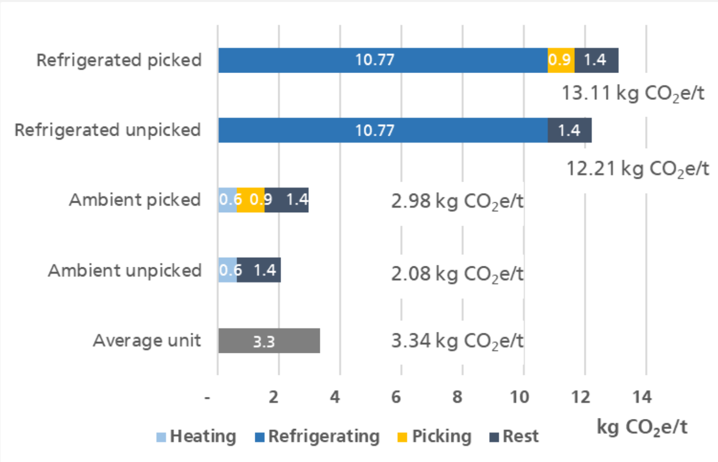
The resulting emission intensities can be calculated as follows:

$$em_{amb,unpicked} = ac_1 + ac_2 = 0.64\ \frac{kg\ CO_2e}{t} + 1.44\ \frac{kg\ CO_2e}{t} = \mathbf{2.08}\ \frac{\mathbf{kg\ CO_2e}}{\mathbf{t}}$$

$$em_{amb,picked} = ac_1 + ac_2 + ac_4 = 0.64\ \frac{kg\ CO_2e}{t} + 1.44\ \frac{kg\ CO_2e}{t} + 0.90\ \frac{kg\ CO_2e}{t} = \mathbf{2.98}\ \frac{\mathbf{kg\ CO_2e}}{\mathbf{t}}$$

$$em_{refr,unpicked} = ac_2 + ac_3 = 1.44\ \frac{kg\ CO_2e}{t} + 10.77\frac{kg\ CO_2e}{t} = \mathbf{12.21}\frac{\mathbf{kg\ CO_2e}}{\mathbf{t}}$$

$$em_{refr,picked} = ac_2 + ac_3 + ac_4 = 1.44\ \frac{kg\ CO_2e}{t} + 10.77\ \frac{kg\ CO_2e}{t} + 0.90\ \frac{kg\ CO_2e}{t} = \mathbf{13.11}\ \frac{\mathbf{kg\ CO_2e}}{\mathbf{t}}$$



The average emission intensity is calculated as follows:

$$em_{av} = \frac{EM_{heat}+EM_{storage}+EM_{general}+EM_{refr}+EM_{picking}}{Q_{units,total}} = \frac{810{,}843\ kg\ CO_2e}{243{,}000\ t} = \mathbf{3.34}\ \frac{\mathbf{kg\ CO_2e}}{\mathbf{t}}$$

6.3.5 Additional allocation procedures

Below, additional allocation procedures for site type no. 21, 24, 25 and 26 (see Table 14) are given as an overview, without providing detailed formulae or examples.

Figure 18:
Allocation procedure for activity-related emission intensities for site type no. 21

