# Integrated Guide for Business Greenhouse Gas and Air Pollutant Emission Assessment

**CHAPTER 3** Methods and Emission Factors for Key emitting sources

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# 03 Methods and Emission Factors for Key Emitting Sources

## 3.1 Estimating Greenhouse Gases and Air Pollutant Emissions from Electricity Consumption

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This section of the Guide 2.0 explains how the emissions of greenhouse gas (GHGs), Short-Lived Climate Pollutants (SLCPs), classical air pollutants and heavy metals (HM) (hereafter referred to as greenhouse gas and air pollutants as defined in Chapter 1) that are related to the electricity consumed at different parts of a company's value chain can be quantified.

This section is structured by first describing the source, then describing the methods, which includes Tier 1 emission factors. The Tier 2 methods are explained in this document, but the Tier 2 (as well as the Tier 1) emission factors are linked to a database where these default values can be found here: https://www.ccacoalition.org/resources/integrated-guide-business-greenhouse-gas-and-air-pollutant-emission-assessment

A link for detailed fuel, technology and country specific tier 2 GHG emission factors is also provided in table S3.1.5. The section then includes an example calculation using the methods and then provides the references for the methods and data. Note that pre- or post-combustion control methods for specific air pollutants are not included in this version of the Guide.

## 3.1.1 Description of the Source

The consumption of electricity from national grids (i.e., not produced by the company) does not release emissions at the point where the electricity is consumed. However, the generation of electricity in fossil fuel, or biomass power plants can be a large source of both greenhouse gas and air pollutant emissions and so quantifying these emissions in an integrated way as part of the value chain is important. The importance can be further illustrated as existing measures to mitigate GHG emissions from electricity consumption will have an impact in also reducing air pollutant emissions particularly through the various energy efficiency strategies that may be present in a company's value chain (Galimova et. Al., 2022).

The consumption of electricity can occur across the value chain, in the extraction of raw materials, during manufacturing, retailing, or when products are in use (e.g., electricity consumed by electric appliances and the charging of electric vehicles used for passenger or freight transport) and at the end of their life. At the point of electricity generation, greenhouse gas and air pollutants such as Carbon Dioxide ($CO_2$), Methane ($CH_4$), Nitrous Oxide ($N_2O$), Particulate Matter ($PM_{10}$, $PM_{2.5}$), Sulphur Dioxide ($SO_2$), Nitrogen Oxide ($NO_x$), Carbon Monoxide (CO), Non-methane volatile organic compounds (NMVOCs), Ammonia ( $NH_3$), Black Carbon (BC), Lead (Pb), Mercury (Hg), Cadmium (Cd), Arsenic (As), Chromium (Cr), Copper (Cu), Nickel (Ni), Selenium (Se), Zinc (Zn). can be emitted into the atmosphere.

When electricity is consumed from national grids, a common methodology can be applied to quantify the greenhouse gas and air pollutant emissions associated with this electricity consumption at different points along the value chain.

The Tier 1 methodology for estimating both greenhouse gas and air pollutant emissions relies on fuel-specific emission factors. However, the Tier 2 method differs slightly between greenhouse gas and air pollutants. According to the IPCC guidelines (2019), the Tier 2 approach for GHG emissions incorporates fuel-, technology- and country-specific emission factors, whereas the EMEP/EEA guidelines for air pollutants (2023) use fuel- and technology-specific emission factors. These methodologies are discussed in detail in Section 3.1.2.

Additionally, a variation exists where users may estimate GHG emissions using fuel- and technology-specific emission factors, consistent with the EMEP/EEA categories, when country-specific data on electricity consumption is unavailable. The methods provided in section 3.1.2 offer a detailed outline for quantifying greenhouse gas and air pollutants emitted from electricity consumption across a company's value chain.

To quantify emissions the user will need to estimate the proportion of electricity consumed at each stage of the value chain that is generated using various fuel types and technologies. Emission control technologies can be applied at power plants to reduce GHG and air pollutant emissions from the stacks of power stations. Understanding where and to what extent these abatement technologies are applied can significantly improve the accuracy of the GHG and air pollutant emission estimates, but the information on the efficacy of these control methods is not included in this version of the Guide 2.0. The data on the efficacy of these control methods vary widely depending on the specific technology, plant design, and operational conditions. Gathering and standardizing this information requires comprehensive, location specific studies, which are beyond the scope of the current edition of the guide.

Electricity consumed that is generated from renewable energy sources such as hydro, wind, and solar does not produce greenhouse gases or air pollutants during operation, because these technologies generate electricity without burning fossil fuels. However, there are emissions associated with the construction, installation, and maintenance of renewable energy infrastructure. These lifecycle emissions are significantly lower than the emissions produced by burning fossil fuels to generate electricity. The fuels which are consumed to generate electricity, and for which methods are included in this section include:

- Hard Coal (Coking coal, other bituminous coal, sub- bituminous coal, coke, manufactured patent fuel)
- Brown Coal (Lignite, oil shale, manufactured patent fuel, peat)
- Gaseous fuels (Natural gas, natural gas liquids, liquefied petroleum gas, refinery gas, gas works gas, coke oven gas, blast furnace gas)
- Heavy fuel oil (Residual fuel oil, refinery feedstock, petroleum coke, orimulsion, bitumen)
- Light oil (Gas oil, kerosene, naphtha, shale oil)
- Biomass (Wood, charcoal, agricultural waste)

These fuel categories are similar to the fuel categories available in the IPCC guidelines and can be found in Chapter 2 of the IPCC (2019) guidelines under stationary combustion (table 2.2).

## 3.1.2 Methodologies for Quantifying Emissions

This section provides methods to estimate emissions for $SO_2$, $NO_x$, CO, NMVOCs, $PM_{10}$, $PM_{2.5}$, Pb, Hg, Cd, As, Cr, Cu, Ni, Se, Zn, BC, $CO_2$, $CH_4$, $N_2O$ associated with electricity consumed across a company's operations that includes electricity consumption during activities such as manufacturing, retailing, and charging of electric vehicles. The EMEP/EEA guidelines (2023) do not provide emission factors for $NH_3$; therefore, these cannot be estimated and are not included in the methods below. Only electricity sourced directly from a grid is considered; any electricity generated onsite is accounted for separately under the chapter titled "Stationary Fuel Combustion" (refer to Section 3.2). The approach to estimating emissions from a company's electricity use across its value chain depends on the availability of activity data, specifically, the total amount of electricity consumed.

Emissions are typically calculated by multiplying the amount of fuel combusted to produce a given amount of electricity by the relevant fuel-specific emission factors. However, in cases where only electricity consumption data is available, which is common for private sector companies using grid electricity, fuel consumption is estimated using the electricity production efficiency of the fuels used in power generation. When additional information is available on both the fuel categories and the power generation technologies employed, a Tier 2 methodology may be used to yield more accurate and representative air pollutant emission estimates. However, the Tier 2 method for GHG emissions provided in the IPCC (2019) guidelines requires data that is disaggregated by fuel type, technology, and the country of electricity generation. The methods presented here offer separate Tier 2 approaches for estimating GHG emissions. In cases where detailed, country-specific data is not available, fuel- and technology-specific GHG emission factors, aligned with the EMEP/EEA categories, are also provided. These emission factors can be used to estimate GHG emissions alongside air pollutant emissions. For both the Tier 1 and Tier 2 methods to be applied, the starting point for quantifying emissions is to quantify the electricity generated from different types of power stations as shown in Equation 3.1.1.

Eq. 3.1.1

$$EG_n = EC_T * P_n$$

Where $EG_n$ is the electricity generation using fuel and technology n (units: KWh), ECT is the total electricity consumed at a particular part of the company's value chain, and Pn is the proportion of the consumed electricity that is generated using fuel and technology n. For clarity, equation 3.1.1 is applicable to both tier 1 and tier 2 methods. The disaggregation is only done in fuel categories for tier 1, while for tier 2 it is done in fuel as well as technology specific categories.

As outlined below, for the Tier 1 and Tier 2 approaches, different levels of disaggregation of electricity generation fuels and technologies are required. For Tier 1 approaches, the fuels may be disaggregated into hard coal, brown coal, gaseous fuels (e.g., natural gas), heavy fuel oil, light oil (e.g., diesel) and biomass. For the Tier 2 approaches, further disaggregation by technology is required (see below).
The amount of electricity consumed at different stages of a company's value chain (ECT) is company-specific and therefore needs to be identified by the inventory compiler, with no default data available.

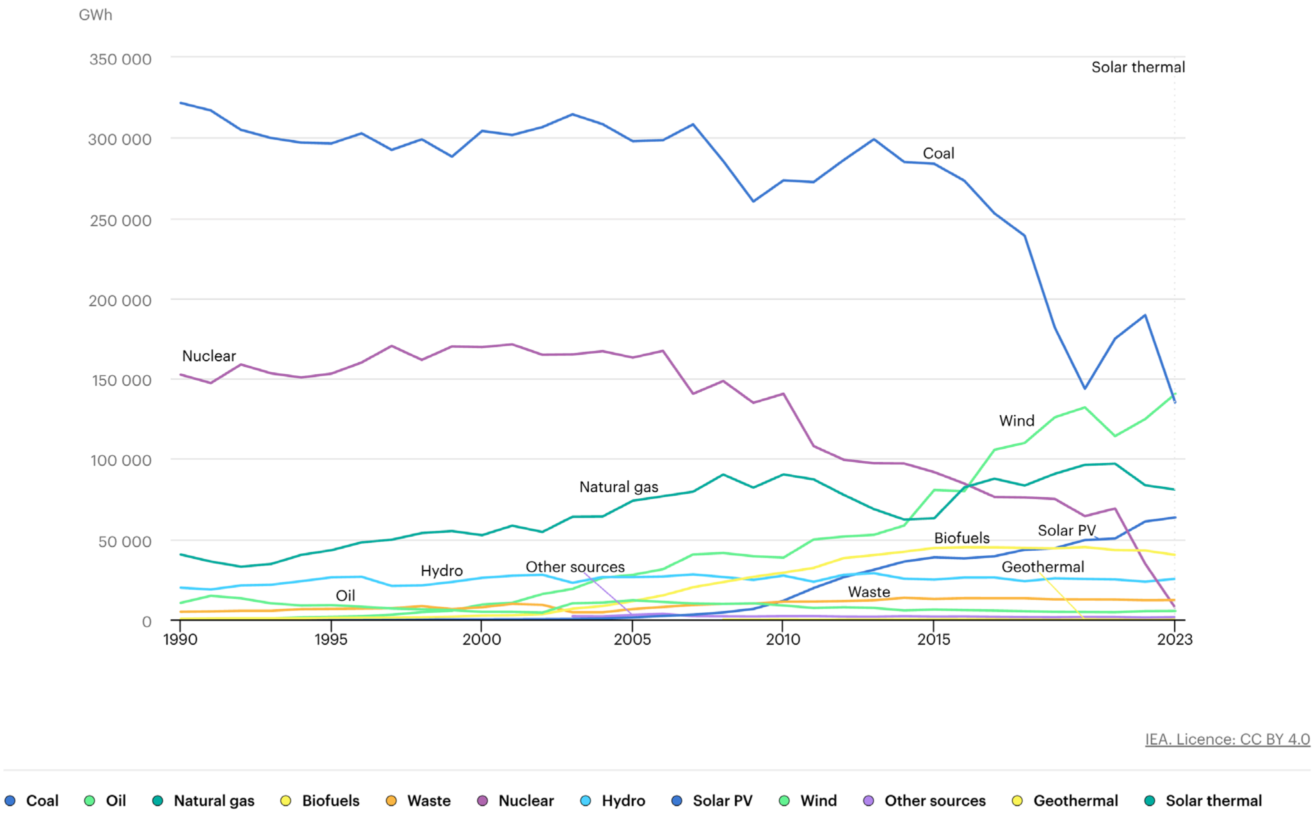
The proportion of electricity generated using different types of fuel and technology (Pn) can be substantially different across different countries. Therefore, to estimate (Pn), the user needs to identify the appropriate data for the electricity generated using different types of fuel and technologies (Pn) for each country where the company operates in. To do this, best practice is to identify the national electricity mix from country specific data (e.g., national energy balances). However, where this information is not available, there are publicly available international data sources, which include databases maintained by OECD, World Bank, and IRENA (OECD, 2023; World bank, 2023; IRENA, 2023).

Another example of such a database is the International Energy Agency (IEA) which includes, global, region and country-specific statistics on energy generation between 1990 and 2020, depending on data availability per country. An example of this dataset for Germany for the years 1990 to 2020 is presented in Figure 3.1.1.

In the absence of country specific information for the countries in which a company operates in, the user can explore the IEA energy database, which provides a comprehensive dataset on electricity generation broken down by source (e.g., oil, coal, natural gas) by region and country. However, the information regarding the types of fuels used for electricity generation by each country from the IEA dataset is not available at a level that is consistent with the emission factors provided by the EMEP/EEA and IPCC guidelines (see Table 3.1.3 and table S3.1.1).

The IEA dataset does not provide a detailed list of the types of coal and oil used for electricity generation by country, it instead aggregates this information under the categories coal and oil. Therefore, in order for the user to apply the information provided by the IEA, assumptions need to be made as to how the fuel classification of the IEA (e.g., coal, oil) maps against the fuel categorisation described in the EMEP/EEA (2023) and IPCC (2019) (e.g., hard coal, heavy fuel oil).

**Figure 3.1.1:** Electricity generation (GWh) by source, Germany 1990-2023. Source, IEA (2025)




According to the IEA World Energy Statistics (2018), globally, approximately 93% of all coal used for electricity generation is hard coal (e.g., bituminous coal), with the remaining 7% being brown coal (e.g., lignite), and approximately 66% of all oil used to generate electricity is heavy oil (e.g., crude oil, fuel oil), with the remaining 34% being light oil (e.g., kerosene, diesel) (Table 3.1.1). Therefore, there are some assumptions that the user needs to make in order to identify the most appropriate emission factors from the EMEP/EEA (2019) guidance (Table 3.2.3). The user can either use the different percentages for electricity generation using hard or brown coal, and heavy and light oil as described above in order to apportion the electricity generation according to those percentages, or they can assume that it is more likely that hard coal and heavy oil are used and therefore consider all coal as hard coal and all oil as heavy oil.

Table 3.1.1 provides an example of the mapping of the fuel classification as provided by the IEA dataset, against the EMEP/EEA (2023) and equivalent IPCC (2006) fuel categories for emission factors that are presented in this section, using the different assumptions that can be made for the different subcategories of fuels. It is recommended that, in the absence of data, the user considers Table 3.1.1 in conjunction with Table 3.1.3 to decide on the appropriate emission factor for each fuel. It should be noted that no emission factors are available for renewable energy and nuclear power in the EMEP/EEA (2023) guidance. For these sources default zero-emission values during operation can be assumed, with appropriate notes on limitations and boundaries of the assessment.

**Table 3.1.1:** Example of mapping of the International Energy Agency (IEA) fuel classification against the IPCC (2006; 2019) and EMEP/ EEA (2023) fuel categories for emission factors.

| IEA Classification | EMEP/EEA Fuel category for emissions factors (without the use of percentages for the different subcategories for coal and oil) | EMEP/EEA Fuel category for emissions factors (with the use of percentages for the different subcategories for coal and oil) | IPCC equivalent Fuel category for emission factors |
|---|---|---|---|
| **Coal** | Hard Coal | 93% Hard Coal | Coking coal, other bituminous coal, sub bituminous coal, patent fuel |
| | | 7% Brown Coal | Lignite, Oil shale, patent fuel, peat |
| **Oil** | Heavy Fuel Oil | 66% Heavy Fuel Oil | Residual fuel oil, refinery feedstock, petroleum coke, Orimulsion, bitumen, gas oil, kerosene, naptha, shale oil |
| | | 34% Light fuel | |
| **Natural gas** | Gaseous fuels | Gaseous fuels | Natural gas, natural gas liquids, liquified petroleum gas, refinery gas, gas works gas, coke oven gas, blast furnace gas |
| **Biofuels** | Biomass | Biomass | Wood/wood waste, municipal waste |
| **Waste** | Biomass | Biomass | Wood/wood waste, municipal waste |
| **Renewables (e.g., wind, solar)** | Not applicable | Not applicable | Not applicable |
| **Nuclear** | Not applicable | Not applicable | Not applicable |

Therefore, Equations 3.1.2, and 3.1.3 (below) should be applied, where possible, disaggregated by countries where a company undertakes different activities across its value chain to ensure that the greenhouse gas and air pollutant emissions from electricity generation associated with a company's activities across its value chain account for country-specific differences in how electricity is generated.

Having determined the amount of electricity generated using a particular fuel and technology in a specific country ($EG_n$) using Equation 3.1.1, for those fuels and technologies that use fossil fuels or biomass for electricity generation, the next step is to determine the amount of fuel that is consumed to generate EGn, as shown in Equation 3.1.2.

Eq. 3.1.2

$$FC_n = (EG_n / Eff_n) * 0.0036$$

Where,

$FC_n$ is the fuel consumption for fuel and technology n (units: GJ),

Effn is the efficiency of technology n in generating electricity, and 0.0036 is the conversion from KWh to GJ.

The efficiency of different power stations ($Eff_n$) is used to estimate the quantity of fuel consumed to generate the electricity consumed by a company as part of its activities. This variable depends on the design of the power station (e.g., for thermal power stations whether it is a single or combined cycle system), as well as the age and degree of maintenance of the power station. Where country and/or company-specific information on the efficiency of power stations is known, then these can be applied with the electricity generated associated with a company's activities to determine the fuel consumed to meet a company's electricity consumption. However, where situation specific Effn values are not available, then default values summarized in Table 3.1.2 below could be applied, which provides an average efficiency of different types of power stations. In addition, default efficiency values for various individual countries, as well as for OECD and non-OECD countries are provided in the table S3.1.7. These values can be applied during the estimation process to improve the accuracy of the emission estimates.

**Table 3.1.2: Example of mapping of the International Energy Agency (IEA) fuel classification against the IPCC (2006; 2019) and EMEP/ EEA (2023) fuel categories for emission factors.**

| Fuel | Efficiency (Effn) | Source |
|---|---|---|
| **Coal** | 0.33 | (World Coal Association, 2014) |
| **Natural Gas** | 0.40 | |
| **Heavy Fuel Oil** | 0.37 | (IEA, 2008) |
| **Diesel** | 0.36 | |
| **Biomass** | 0.80 | (IEA, 2012) |

Having estimated the fuel consumption associated with the electricity consumption across different parts of a company's value chain, greenhouse gas and air pollutant emissions are then calculated by multiplying this value of their fuel consumption by fuel- specific emission factors (Tier 1) or fuel and technology- specific emission factors (Tier 2), as outlined below.

### Tier 1

For the Tier 1 approach, the emissions of pollutant k are then calculated by multiplying the fuel consumption by fuel-specific emission factors as shown in Equation 3.1.3.