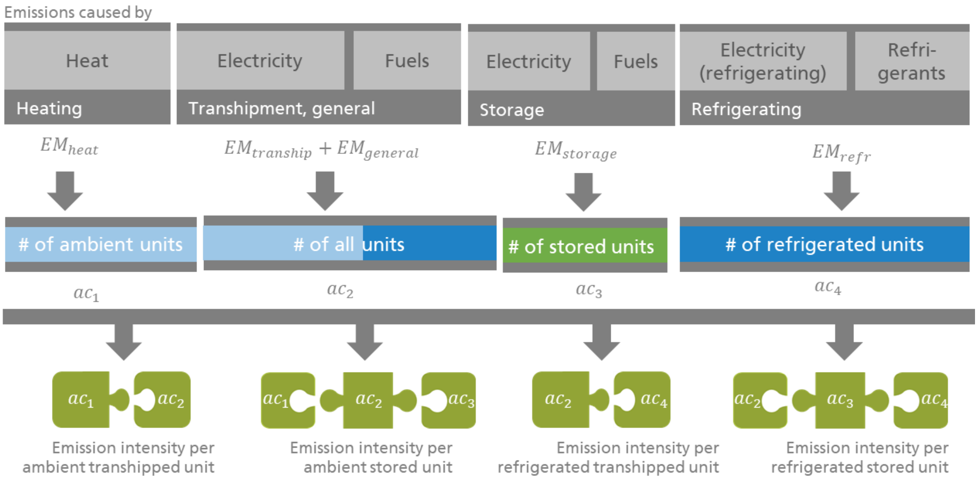
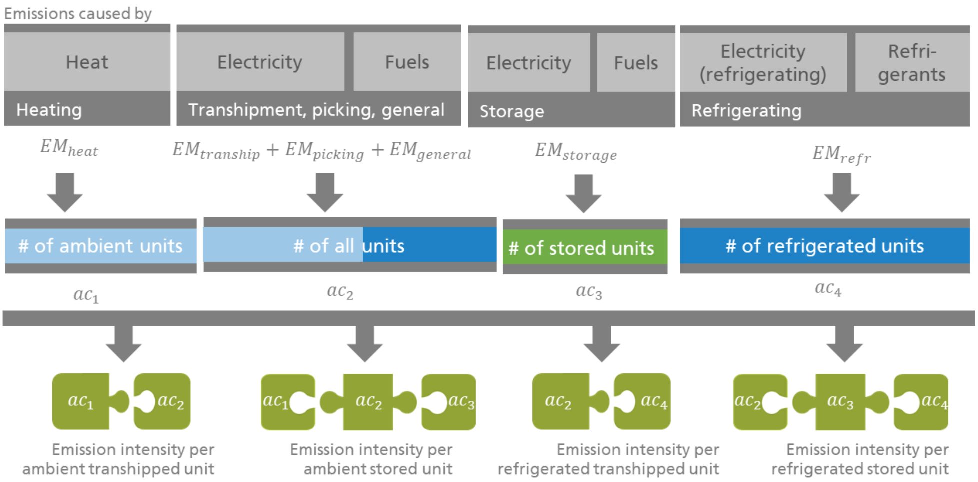


Figure 19:
Allocation procedure for activity-related emission intensities for site type no. 24



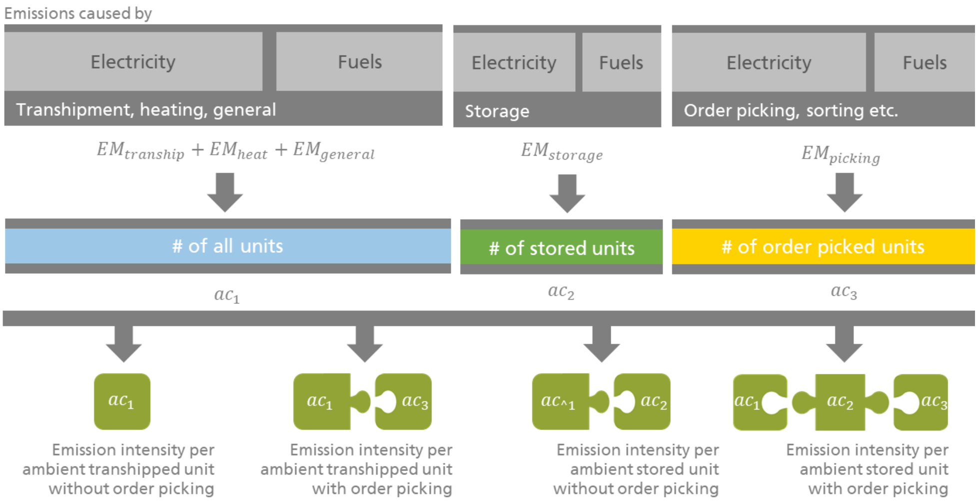


Figure 20: Allocation procedure for activity-related emission intensities for site type no. 25

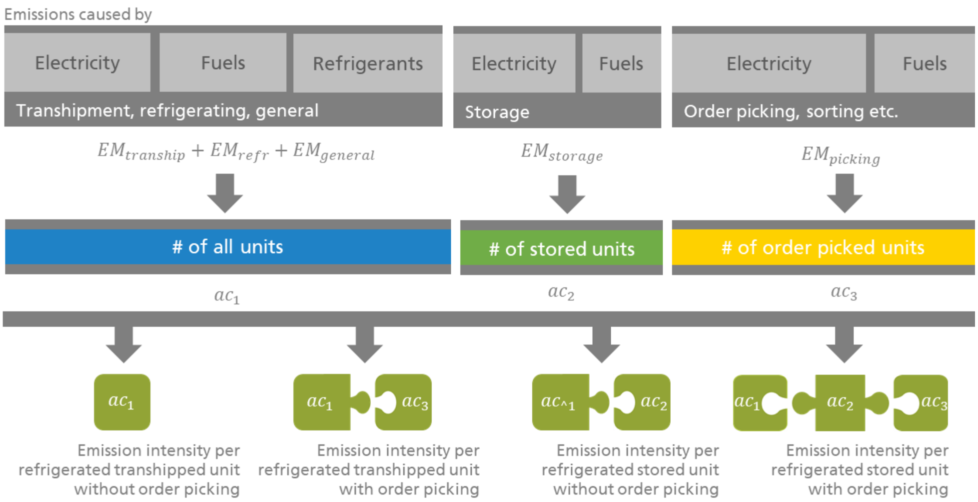
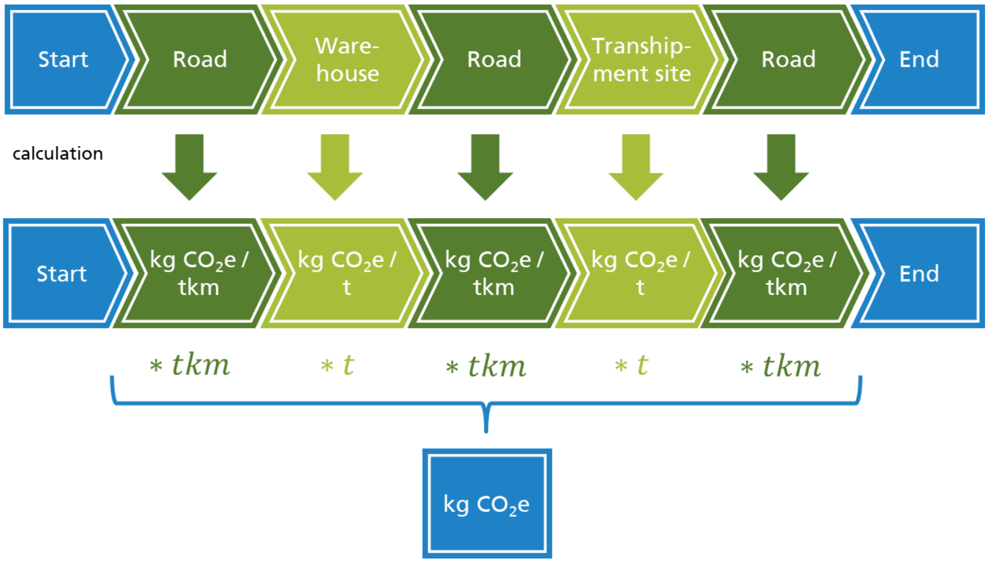


Figure 21: Allocation procedure for activity-related emission intensities for site type no. 26

7
Use of calculated emissions and emission intensities

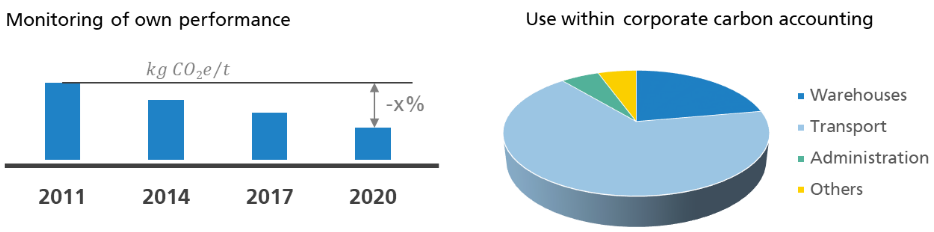
The calculation of GHG emissions of warehouses and transhipment sites enables different options for internal and external use as shown in the following figures. First, the information can be used to provide information for clients and/ or shippers to be included in logistics chain calculations. For this purpose, the calculated average or activity-related emission intensities are multiplied by the total amount of shipments relevant for the respective logistics chain and added together with relevant transport emissions as shown in Figure 22 and in Example 3.