Eq. 3.1.3

$$Em_k = FC_n * EF_{n,k}$$

Where,

$EF_{n,k}$ is the emission factor for pollutant k for fuel n, and

$Em_k$ are the emissions of the specific pollutant k.

Equation 3.1.3 should be applied separately for each fuel consumed in power stations providing electricity that is consumed across different parts of a company's value chain. Fuel-specific default emission factors that can be applied with this Tier 1 approach are shown in Table 3.1.3 for the different types of fuel. The limitation of the Tier 1 approach is that the technology within power stations that consume fuel to generate electricity will also determine the magnitude of emissions. For example, the application of more efficient technologies for power generation, or the operation of emission reduction technologies within power stations (e.g., flue gas desulphurisation (FGD), particle filters) significantly reduce emissions from power stations for particular pollutants. These are not accounted for in applying Tier 1 approaches. Where possible, Tier 2 approaches should be used to take into account fuel and combustion technology used to generate the electricity used across a company's value chain.

**Table 3.1.3:** Tier 1 emission factors for the different types of fuel and the different air pollutants [Source: EMEP/EEA, 2023, source category- 1.A.1 Energy Industries, tables 3-2, 3-3, 3-5 to 3-8 ; IPCC 2006, Chapter 2- Stationary combustion (table 2.2)]. Table S3.1.1, S3.1.2, and S3.1.3 should be referred for emission factors for the full list of GHG and air pollutants.

| | CO g/Gj | NMVOCs g/Gj | $NO_x$ g/Gj | $SO_2$ g/Gj | $PM_{10}$ g/Gj | $PM_{2.5}$ g/Gj | BC % of $PM_{2.5}$ | $CO_2$ g/Gj | $CH_4$ g/Gj | $N_{20}$ g/Gj | b mg/Gj | Hg mg/Gj | Cd mg/Gj |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Hard Coal** | 8.7 | 1 | 209 | 820 | 7.7 | 3.4 | 2.2 | 98300 | 10 | 1.5 | 7.3 | 1.4 | 0.9 |
| **Brown Coal** | 8.7 | 1.4 | 247 | 1680 | 7.9 | 3.2 | 1 | 101000 | 10 | 1.5 | 15 | 2.9 | 1.8 |
| **Gaseous Fuel** | 39 | 2.6 | 89 | 0.281 | 0.89 | 0.89 | 2.5 | 56100 | 1 | 0.1 | 0.0015[a] | 0.05 | 0.00025[a] |
| **Heavy Fuel Oil** | 15.1 | 2.3 | 142 | 495 | 25.2 | 19.3 | 5.6 | 77400 | 3 | 0.6 | 4.56 | 0.341 | 1.2 |
| **Light Oil** | 16.2 | 0.8 | 65 | 46.5 | 3.2 | 0.8 | 33.5 | 74100 | 3 | 0.6 | 4.07 | 1.36 | 1.36 |
| **Biomass** | 90 | 7.31 | 81 | 10.8 | 155 | 133 | 3.3 | 100000 | 30 | 4 | 20.6 | 1.51 | 1.76 |

## *Tier 2*

The Tier 2 method for estimating air pollutant emissions requires information of the specific fuel used as well as the combustion technology that consumes these fuels. The combustion technologies and corresponding fuels described in this section are those for which default technology- and fuel-specific emission factors are provided in the EMEP/EEA guidelines (2023). The combustion technologies and relevant fuels are:

- **Dry bottom boiler:** Coking coal, steam coal, sub- bituminous coal, brown coal, lignite, wood, peat, coke, oven coke, residual oil, natural gas
- **Wet bottom boiler:** Coking coal, steam coal, sub- bituminous coal, brown coal, lignite,
- **Fluid bed boiler:** Hard coal, brown coal
- **Gas turbine:** Natural gas, gas oil, refinery gas, blast furnace gas
- **Stationary engine:** Natural gas, gas oil

According to the IPCC Guidelines, Tier 2 GHG emissions are estimated using country-, fuel-, and technology-specific emission factors. Where such detailed Tier 2 data are available, users should refer directly to the IPCC Guidelines for their estimation. However, for GHGs (specifically $CH_4$ and $N_2O$), the IPCC Guidelines provide emission factors that are both fuel- and technology-specific. These categories are generally aligned with those found in the EMEP/EEA Guidebook and discussed above. To facilitate consistency and cross-referencing between inventory approaches, the IPCC emission factor categories for $CH_4$ and $N_2O$ can be mapped to the equivalent EMEP/EEA fuel and abatement technology categories. These mappings can allow users to apply IPCC-compliant GHG estimation methods within the more detailed structural framework provided by the EMEP/EEA Guidebook. The fuel and technology specific categories available in IPCC guidance are best mapped to EMEP/EEA categories as follows:

- **Dry bottom boiler:** Other Bituminous/Sub-bituminous Pulverised, Natural Gas
- **Wet bottom boiler:** Other Bituminous/Sub-bituminous Pulverised
- **Fluidized bed combustor:** Other Bituminous /Sub-bituminous Coal
- **Gas turbines:** Gas fired
- **Stationary Engines:** Natural Gas, Diesel oil
- **Wood and wood waste boilers:** Biomass

As the data available for tier emission estimation would be disaggregated in fuel and technology categories (additionally country specific for GHG emissions), it is therefore necessary, when applying a Tier 2 approach, to estimate the fraction of electricity consumed by the company across its value chain (i.e., Pn) disaggregated by fuel and technology (and country for GHG emissions). This allows the total fuel consumption to generate this electricity (FC) to be derived disaggregated by fuel and technology (and country for GHG emissions). Due to a lack of default data at this level of detail, the inventory compiler would need to identify the power stations and fuels and/or technologies used by those power stations within which the country where the company operates. Equation 3.1.4 is then applied to multiply the fuel consumption (disaggregated by fuel and technology) used to generate electricity by fuel and technology-specific emission factors to estimate the magnitude of GHG and air pollutant emissions from electricity consumption across the company's value chain. If the inventory compiler is using the fuel and technology specific emission factors provided in Table S3.1.5, equation 3.1.4 can be used for GHG emission estimation as well.

Eq. 3.1.4

$$Em_k = \sum_t FC_{n,t} \, x \, EF_{t,k}$$

where:

$FC_{n,t}$ = the fuel n consumed by a specific technology t within the source category (Gj)

$EF_{t,k}$= the emission factor for this technology t and the GHG and air pollutant k (g/Gj)

$Em_k$ = emissions of the specific pollutant k (g)

The default Tier 2 emission factors for each pollutant used to quantify air pollutant emissions from the different types of technologies consuming different types of fuels to generate electricity are shown in Table S3.1.4, Table S3.1.5, and Table S3.1.6. This is to note that table S3.1.5 includes emission factors for GHGs in fuel and technology specific categories aligning with categories provided in EMEP/EEA guidance for air pollutants emission factors. If detailed data is available and the tier 2 method provided in IPCC guidelines which uses fuel, technology and country specific emission factors is followed, the user should retrieve these emission factors from IPCC guidance (IPCC, 2006).

If detailed fuel, technology, and country-specific data is available, good practice is to use the most disaggregated, technology and country-specific emission factors available. Therefore, equation 3.2.4 is further modified and replaced by equation 3.1.5 to estimate GHG emissions by including country specific emission factors. Table S3.1.5 also provides a link to the IPCC emission factor database where fuel, technology, and country specific emission factors can be found.

Eq. 3.1.5

$$Em_k = \sum_{t,c} FC_{n,t,c} \; x \; EF_{t,c,k}$$

Where,

$FC_{n,t,c}$ = the fuel $n$ consumed by a specific country c and technology t within the source category (Gj)

$EF_{t,c,k}$= the emission factor specific to the country c and technology for pollutant k (g/Gj)

$Em_k$ = emissions of the specific pollutant k (g)

## 3.1.3 Example

Section 3.1.3 provides an example that will demonstrate to the user of this document how to calculate emissions from electricity consumption using the methods and steps outlined above in Section 3.1.

### Estimating emissions from electricity consumption in manufacturing process of a company

**Scenario:** A company consumes 10,000 MWh (10,000,000 kWh) of electricity in its manufacturing process. The electricity consumption is spread across Country A, Country B, and Country C 40%, 35%, and 25% Respectively. The process below estimates CO emissions from the manufacturing process.

The estimation procedure below depicts how Carbon Monoxide emissions are calculated using country specific datasets.

#### Estimation Procedure:

1

**Step 1: Disaggregation among countries of operation**

Based on percentage of electricity consumed in various countries, disaggregate the electricity consumed among individual countries.

| Country | Proportion of Electricity Consumption | Electricity Consumption (kWh) |
|---|---|---|
| **Country A** | 40% | 4000,000 |
| **Country B** | 35% | 3500,000 |
| **Country C** | 25% | 2500,000 |

2

**Step 2: Disaggregation among various fuel types**

Using fuel proportion data as used in the individual country to generate electivity, estimate electricity consumed by the type of fuel used to generate electricity in individual countries.