Figure 22:
Information for logistics chains calculations



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

Figure 23:
Monitoring of own performance and use in corporate balance sheets



To achieve this, it is important to transparently document the emissions values as well as underlying assumptions. For this reason, a general framework for documentation is provided with this guide as follows.

7.1 General documentation framework for logistics chain calculations

Use of calculated emissions and emission intensities

The following documentation framework refers to information provided to external partners, for example, for an add-on emissions calculations of logistics chains. The template given in Table 19 covers the following main information:

1. Specification of the site
2. Specification of the type of site, temperature and picking requirements
3. Reporting year
4. Calculated emission intensities (either on average or activity-related)
5. Comments on emissions factors or other assumptions used (if those recommended by the GLEC Framework are not used.

Table 19: Documentation framework for logistics chain calculations

Specification of site	[Name, location] - [country]	
Operations	☐ Transhipment	☐ Storage
Temperature requirement	☐ Ambient	☐ Refrigerated
Picking requirement	☐ Yes	☐ No
Reporting year	MM / YYYY – MM / YYYY	
Emissions intensities per tonne	Average:	#.## kg CO_2e/tonne
	Activity related:	#.## kg CO_2e/tonne $_{ambient}$ #.## kg CO_2e/tonne $_{refrigerated}$
		#.## kg CO_2e/tonne $_{picked}$ #.## kg CO_2e/tonne $_{unpicked}$
		#.## kg CO_2e/tonne $_{ambient,\ picked}$ #.## kg CO_2e/tonne $_{ambient,\ unpicked}$ #.## kg CO_2e/tonne $_{refrigerated,\ picked}$ #.## kg CO_2e/tonne $_{refrigerated,\ unpicked}$
Emissions factors used	☒ GLEC Framework version [version] Comments on any deviations to GLEC: [description]	

Example 13: Reporting framework for logistics chain calculations

Specification of site	Example 2 - [Belgium]	
Operations	☒ Transhipment	☐ Storage
Temperature requirement	☐ Ambient	☒ Refrigerated
Picking requirement	☐ Yes	☒ No
Reporting year	01 / 2017 – 12 / 2017	
Emission intensities per tonne	Average 3.17 kg CO_2e/tonne	
Emission factors used	Electricity [EEA 2014]; diesel [EN 16258]; Refrigerants [R-410A EU517/2014]	

7.2 Internal documentation framework for monitoring a site's performance

The following documentation framework refers to internal monitoring tasks (Figure 23), for example. The sample template given in Table 20 covers additional information to Table 19 such as:

1. Total annual GHG emissions of the site
2. Partial emissions
3. Relevant throughput
4. Additional results on calculations based on other emissions factors (e.g. electricity mix of supplier)

Table 20: Exemplary documentation framework for internal monitoring

Specification of site	[Name, location] - [country]
Total annual emissions	#.## t CO_2e
Transhipment emissions	#.## t CO_2e
Storage emissions	#.## t CO_2e
Order picking emissions	#.## t CO_2e
Emissions from general activities	#.## t CO_2e
Heating emissions	#.## t CO_2e
Refrigeration emissions	#.## t CO_2e
Total outgoing shipments	#,### [tonnes]
Total emissions (supplier's mix)	#.### t CO_2e
Average emission intensity with supplier's mix	#.## kg CO_2e/tonne

8
Additional guidance

8.1 Measuring energy consumption at the logistics site

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 site or by the electricity supplier. The latter may also be able to provide information on the relevant electricity mix (see chapter 8.3). Detailed information on energy consumption may already be covered by the company's energy audit following EN 16247.

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 site 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.

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

- Mode of site 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 site of the company, this site has to offer
  - A comparable mode of operation (e.g. same number of shifts per day and operation days)
  - Equivalent activities (i.e. storage/ transhipment) and temperature or picking requirements
  - 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 site at hand is 25% more GHG intense (i.e. 25% more emissions per tonne) than the average site.

8.2 Key performance indicators for logistics sites

The recommended metric for the emission intensity of logistics sites is kg CO_2e emissions per tonne cargo outbound. This is motivated by the objective to provide a performance indicator that can be used within logistics chain calculations (see also Figure 22).