***Note:*** *Most common and the default data used for fuel proportion in various regions and countries is IEA dataset for source of electricity generation*

*Assuming the fuel proportion used to generate electricity in individual countries to be-*

| Country A | Country B | Country C |
|---|---|---|
| Hard Coal - 0.4 | Hard Coal - 0.3 | Hard Coal - 0.45 |
| Natural gas - 0.3 | Natural gas - 0.3 | Natural gas - 0.25 |
| Biomass - 0.2 | Biomass - 0.3 | Biomass - 0.15 |
| Heavy Fuel Oil - 0.1 | Heavy Fuel Oil - 0.1 | Heavy Fuel Oil - 0.15 |

Using Equation 4.1:

$$EG_n = ECT \times P_n$$

Where:

ECT= Electricity Consumption (kWh)

$P_n$ = proportion of each fuel type

*Calculate the electricity generated from each type of fuel:*

| Country (Electricity Consumption) | Hard Coal | Natural Gas | Biomass | Heavy Fuel Oil |
|---|---|---|---|---|
| **Country A (4,000,000 kWh)** | 1600000 | 1200000 | 800000 | 400000 |
| **Country B (3,500,000 kWh)** | 1050000 | 1050000 | 1050000 | 350000 |
| **Country C (2,500,000 kWh)** | 1125000 | 625000 | 375000 | 375000 |

## 3 Step 3: Determine the Amount of Fuel Consumed

Using Equation 4.2:

$$FC_n = (EG_n/Eff_n) \times 0.0036$$

Where:

$Ef_n$ is the efficiency of the technology (Hard Coal: 0.33; Natural Gas: 0.49; Biomass: 0.80; Heavy Fuel Oil: 0.40

*Calculate the electricity generated from each type of fuel:*

| Country | Hard Coal | Natural Gas | Biomass | Heavy Fuel Oil |
|---|---|---|---|---|
| **Country A** | (1600000/0.33) *0.0036 = 17455 GJ | (1200000/0.49) *0.0036 = 8816 GJ | (800000/0.80) *0.0036 = 3600 GJ | (400000) *0.0036 = 3600 GJ |
| **Country B** | (1050000/0.33) *0.0036 = 11455 GJ | (1050000/0.49) *0.0036 = 7714 GJ | (1050000/0.80) *0.0036 = 4725 GJ | (350000) *0.0036 = 3150 GJ |
| **Country C** | (1125000/0.33) *0.0036 = 12273 GJ | (625000/0.49) *0.0036 = 4592 GJ | (3 75000/0.80) *0.0036 = 1688 GJ | (375000) *0.0036 = 3375 GJ |

## 4 Step 4: Calculate Air Pollutant Emissions

Using Equation 4.3:

$$Em_k = FC_n \times EF_{n,k}$$

Where:

$EF_{n,k}$ are the emission factors (g/GJ) for each fuel type:
If we calculate emissions for carbon monoxide, then emission factors-

*If we calculate emissions for carbon monoxide, then emission factors-*

**Hard Coal: 8.7 g/GJ; Natural Gas: 39 g/GJ; Biomass: 90 g/GJ; Heavy Fuel Oil: 15.1 g/GJ**

| Country | Hard Coal | Natural Gas | Biomass | Heavy Fuel Oil |
|---|---|---|---|---|
| **Country A** | 17455 * 8.7 = 151855 | 8816 * 39 = 343837 | 3600 * 90 = 324000 | 3600 * 15.1 = 54360 |
| **Country B** | 11455 * 8.7 = 99655 | 7714 * 39 = 300857 | 4725 * 90 = 425250 | 3150 *15.1 = 47565 |
| **Country C** | 12273 * 8.7 = 106773 | 4592 * 39 = 179082 | 1688 * 90 = 151875 | 3375 * 15.1 = 50963 |

**Total CO emissions = 2236070 g = 2.23 tonnes**

## 3.1.4 References


EMEP/EEA. (2019). EMEP/EEA *air pollutant emission inventory guidebook 2019: Technical guidance to prepare national emission inventories* (EEA Report No. 13/2019). European Environment Agency. https://www.eea.europa.eu/publications/emep-eea-guidebook-2019

European Environment Agency. (2023). E*MEP/EEA air pollutant emission inventory guidebook 2023*. https://www.eea.europa.eu/en/analysis/publications/emep-eea-guidebook-2023

International Energy Agency (IEA). (n.d.). *Electricity generation by fuel – World*. Retrieved June 1, 2025, from https://www.iea.org/data-and-statistics/data-tools/energy-statistics-data-browser?country=WORLD&fuel=Energy%20supply&indicator=ElecGenByFuel

International Energy Agency. (n.d.-a). *Emissions of fine particules ($PM_{2.5}$) by sector and scenario, 2017 and 2040*. https://www.iea.org/data-and-statistics/charts/emissions-of-fine-particules-pm-25-by-sector-and-scenario-2017-and-2040

International Energy Agency. (n.d.-b). *Emissions of nitrogen oxyde ($NO_x$) by sector and scenario, 2015 and 2040*. https://www.iea.org/data-and-statistics/charts/emissions-of-nitrogen-oxyde-nox-by-sector-and-scenario-2015-and-2040

Intergovernmental Panel on Climate Change. (2006). *2006 IPCC guidelines for national greenhouse gas inventories*. IGES. https://www.ipcc-nggip.iges.or.jp/public/2006gl/

Intergovernmental Panel on Climate Change. (2019). *2019 refinement to the 2006 IPCC guidelines for national greenhouse gas inventories*. https://www.ipcc-nggip.iges.or.jp/public/2019rf/

Galimova, T., Ram, M., & Breyer, C. (2022). Mitigation of air pollution and corresponding impacts during a global energy transition towards 100% renewable energy system by 2050. *Energy Reports, 8*, 14124–14143. https://doi.org/10.1016/j.egyr.2022.10.343

World Bank. (2023). *World development indicators: Energy data*. https://databank.worldbank.org/source/world-development-indicators

International Renewable Energy Agency. (2023). *Renewable energy statistics 2023*. https://www.irena.org/Publications/2023/Jul/Renewable-energy-statistics-2023

Organisation for Economic Co-operation and Development. (2023). *IEA energy statistics and balances*. https://stats.oecd.org/Index.aspx?DataSetCode=IEA

# 3.2 Estimating Greenhouse Gases and Air Pollutant Emissions from Stationary Fuel Combustion

**Quote as:** CCAC and SEI (2025). Section 3.2 Estimating Greenhouse Gas and Air Pollutant Emissions from Stationary Fuel Combustion. In: Integrated Guide for Business Greenhouse Gas and Air Pollutant Emission Assessment. Climate and Clean Air Coalition and Stockholm Environment Institute, Paris.

**URL:** https://www.ccacoalition.org/resources/integrated-guide-business-greenhouse-gas-and-air-pollutant-emission-assessment

This section of the Guide 2.0 explains how the emissions of greenhouse gas (GHGs), Short-Lived Climate Pollutants (SLCPs), classical air pollutants and heavy metals (HM) (hereafter referred to as greenhouse gas and air pollutants as defined in Chapter 1) that are related to the stationary fuel combusted at different parts of a company's value chain can be quantified.

This section is structured by first describing the source, then describing the methods, which includes Tier 1 emission factors. The Tier 2 methods are explained in this document, but the Tier 2 (as well as the Tier 1) emission factors are linked to a database where these default values can be found here: https://www.ccacoalition.org/resources/integrated-guide-business-greenhouse-gas-and-air-pollutant-emission-assessment. One exception is the Tier 2 GHG emissions factors, for which a link to the IPCC emission factor database is provided. The section then includes an example calculation using the methods and then provides the references for the methods and data.

### 3.2.1 Description of the Source

Stationary fuel combustion is the burning of fuels 'on- site' in manufacturing, retail or other parts of a business' value chain. The combustion of these fuels leads to emissions of pollutants such as arbon Dioxide ($CO_2$), Methane ($CH_4$), Particulate Matter ($PM_{10}$, $PM_{2.5}$), Sulphur Dioxide ($SO_2$), Nitrogen Oxide ($NO_x$), Carbon Monoxide (CO), Non-methane volatile organic compounds (NMVOCs), Ammonia ( $NH_3$), Nitrous Oxide ($N_2O$), Black Carbon (BC), Lead (Pb), Mercury (Hg), Cadmium (Cd), Arsenic (As), Chromium (Cr), Copper (Cu), Nickel (Ni), Selenium (Se), Zinc (Zn). Stationary fuel combustion, and the greenhouse gas and air pollutant emissions occurring from it is distinct from electricity consumption, in which the emissions are produced during electricity generation, which may not be part of the business' operations (e.g., if the electricity consumed comes from the national grid). It is also distinct from greenhouse gas and air pollutant emissions that occur from mobile sources (e.g., road transport) along a company's value chain. The stationary fuel combustion category includes combustion at a fixed site. The guidance provided in the following sections can be used to quantify greenhouse gas and air pollutant emissions.

In the EMEP/EEA (2023) guidelines, sub-sectors for which methods are included to quantify emissions from stationary fuel combustion are Manufacturing and Construction Industries, including Iron and steel (1.A.2.a), Non-ferrous metals (1.A.2.b), Chemicals (1.A.2.c), Pulp, paper and print (1.A.2.d), Food processing, beverages and tobacco (1.A.2.e), Non-metallic minerals (1.A.2.f), Others (1.A.2.g.viii). In the IPCC Guidelines, methods for estimating GHG emissions from stationary fuel combustion are included in Chapter 2 (IPCC 2019), Stationary Combustion, under manufacturing industries and construction. The relevant emission factors are provided in Chapter 2, Stationary Combustion (specifically in Table 2.3). The fuel categories listed in the IPCC (2019) Guidelines align with those discussed below under solid fuels, gaseous fuels, liquid fuels, and biomass. These categories of stationary fuel combustion are likely to occur in the raw material extraction, manufacturing and distribution parts of the value chain included in Chapter 2 of this guide.