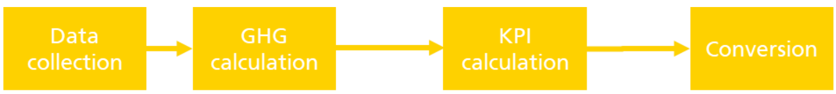
However, depending on the type of logistics site and the activities provided by the operator, this indicator does not reflect the full picture. It is beyond the scope of this guide to provide a comprehensive description of which key performance indicators are most appropriate for the environmental performance of a logistics site. 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 are 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 24 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 24: Procedure using pallet-based indicators



kWh, $\# \, pallets$, $tonne/pallet$ ▶ $EM_{total} = kWh \times EF_{elec}$ ▶ $em_{pallet} = \frac{EM_{total}}{\# \, pallets}$ ▶ $em_{tonne} = \frac{em_{pallet}}{tonne/pallet}$

Furthermore, refrigerated 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 refrigerated warehouses.

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.

Additional guidance

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 sites. However, corporate accounting may ask for a higher level of aggregation, e.g. key performance indicators for logistics sites within one region or a country. Therefore, the company may want to use site-specific indicators to derive average indicators for the same type of logistics sites, i.e. with the same operations, temperature and picking requirements, as shown below.

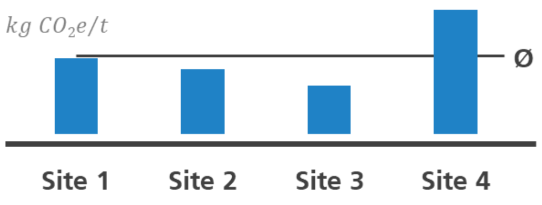


Figure 25: Higher level of aggregation for average KPI within e.g. a region

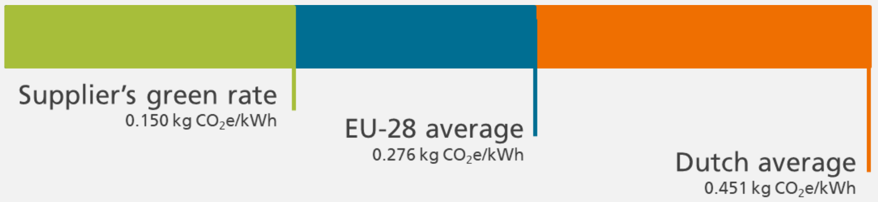
8.3 Calculation of emissions factor with supplier's mix

Some companies purchase particular electricity products to support renewable electricity generation (green rates) and thus reduce the environmental impact of their electricity consumption. The emissions 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.

Example 14 shows how much the choice of emissions factors may influence the total result of a site.

Example 14: How much does the choice of emissions factors influence the result?

The example refers to a medium-sized European container terminal located in the Netherlands. The GLEC Framework requires the use of the national electricity grid factor, which is 451.4 g CO_2e/kWh [EEA 2014] in this Dutch example. If the operator chose the use of an EU-28 average value (0.276 kg CO_2e/kWh [EEA 2014]), this would result in a declaration of 39% less emissions from the terminal. Considering the supplier's green rate and using the corresponding emissions factor of only 0.150 kg CO_2e/kWh would reduce the declared total result by another 46%.



8.4 Which scopes of the GHG protocol are covered?

The guide addresses the perspective of operators of logistics sites. Aligned with the lifecycle approach for energy use as proposed by the GHG protocol (WRI & WBCSD 2004) and the GLEC Framework, the total fuel and electricity consumption of all relevant operations are assessed. Adding the leakage of refrigerants at sites with temperature controlled conditions, the assessment boundaries of calculating GHG emissions according to the GHG protocol (WRI & WBCSD 2004 and 2013) are:

- Scope 1 emissions (burning of fuels, leakage of refrigerants)
- Scope 2 emissions (purchased electricity, steam, heating and cooling for own use)
- Category 3 of upstream scope 3 emissions (fuel-related and energy-related activities not included in scope 1 or scope 2).