Stationary fuel combustion can also occur in other parts of a business' value chain. For example, during retail, or when products are in-use, there may be consumption of fuel. Methods for the quantification of greenhouse gas and air pollutant emissions from these sources are also included in this section. For all these sources, the magnitude of greenhouse gas and air pollutant emissions depends on the type (and quantity) of fuel consumed within a particular part of the business value chain. The types of fuels which are commonly used within stationary fuel combustion include:

- **Solid fuels:** Hard coal, coking coal, other bituminous coal, sub-bituminous coal, coke, brown coal, lignite, oil shale, manufactured 'patent' fuel, peat.
- **Gaseous fuels:** Natural gas, gas works gas, coke oven gas, blast furnace gas, natural gas liquids, liquefied petroleum gas, biogas, refinery gas
- **Liquid fuels:** Gasoline, diesel, kerosene, heavy fuel oil
- **Biomass:** Wood, charcoal, vegetable (agricultural) waste

Section 3.2.2 presents the Tier 1 methods that can be used to quantify the greenhouse gas and air pollutant emissions from stationary fuel combustion along a company's value chain for any of the fuels listed above. However, the magnitude of air pollutant emissions from burning different fuels also depends on the technology used to burn the fuel, and the efficiency of combustion. Where possible, the technology used in the combustion of each type of fuel in stationary combustion should also be considered. In addition to fuel and technology, the non-$CO_2$ GHG emissions ($CH_4$ and $N_2O$) also take into account the country where the fuel is combusted. Therefore, a common Tier 1 method to estimate greenhouse gas and air pollutants is provided, but separate Tier 2 methods for GHG and air pollutant emissions are provided in section 3.2.3.

## 3.2.2 Methodologies for Quantifying Emissions

Methods for estimating greenhouse gas and air pollutant emissions from stationary fuel combustion can be based either solely on the type of fuel combusted (Tier 1)) or on a more detailed combination of fuel type and combustion technology (Tier 2). The choice between a Tier 1 or Tier 2 approach depends on the availability of activity data—whether it is categorized only by fuel type or further disaggregated by specific combustion technologies. The pollutants covered in the method are $SO_2$, $NO_x$, CO, NMVOCs, $PM_{10}$, $PM_{2.5}$, $NH_3$, Pb, Hg, Cd, As, Cr, Cu, Ni, Se, Zn, BC, $CO_2$, $CH_4$, $N_2O$. For $NH_3$; emission factors are not available in EMEP/EEA (2023) guidance, so these do not appear in the methods or emission factors covered.

### ▸ *Tier 1*

Stationary fuel combustion may be a source of greenhouse gas and air pollutant emissions across a company's value chain, including in raw material extraction (e.g., consumption of diesel in off-road machinery), in manufacturing processes (e.g., consumption of solid, liquid or gaseous fuels for heat or motive power), as well as in retail (e.g., use of diesel in on- site generators) or when a product is in use (e.g., use of gasoline to power a particular product). In all cases, using a Tier 1 methodology, Equation 3.2.1 is used to quantify the magnitude of greenhouse gas and air pollutant emissions. Equation 3.2.1 multiplies the amount of fuel consumed (disaggregated by fuel type, and, if known technology within which the fuel is consumed), by fuel-specific emission factors. Equation 3.2.1 expresses the amount of fuel consumed in energy units. If the fuel consumed is known in mass (e.g., kilogramme, tonnes), volume (litres, cubic metres) or other units, then these should be converted to energy units for compatibility with emission factors for stationary fuel combustion.

Eq. 3.2.1

$$Em_k = FC_n \text{ x } EF_k$$

Where:

$FC_n$ = the fuel n consumed within the source category (Gj)
$EF_k$ = the emission factor for this GHG and air pollutant k (g/Gj)
$Em_k$ = emissions of the specific pollutant k (g)

The activity data i.e., fuel consumption, to estimate greenhouse gas and air pollutant emissions, is company-specific depending on where in the value chain the stationary combustion takes place, and the magnitude of these activities. Therefore, it is necessary for the inventory compiler to identify the fuel consumption data, disaggregated by fuel, that a company consumes at different stages of its value chain, as default data for the activity are not available.

Table 3.2.1 includes Tier 1 default emission factors for stationary fuel combustion, taken from the EMEP/EEA (2023) and IPCC (2006) guidance for air pollutants and greenhouse gases respectively. Their units (g pollutant per GJ fuel consumed) are compatible with activity data expressed as fuel consumption in energy units. A limitation of these emission factors, and the application of the Tier 1 approach for stationary fuel combustion is that they do not take into account the technology that is used to combust the different types of fuels. The type of combustion technology used can have a large impact on the magnitude of emissions from burning a particular fuel as the technology determines the efficiency of combustion and may have different emission reduction technologies fitted to it which are expressly designed to minimize air pollutant emissions. For example, the fitting of particle filters to stationary equipment can substantially reduce the particulate matter emissions from burning fuels in stationary combustion. When information is available on the technology used in stationary fuel combustion, Tier 2 methods can be used to more accurately estimate emissions from these sources along the value chain.

**Table 3.2.1:** **Tier 1 emission factors for the different types of fuel and the different pollutants [Source: EMEP/EEA, 2023, source code- 1.A.2, Table 3.2 to 3-5; IPCC 2006, Chapter 2- Stationary combustion, Table 2.3]. Table S3.2.1, S3.2.2, and S3.2.3 should be referred for emission factors for the full list of GHG and air pollutants.**

| Fuel Category | CO g/Gj | NMVOCs g/Gj | $NO_x$ g/Gj | $SO_2$ g/Gj | $PM_{10}$ g/Gj | $PM_{2.5}$ g/Gj | BC % of $PM_{2.5}$ | $CO_2$ g/Gj | $CH_4$ g/Gj | $N_{20}$ g/Gj | b mg/Gj | Hg mg/Gj | Cd mg/Gj |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Solid Fuels | 931 | 88.8 | 173 | 900 | 117 | 108 | 6.4 | 97800 | 10 | 1.5 | 134 | 7.9 | 1.8 |
| Gaseous Fuels | 29 | 23 | 74 | 0.67 | 0.78 | 0.78 | 4 | 56100 | 1 | 0.1 | 0.011a | 0.1 | 0.0009a |
| Liquid Fuels | 66 | 25 | 513 | 47 | 20 | 20 | 56 | 73350 | 3 | 0.6 | 8 | 0.1 | 0.15 |
| Biomass | 570 | 300 | 91 | 11 | 143 | 140 | 28 | 100000 | 30 | 4 | 27 | 0.56 | 13 |

[a] The value provided is the maximum per unit emission and can be used to estimate maximum possible emission from the activity

## Tier 2

As outlined in the EMEP/EEA (2023) guidelines, the key advancement when moving to a Tier 2 approach is the consideration of technology alongside the fuel being combusted in stationary fuel combustion. Equation 3.2.2 shows the equation for estimating emissions from stationary fuel combustion using a Tier 2 approach. The methodology is similar to that outlined above for Tier 1 in Equation 3.2.2, in which the amount of fuel consumed (expressed in energy units) is multiplied by fuel-specific emission factors. For the Tier 2 approach, the activity data on fuel consumption is also disaggregated by technology that reflects the sub- sector where the fuel is being combusted, the efficiency of the machinery where the fuel is being combusted, and/or any emission reduction technologies that are in place in the machinery being used.

As with the Tier 1 approach, the fuels and technologies consumed in stationary combustion are dependent on the company and their specific value chain. Hence for the Tier 2 approach, there is also no default activity data that can be applied for the Tier 2 method, and company-specific data is needed. Emission factors for the Tier 2 approach may be directly measured from particular machinery being used within a company's value chain, but there are a range of sources of default Tier 2 emission factors that have been compiled for different sub-sectors, technologies and fuels, including those in the EMEP/EEA (2023) guidelines. These emission factors are included in the SI.

Eq. 3.2.2

$$Em_k = \sum_t FC_n \, x \, EF_{t,k}$$

where:

$FC_{n,t}$ = the fuel n consumed by a specific technology t within the source category (Gj)

$EF_{t,k}$ = the emission factor for this technology and the pollutant k (g/Gj)

$Em_k$= emissions of the specific pollutant k (g)

The estimation of Tier 2 greenhouse gas emissions would require data on fuel consumption in a specific country, as use of country and technology specific emission factors are suggested for use in the emission estimation process (IPCC, 2006). If the fuel consumption by the company is disaggregated in the countries of operation, this data can be used to estimate greenhouse gas emissions. In case where the disaggregated fuel consumption is not available, the fuel consumption can be disaggregated into the fuel, technology and countries of operation using proportion (Pn) of fuel combusted across these categories. Greenhouse gas emissions can now be calculated using equation 3.2.3.

Eq. 3.2.3

$$Em_k = \sum_t FC_{n,c,t} \; x \; EF_{t,c,k}$$

where:

$FC_{n,c,t}$ = the fuel n consumed by a specific technology t, in country c within the source category (Gj)

$EF_{t,c,k}$ = the emission factor for this technology t, for country c and the pollutant k (g/Gj)

$Em_k$= emissions of the specific pollutant k (g)

## 3.2.3 Example

Section 3.2.3 provides an example that will demonstrate to the user of this document how to calculate emissions from electricity consumption using the methods and steps outlined above in Section 3.2.

### Stationary Fuel Combustion

Estimate $NO_x$ emissions from a company which operates in manufacturing sector and uses various fuels as provided below.

| Fuel type | Solid Fuels | Gaseous Fuels | Liquid Fuels | Biomass |
|---|---|---|---|---|
| **Fuel consumed (GJ)** | 50,000 | 30,000 | 20,000 | 10,000 |

### Step-by-Step estimation Process

The tier 1 method of emission estimation for stationary fuel combustion is straightforward. The emissions can be calculated by directly using the emission factors if the fuel usage categories are already defined.