The Technical Guidance for Calculating Scope 3 Emissions (WRI & WBCSD 2013 p. 7), a supplement of the GHG protocol, describes this category as follows:

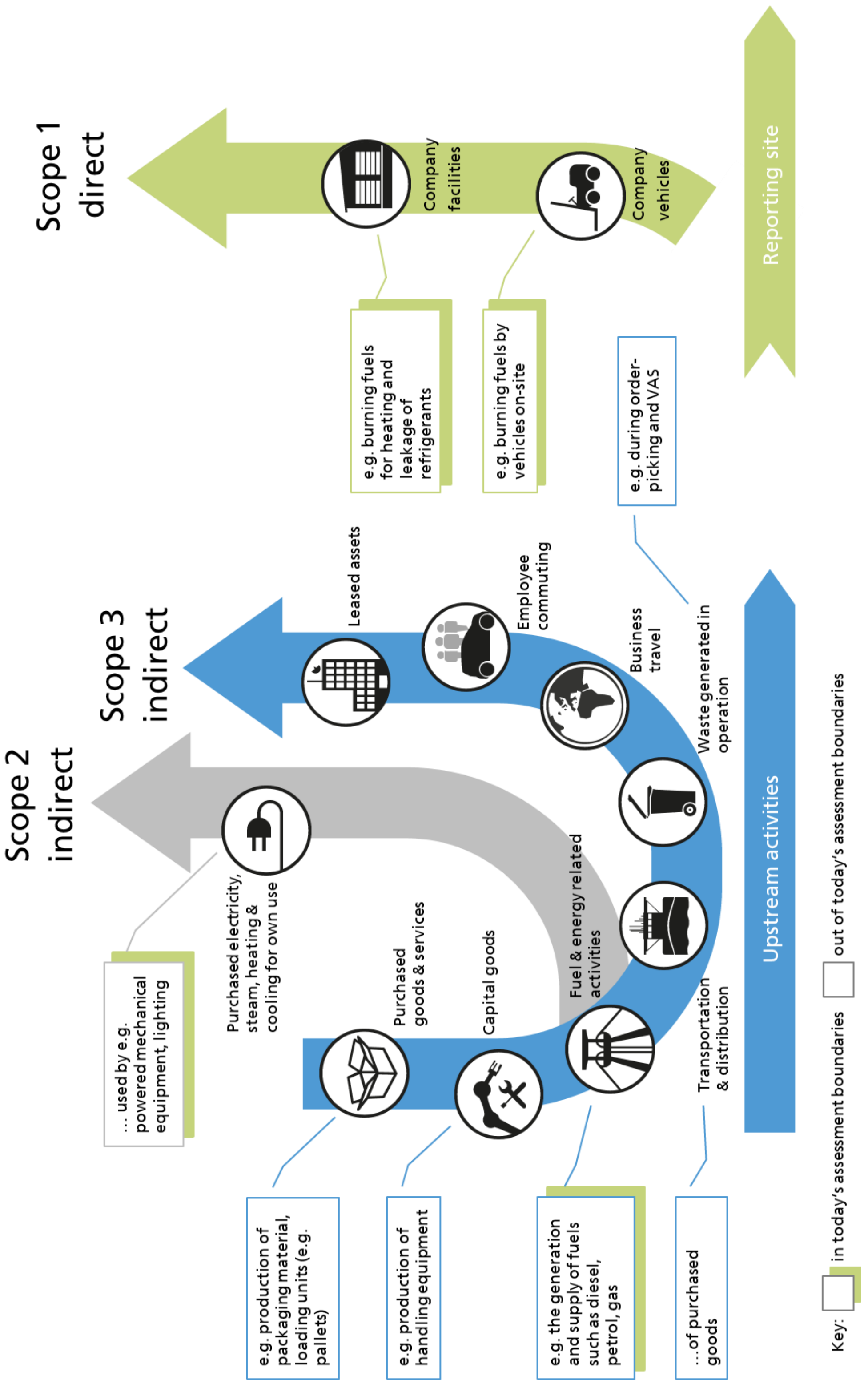
> 3. Fuel-related and energy-related activities (not included in scope 1 or scope 2)
>
> Extraction, production, and transportation of fuels and energy purchased or acquired by the reporting company in the reporting year, not already accounted for in scope 1 or scope 2, including:
>
> a. Upstream emissions of purchased fuels (extraction, production, and transportation of fuels consumed by the reporting company)
> b. Upstream emissions of purchased electricity (extraction, production, and transportation of fuels consumed in the generation of electricity, steam, heating, and cooling consumed by the reporting company)
> c. Transmission and distribution (T&D) losses (generation of electricity, steam, heating and cooling that is consumed (i.e. lost) in a T&D system) – reported by end user
> d. Generation of purchased electricity that is sold to end users (generation of electricity, steam, heating, and cooling that is purchased by the reporting company and sold to end users) – reported by utility company or energy retailer only

All other upstream or downstream scope 3 emissions are excluded, e.g.