However, if the fuel usage is disaggregated at a higher level, the user needs to aggregate the fuel use in their appropriate categories before applying tier 1 emission factors.

- *Tier 1 method:*

1 **Step 1: Use the Tier 1 emission factors for $NO_x$ ($EF_k$)**

| Fuel type | Solid Fuels | Gaseous Fuels | Liquid Fuels | Biomass |
|---|---|---|---|---|
| **Emission factor (g/GJ)** | 173 | 74 | 513 | 91 |

*Apply Equation 4.5 to estimate the emissions ($Em_k$):*

Emissions ($Em_k$) = Fuel Consumption ($FC_n$) × Emission Factor ($EF_k$)

**Calculation:**

$\text{Emissions}_{\text{Solid fuels}}$ = 50,000 GJ x 173 g/GJ = 8,650,000 g = 8.65 tons

$\text{Emissions}_{\text{Gaseous fuels}}$ = 30,000GJx74g/GJ=2,220,000g = 2.22tons

$\text{Emissions}_{\text{Liquid fuels}}$ =20,000GJx513 g/GJ=10,260,000g = 10.26tons

$\text{Emission}_{\text{Biomass fuels}}$ = 10,000GJx91g/GJ=910,000g = 0.91tons

**Total $NO_x$ Emissions**

*Sum of $NO_x$ emissions from all fuel types:*

**Total $NO_x$ Emissions=8.65 tons + 2.22 tons + 10.26 tons + 0.91 tons = 22.04 tons**

## 3.2.4 References

EMEP/EEA. (2019). *EMEP/EEA air pollutant emission inventory guidebook 2019: Technical guidance to prepare national emission inventories* (EEA Report No. 13/2019). European Environment Agency. https://www.eea.europa.eu/publications/emep-eea-guidebook-2019

European Environment Agency. (2023). *EMEP/EEA air pollutant emission inventory guidebook 2023*. https://www.eea.europa.eu/en/analysis/publications/emep-eea-guidebook-2023

Intergovernmental Panel on Climate Change. (2006). *2006 IPCC guidelines for national greenhouse gas inventories*. IGES. https://www.ipcc-nggip.iges.or.jp/public/2006gl/

Intergovernmental Panel on Climate Change. (2019). 2019 refinement to the *2006 IPCC guidelines for national greenhouse gas inventories*. https://www.ipcc-nggip.iges.or.jp/public/2019rf/

# 3.3 Estimating Greenhouse Gas and Air Pollutant Emissions from Transport

**Quote as:** CCAC and SEI (2025). Section 3.2 Estimating Greenhouse Gas and Air Pollutant Emissions from Stationary Fuel Combustion. In: Integrated Guide for Business Greenhouse Gas and Air Pollutant Emission Assessment. Climate and Clean Air Coalition and Stockholm Environment Institute, Paris.

**URL:** https://www.ccacoalition.org/resources/integrated-guide-business-greenhouse-gas-and-air-pollutant-emission-assessment

This section of the Guide 2.0 explains how the emissions of greenhouse gas (GHGs), Short-Lived Climate Pollutants (SLCPs), classical air pollutants and heavy metals (HM) (hereafter referred to as greenhouse gas and air pollutants as defined in Chapter 1) that are related to the transportation activities for movement of freight and passengers at different parts of a company's value chain can be quantified.

This section is structured by first describing the source, then describing the methods, which includes Tier 1 emission factors. The Tier 2 methods are explained in this document, but the Tier 2 (as well as the Tier 1) emission factors are linked to a database where these default values can be found (https://www.ccacoalition.org/resources/integrated-guide-business-greenhouse-gas-and-air-pollutant-emission-assessment). The section then includes an example calculation using the methods and then provides the references for the methods and data.

## 3.3.1 Description of the Source

Transport can be a source of greenhouse gas and air pollutants at multiple points across a company's value chain. The movement of raw materials, as well as manufactured goods can contribute to greenhouse gas and air pollutant emissions from the transport of freight. In addition, during the retail stage of a company's value chain, the delivery of goods directly to the customer can add to greenhouse gas and air pollutant emissions from freight transport, while the transport of customers to stores, either through private vehicles or public transport, can result in greenhouse gas and air pollutant emissions from passenger travel. Finally, emissions can occur because of the use of non-road mobile sources and machinery such as commercial, household and gardening, and agricultural machinery. The pollutants released during transportation activities across a company's value chain are Carbon Dioxide ($CO_2$), Methane ($CH_4$), Nitrous Oxide ($N_2O$), Particulate Matter ($PM_{10}$, $PM_{2.5}$), Sulphur Dioxide ($SO_2$), Nitrogen Oxide ($NO_x$), Carbon Monoxide (CO), Non-methane volatile organic compounds (NMVOCs),  Black Carbon (BC), Lead (Pb), Mercury (Hg), Cadmium (Cd), Arsenic (As), Chromium (Cr), Copper (Cu), Nickel (Ni), Selenium (Se), Zinc (Zn).

Greenhouse gas and air pollutants can be estimated using a Tier 1 as well as a Tier 2 method. The methods to estimate both GHG and air pollutant emissions is same and follows similar steps for disaggregation of data in fuel, vehicle and engine standard categories. However, the level of disaggregation for GHG and air pollutant emission estimation differs for both tier 1 as well as tier 2 and is discussed in more detail in section 3.3.2.

## 3.3.2 Methodologies for Quantifying Emissions

In national emission inventory guidance, the most common methodologies for quantifying GHG and air pollutant emissions from transport include:

- Multiplying the total fuel consumed (e.g., diesel, gasoline, compressed natural gas) in transport by pollutant specific emission factors. This 'Tier 1' method is described in EMEP/EEA (2023) and IPCC (2006; 2019)
- Multiplying the total number of vehicles of different types (passenger cars, light commercial vehicles, heavy duty vehicles etc.) by the average distance travelled by one vehicle of each type per year to calculate the total number of vehicle-km travelled by vehicles. The total number of vehicle-km are then multiplied by vehicle type-, fuel- and technology- and pollutant-specific emission factors to calculate the total emissions within the transport sector. These 'Tier 2' methodologies, described in detail in EMEP/EEA (2019) respectively are most commonly applied to air pollutant emissions from the road transport sector.

These two approaches are appropriate for the quantification of national total emissions in the transport sector for a particular country, or other geographic grouping, but are limited in their ability to be applied in a company's value chain.  Firstly, these methods do not disaggregate the activities that are leading to the number of vehicle-km, vehicle fuel consumption, and hence emissions that result from the transport sector. This limits these methods in their ability to disaggregate greenhouse gas and air pollutant emissions in different parts of the value chain, e.g., transporting goods, and customer travel. Secondly, using overall fuel consumption of a vehicle, or the total number of vehicle-km that are travelled by a vehicle as the activity variable to quantify greenhouse gas and air pollutant emissions from transport may not allow for an appropriate allocation of greenhouse gas and air pollutant emissions from transport, where company's goods are transported on a vehicle or vessel alongside goods from other companies, or where customers travel to a business using public transport, alongside other passengers.

The methodologies outlined below allow the user to quantify the emissions of pollutants such as CO, NMVOCs, $NO_x$, $SO_2$, $PM_{2.5}$, $PM_{10}$, BC, $CO_2$, $CH_4$, $N_2O$, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, and Zn. Two key types of activities variables are used across all transport modes (e.g., road, rail, sea and air) to characterize the type and size of transport sector activities within different parts of a company's value chain:

- **Freight transport:** The transport of goods within a company's value chain, including the transport of raw materials to manufacturing plants, and the distribution of finished products to retail, or customers, is included under 'freight transport'. For these activities, the activity variable is the total number of 'tonnes-km' travelled within different parts of a company's value chain. The number of tonnes-km are calculated by multiplying the total mass of goods that are transported within a company's value chain, by the average distance that those goods are transported. The number of tonnes-km provides a measure of the total volume of freight transport within a company's value chain and provides a consistent activity variable that can be used across transport modes. Specifically for road transport, the Guide 2.0 includes two approaches that the user can use in order to quantify GHG and air pollutant emissions, a tier 1 and a tier 2 method. The tier 2 method requires the user to have information on the types of different vehicles, the consumption of fuel for each type of vehicle, but also the emission standards for each different type. However, if this information is not available and no assumptions can be made to estimate the level of disaggregation required to apply this method, the tier 1 method can be used. The information needed in order to apply the tier 1 method is the number of vehicles and the consumption of different fuel for each vehicle category. It is up to the user to identify which method is the most appropriate based on the data that is available.

- **Passenger transport:** The transport of people (i.e., customers, employees) to and from retail stores or to participate in other company activities are included under 'customer transport'. The activity variable used for customer travel is the number of 'passenger-km' travelled within a company's value chain. The number of passenger-km are calculated by multiplying the total number of people visiting company's stores, other premises, or travelling to participate in company activities, by the average distance travelled each person has travelled. Like tonnes-km for freight, the total number of passenger-km provides a measure of the total demand for passenger travel within a company's value chain and provides a consistent activity variable that can be used across transport modes. As described above for freight road transport, the Guide includes a detailed and simplified method for passenger transport as well.

- **Non-road mobile machinery:** The use of different types of non-road mobile machinery is included under 'mobile machinery'. For these activities, the key variable is the amount of fuel (tonnes) used for the different types of machinery, disaggregated by the type of fuel that they use, engine type (two stroke or four stroke) and the different sectors that they belong to. For example, the user will need to identify the total amount of agricultural machinery that use diesel and the total amount of fuel (in this case diesel) they are using. The amount of fuel used for each type for machinery is then multiplied by a fuel, sector, and pollutant emission factor to estimate emissions from this source.