- Category 1: Purchased goods and services (e.g. packaging material for safety measures)
- Category 4: Upstream transportation and distribution
- Category 5: Waste generated in operations
- Category 6: Business travel
- Category 7: Employee commuting

Additional guidance

Figure 26:
Scopes of emissions accounting (source: basing on WRI & WBCSD 2004)



9
Emissions 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 emissions factors recommended by the **GLEC Framework** in its current version should be used and the sources of emission factors used should be documented transparently.

Direct 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 EU 517/2014 that is based on GWP 100 published in IPCC 2007, the second column is based on GWP 100 published in IPCC 2013. All emission factors refer to direct emissions; no indirect emissions associated with the production and supply of refrigerants are included.

Table 21: GWP 100 values for refrigerants

Type	Chemical formula	Alternative name	[g CO_2e/g] (EU 517/2014)	[g CO_2e/g] (IPCC 2013)
R-717	NH_3	Ammonia	0.00	
R-290	C_3H_8	Propane	3.00	
R-600	C_4H_{10}	Butane	4.00	
R-744	CO_2	Carbon dioxide	1.00	1.00
R-22	$CHClF_2$	Chlorodifluoromethane	1,810.00	1,760.00
R-32	CH_2F_2	Difluoromethane	675.00	677.00
R-115	$CClF_2CF_3$	Chloropentafluoroethane	7,360.00	7,670.00
R-125	CHF_2CF_3	Pentafluoroethane	3,500.00	3,170.00
R-134a	CH_2FCF_3	1,1,1,2-Tetrafluorethan	1,430.00	1,300.00
R-143a	CH_3CF_3	1,1,1-Trifluorethan	4,470.00	4,800.00
R-404A	Mixture: (own calculation)	44,0% R-125 4,0% R-134a 52,0% R-143a	3,921.60	3,942.80
R-407C	Mixture: (own calculation)	23,0% R-32 25,0% R-125 52,0% R-134a	1,773.85	1,624.21
R-410A	Mixture: (own calculation)	50,0% R-32 50,0% R-125	2,087.50	1,923.50
R-417C	Mixture: (own calculation)	19,5% R-125 78,8% R-134a 1,7% R-600	1,809.41	1,642.56
R-504	Mixture: (own calculation)	48,2% R-32 51,8% R-115	4,137.83	4,299.37

10 Templates for data collection

10.1 Calculating an average emission intensity value for a logistics site

Specification of site	[Name, location] - [country]	
Operations	☐ Transhipment	☐ Storage
Temperature requirement	☐ Ambient	☐ Refrigerated
Picking requirement	☐ Yes	☐ No
Reporting year	MM / YYYY – MM / YYYY	

All infrastructure/ equipment	**Electricity [kWh]**	**Diesel [litre]**	**Other energy sources* to be specified:**	
Total consumption of site				

* e.g. petrol, LNG, CNG, hydrogen or heating (e.g. natural gas, heating oil, district heating, geothermal energy, wood chips/ pellets)

Type of refrigerant	**[kg]**

Logistics data	**[tonnes]**
Logistics units leaving site	

10.2 Calculating emission intensities at activity level

Specification of site	[Name, location] - [country]	
Operations	☐ Transhipment	☐ Storage
Temperature requirement	☐ Ambient	☐ Refrigerated
Picking requirement	☐ Yes	☐ No
Reporting year	MM / YYYY – MM / YYYY	

Activity/ functional area		**Electricity [kWh]**	**Diesel [litre]**	**Other energy sources* to be specified:**
Storage	Handling			
	Lighting			
Transhipment	Handling			
	Lighting			
Order picking	Handling			
	Lighting			
Goods receipt, dispatch, general facilities (IT, office…)	Lighting			
	others			
Heating devices				
Refrigerating devices				
Total consumption of site				

* e.g. petrol, LNG, CNG, hydrogen or heating (e.g. natural gas, heating oil, district heating, geothermal energy, wood chips/ pellets)

Type of refrigerant	**[kg]**

Logistics data	**[tonnes]**
Logistics units leaving site	
• of this: picked units	
• of this: refrigerated units	

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