Within this section, methods to estimate the greenhouse gas and air pollutant emissions for different sources within the transport sector using tonnes-km or passenger-km are described for the following sectors:

- **Freight Transport**
  - Road including heavy duty vehicles and light commercial vehicles
  - Rail
  - Shipping
  - Aviation

- **Passenger Transport**
  - Road including private travel (cars) and public transport (buses)
  - Rail
  - Non- road Mobile Machinery

Finally, this section also outlines methods for quantifying emissions from mobile machinery, i.e., off-road machinery used in construction or agriculture.

# Freight transport

The methods for quantifying greenhouse gas and air pollutant emissions from freight transport are outlined below separately for different transport modes (road, rail, aviation, and shipping). For all transport modes, the activity variable is the total number of tonnes-km transport using different transport modes. Hence a prerequisite for quantifying air pollutant emissions within a company's value chain is understanding the total mass of product/material transported (or fuel consumed) at a particular part of the company's value chain, and the average distance that these products are transported. The sub-sections below outlined the level of disaggregation that is required to calculate tonnes-km (i.e., by vehicle types, fuel types etc.), and how this activity variable can be combined with appropriate emission factors to quantify emissions of different pollutants.

## Road transport

To quantify greenhouse gas and air pollutant emissions from road transport, there are two methods that can be used based on the information that is available to the user. The tier method, which requires information on the vehicle type, fuel used by each type of vehicle, but also vehicle emission standard, and the tier 1 method that only requires information on the number of different types of vehicles and fuel consumed by each type of vehicle. It is up to the user to identify which method is best suited to calculate greenhouse gas and air pollutant emissions, based on the data that is available to them.

### Tier 1

#### a) Air Pollutants

If the only information available is the type of fuel consumed by each type of vehicle, then the emissions can be simply calculated by following the steps as provided below:

1

**Step 1: Collect information on the number of different types of vehicles used.**

The user needs to identify the number of different types of vehicles used within their value chain. This should include the number of passenger cars (PC), light commercial vehicles (LCV), heavy duty vehicles (HDV) and the L- category (i.e., mopeds, motorcycles, mini-cars and all- terrain vehicles). For freight, not all of these categories might be relevant however the relevant categories should be determined by the user and the company specific value chain. For example, a company could be using passenger cars in order to transport their goods and in that case, it is recommended that the passenger cars used to transport goods are grouped under freight rather than under passenger transport.

2

**Step 2: Disaggregate each type of vehicle by type of fuel used.**

The user then needs to disaggregate each vehicle type by the different types of fuel used by each vehicle type. For passenger cars, the fuels that can be considered are petrol, diesel and LPG, for light commercial vehicles the fuels that need to be considered are petrol and diesel, for heavy duty vehicles the fuels that need to be considered are diesel and CNG and for the L-category it's petrol.

3

**Step 3: Multiply the amount fuel consumed (kg) for different types of vehicles by pollutant-specific emission factors.**

Steps 1-2 derive the activity data (kg of fuel consumed by type of vehicle) that will allow GHG and air pollutant emissions to be estimated for freight transport within a company's value chain. These data are then required to be combined with emission factors that quantify the air pollutant emissions from this freight transport activity. The available emission factors, from EMEP/EEA (2023) for all relevant greenhouse gas and air pollutants, respectively, have units of gram pollutant emitted per vehicle-km travelled.

Equation 3.3.1 shows how air pollutant emissions are estimated for freight transport for a particular vehicle type and fuel:

Eq. 3.3.1

$$Em_k = FC_{v,t} \, x \, EF_{k,v,f}$$

Where,

$FC_{v,f}$ = fuel consumption of vehicle type v using fuel f (kg)

$EF_{k,v,f}$ = emission factor for pollutant k for vehicle type v, and fuel f (g vehicle-km$^{-1}$)

$Em_{k,v,,f}$ = emissions of the specific pollutant k for vehicle type v, and fuel f (g)

**Alternative fuel and abatement**

Companies often use diesel blended with various proportions of biofuels, which can significantly influence emission levels compared to using pure diesel. According to the EMEP/EEA (2023) guidelines, emission factors vary based on the blend ratio of biofuel to diesel. These guidelines provide percentage reductions in emissions for standard blends such as B0 (100% diesel), B10, B20, and B100 (100% biofuel). The emission estimation for these fuel categories can be estimated using equation 3.3.1. Emission factors in these individual blend ratios are available in Table S3.3.39.

### b) GHG emissions

If the only information available is the type of fuel consumed by each type of vehicle, then the emissions can be simply calculated by following the steps as provided below:

**$CO_2$ emissions**

The emission estimation for $CO_2$ differs significantly from that of air pollutants as well as non-$CO_2$ GHGs, as it is not dependent on the combustion and emission control technology and is solely based on the type of fuel combusted. Therefore, the tier 1 method calculates $CO_2$ emissions from road transport based on the amount of fuel used. Table 3.3.1 provides the emission factors that can be used to estimate these emissions based on the type of fuel being used.

Table 3.3.1: Default $CO_2$ emission factors for various fuel categories

| Fuel Type | Motor Gasoline | Gas/ Diesel Oil | Liquefied Petroleum Gases | Kerosene | Lubricants | Compressed Natural Gas | Liquefied Natural Gas |
|---|---|---|---|---|---|---|---|
| Emission Factor (g/kg) | 1558 | 1631 | 1368 | 1674 | 1744 | 1122 | 1019 |

### $N_2O$ and $CH_4$ emissions

$CH_4$ and $N_2O$ emission rates from vehicles can vary significantly based on the combustion and emission control technology available, therefore using default fuel-based emission factors that do not specify vehicle technology can be highly uncertain. Table 3.3.2 provides Tier 1 emissions factors for road transportation vehicles with their combustion and emission technology accounted.

**Table 3.3.2:** **Default $CH_4$ and $N_2O$ emission factors for various fuel categories**

| Fuel Type/ Representative Vehicle Category | Motor Gasoline -Uncontrolled | Motor Gasoline –Oxidation Catalyst | Motor Gasoline –Low Mileage Light Duty Vehicle Vintage 1995 or Later | Gas / Diesel Oil | Natural Gas |
|---|---|---|---|---|---|
| **$CH_4$ (g/kg)** | 0.74 | 0.56 | 0.085 | 0.085 | 1.84 |
| **$N_2O$ (g/kg)** | 0.072 | 0.18 | 0.13 | 0.085 | 0.06 |

Emissions of $CH_4$ and $N_2O$ are more complex to estimate than those for $CO_2$ because emission factors depend on vehicle technology, fuel and operating characteristics. Both distance-based activity data (e.g. vehicle kilometres travelled) and disaggregated fuel consumption may be considerably less certain than overall fuel combustion. $CH_4$ and $N_2O$ emissions are significantly affected by the distribution of emission controls in the fleet. Thus, higher tiers use an approach considering different vehicle types and their different pollution control technologies.

The fuel consumption data for different vehicles categories can be used to estimate the amount of fuel used, when data is available in the form distance travelled. Table 3.3.3 lists default fuel consumption by the category of a vehicle.

**Table 3.3.3:** **Vehicle category specific default fuel consumption (g/km)**

| Fuel Type/ Representative Vehicle Category | Motor Gasoline -Uncontrolled | Motor Gasoline –Oxidation Catalyst | Motor Gasoline –Low Mileage Light Duty Vehicle Vintage 1995 or Later | Gas / Diesel Oil | Natural Gas |
|---|---|---|---|---|---|
| **$CH_4$ (g/kg)** | 0.74 | 0.56 | 0.085 | 0.085 | 1.84 |
| **$N_2O$ (g/kg)** | 0.072 | 0.18 | 0.13 | 0.085 | 0.06 |

### Tier 2

This option should be selected if there is information available on the different types of vehicles used, the different types of fuels consumed by each vehicle type and emission standards. To estimate greenhouse gas and air pollutant emissions from the road transport sector, the activity data (tonnes-km) can be disaggregated by vehicle type, fuel used, and vehicle emission standard (e.g., Euro standard) if this information is available. The following steps should be taken to derive tonnes-km estimates disaggregated at this level and then combined with emission factors to estimate GHG and air pollutant emissions.

**a) Air Pollutants**

1

**Step 1: Estimate tonnes-km for different vehicle types.**

The calculation of tonnes-km for different vehicle types can be estimated either by i) disaggregating a total tonnes-km estimate for all vehicle types into different vehicle categories based on the percentage of tonnes-km transport by different types of vehicles or ii) developing estimates of tonnes-km for different vehicle types independently.
The categorization of vehicles differs across jurisdictions, reflecting variations in regulatory frameworks, vehicle fleets, and data collection practices. For example, some countries may classify vehicles simply as light-duty or heavy-duty, while others may have more detailed categories such as passenger cars, light commercial vehicles, heavy-duty trucks, and buses, each with further subdivisions based on fuel type or engine technology. These differences can affect emission estimation methods and comparability of data across regions. As the Guide 2.0 considers emission factors from the EMEP/EEA (2023) guidelines for air pollutants, the Guide adopts the disaggregation of vehicles according to the EME/EEA categorization and these categories are aligned to vehicle categories available in IPCC (2006; 2019) guidance used for greenhouse gas emissions. For freight, the two key vehicle types in the EMEP/EEA guidelines are 'heavy-duty vehicles', which are vehicles greater than 3.5 tonnes and 'light commercial vehicles', less than 3.5 tonnes. The estimation of tonnes-km for the different vehicle types using either approach described above requires company-specific data on the mass of product/material transported, and the distance that these products are transported. These are highly specific to the value chain of the individual company. For this reason, no default data is available and company-specific data is required on the number of tonnes-km travelled by different vehicles.

2

**Step 2: Disaggregate tonnes-km for different vehicles by fuel.**

The types of fuels where air pollutant emissions can be estimated include gasoline, diesel, liquified petroleum gas (LPG), and compressed natural gas (CNG), which result in exhaust emissions when used in transport.
The total number of tonnes-km that are taken using electric vehicles in a company's value chain should also be estimated, by multiplying the total tonnes-km taken by each vehicle type by the fraction of those journeys taken in electric vehicles. No exhaust emissions result from electric vehicles, and therefore the air pollutant emissions from electric vehicles are only those resulting from the generation of electricity. The user should therefore use the methods outlined in Section 3.1 to estimate the air pollutant emissions associated with electric vehicle use in a value chain, as with other sources of electricity consumption within a company.

## 3 Step 3: Disaggregate tonnes-km by technology/vehicle emission standards.

For fossil fuel powered cars, different countries and regions have progressively introduced more stringent vehicle emission standards to reduce the emissions of key greenhouse gas and air pollutants in their vehicle fleets. For example, since the early 1990s in Europe, the 'Euro' standards, now in their 6th iteration, have provided emission limits for new vehicles introduced to the vehicle fleet in Europe, for both passenger and freight vehicles. The Euro standards reflect the use of different technologies to control vehicle air pollutant emissions. Other regions have adopted Euro standards, or similar in their national vehicle emission standards. In other cases, e.g., in the United States, a different set of vehicle emission standards have been introduced, with air pollutant emission limits ranging from Tier 1 (least stringent) to Tier 4 (most stringent).

To robustly estimate emissions from freight transport within a company's value chain, it is therefore necessary to disaggregate the tonnes-km for heavy duty vehicles, and light duty vehicles, for different fuel types, by vehicle emission standard. The most commonly used emission standard globally is the Euro standard, and therefore they are reflected in this methodology. However, other emission standards can be used. Similarly for Step 2 above, to estimate the number of tonnes-km taken by vehicles meeting different Euro standards (disaggregated by fuel), the number of tonnes- km taken by, e.g. heavy duty vehicles using diesel, which are calculated by applying Steps 1 and 2 above, should be multiplied by the fraction of tonnes-km transport in vehicles that are either Uncontrolled, or meet Euro I, Euro II, Euro III, Euro IV, EURO V, or Euro VI standards.

## 4 Step 4: Multiply tonnes-km for different vehicles, fuels and emission standards by pollutant-specific emission factors.

Steps 1-3 derive the activity data (tonnes-km) in a sufficient level of detail to allow greenhouse gas and air pollutant emissions to be estimated for freight transport within a company's value chain. These data are then required to be combined with emission factors that quantify the GHG and air pollutant emissions from this freight transport activity. The available emission factors, from IPCC (2006; 2019) and EMEP/EEA (2023) for all relevant air pollutants, have units of gram pollutant emitted per vehicle-km travelled. Therefore, to apply in company's value chain, it is necessary that a conversion is made so that they can be combined with tonnes-km data.II, Euro III, Euro IV, EURO V, or Euro VI standards.

Equation 3.3.2 shows howair pollutant emissions are estimated for freight transport for a particular vehicle type, fuel, and emission standard:

Eq. 3.3.2

$$Em_{k,v,f,s} = (tkm_{v,f,s} / Load\ Factor) * EF_{k,v,f,s}$$

$tkm_{v,f,s}$ = tonnes-km travelled using vehicle type v, fuel f, and emission standard s (tonnes-km)

$EF_{k,v,f,s}$ = emission factor for pollutant k for vehicle type v, fuel f, and emission standard s (g vehicle-km$^{-1}$)

Load Factor = The load factor (tonnes freight vehicle-1)

$Em_{k,v,f,s}$ = emissions of the specific pollutant k for vehicle type v, fuel f, and emission standard s (g)

Equation 3.3.2 takes tonnes-km estimates for different vehicle types, fuels and emission standards and divides it by i) a load factor and multiplies it by ii) emission factors for different pollutants with units g vehicle-km$^{-1}$. The load factor is the conversation factor that allows the emission factors to be combined with tonnes-km estimates for a company's value chain. The load factor is the average number of tonnes of freight that one vehicle is able to transport. Dividing the tonnes-km by the load factor converts the tonnes-km to vehicle-km estimates, consistent with the default emission factors available in international air pollutant emission guidelines such as EMEP/EEA (2019) respectively. Company-specific data on the occupancy rates of heavy duty and light commercial vehicles may be available. However, in the absence of company specific data, then default occupancy rates included in Table 3.3.13 below could be used with company-specific tonnes-km data.

### b) GHG Emissions

Tier 2 emissions for GHGs from road transport are estimated using fuel consumed by vehicles disaggregated by fuel, vehicle, and emission control technology specific categories. The emissions should be estimated using equation 3.3.3.

Eq. 3.3.3

$$E = \sum_{(a,b,c)} FC_{(a,b,c)} \times EF_{(a,b,c)}$$

Where:

Emission = emission in kg.

$EF_{a,b,c}$ = emission factor (kg/TJ)

$Fuel_{a,b,c}$ = fuel consumed (TJ) (as represented by fuel sold) for a given mobile source activity

a = fuel type (e.g., diesel, gasoline, natural gas, LPG)

b = vehicle type

c = emission control technology (such as uncontrolled, catalytic converter, etc)

## Rail

When estimating GHG and air pollutant emissions from freight transported by rail, the activity data (tonnes-km) should be disaggregated by fuel (e.g., diesel). The development of tonnes-km estimates for rail transport using different fuels can be estimated either by i) disaggregating a total tonnes-km estimate for all rail freight transport into different fuel types based on the percentage of tonnes-km transport by rail using different fuels (a top-down approach) or ii) developing estimates of tonnes-km for different fuels independently (a bottom-up approach).

The total number of tonnes-km that are travelled using electric rail in a company's value chain should also be estimated, and GHG and air pollutant emissions from the electricity generation accounted for. The reader should therefore use the methods outlined in Section 3.1 to estimate the GHG and air pollutant emissions associated with electric rail transport in a value chain, as with other sources of electricity consumption within a company. If data on electricity consumption is available, it can directly used to estimate emissions under section 3.1. In an alternative case, where only data on tonnes-km is available, data on fuel consumed in transporting per unit tonnes-km can be used to estimate electricity consumption and further emission estimation can be completed.

For the number of tonnes-km of freight transported by diesel rail, there are direct emissions of GHG and air pollutants as the freight is transported. Equation 3.3.3 below can be used to estimate the GHG and air pollutant emissions associated with freight transport by rail:

Eq. 3.3.4

$$Emission_{k,f} = tkm_f * FC_f \times EF_{k,f}$$

$tkm_f$ = tonnes-km travelled using rail powered by fuel f (tonnes-km)

$EF_{k,f}$= emission factor for pollutant k for rail using fuel f (g kg fuel consumed-1)

$FC_f$ = Fuel consumption for rail using fuel f (kg fuel tonne- $km^{-1}$)

$Emissions_{k,f}$ = emissions of the specific pollutant k for rail transport using fuel f (g)

The application of Equation 3.3.3 first converts the number of tonnes-km transported using rail into the total fuel consumed to transport this freight using fuel consumed per tonne-km and then multiplies it with emission factors (g pollutant emitted per kg fuel consumed) for rail freight transport to estimate emissions. The energy consumption of different types of locomotives is very different and needs to be accounted for. However, detailed default data for the different types of technologies, fuel and fuel consumption, are sparse. An example of default data is included in Table 3.3.4 which contains default values for energy consumption (MJ tonne-$km^{-1}$) derived from the Railway Handbook (2012, 2015, 2017). Dividing the energy consumption by the energy content of the fuel (e.g., diesel), fuel consumption (kg fuel tonne-$km^{-1}$) can be estimated. These values are not representative of all types of locomotives and all types of fuel and technologies. The user is highly encouraged to include fuel and technology specific values.

**Table 3.3.4:** **Default energy consumption (MJ tonne-$km^{-1}$) (Source: Railway Handbook 2012; 2015; 2017) statistics for diesel rail transport and estimated values for fuel consumption using the energy content for diesel.**

| All types | Energy Consumption (MJ/ tonnes km) | Energy Content (MJ/kg) | Fuel consumption (Kg fuel tonne-$km^{-1}$) |
|---|---|---|---|
| **Diesel** | 0.3 | 42.91 | 0.006 |

EMEP/EEA Tier 1 emission factors are listed in Table 3.3.5 for rail transport using diesel.

**Table 3.3.5:** Tier 1 emission factors for railways [Source: EMEP/EEA, 2023; IPCC, 2006]. Table S3.3.7, S3.3.8, and S3.3.9 should be referred for emission factors for the full list of GHG and air pollutants.

| Pollutant | Gas oil/Diesel |
|---|---|
| CO (kg/ tonne of fuel) | 10.7 |
| NMVOCs (kg/tonne of fuel) | 4.65 |
| $NO_x$ (kg/tonne of fuel) | 52.4 |
| $PM_{10}$ (kg/tonne of fuel) | 1.44 |
| $PM_{2.5}$ (kg/tonne of fuel) | 1.36 |
| BC % of $PM_{2.5}$ | 0.65 |
| $NH_3$ (kg/tonne of fuel) | 0.007 |
| $CO_2$ (kg/tonne of fuel) | 3186.3 |
| $CH_4$ (kg/tonne of fuel) | 0.1785 |
| $N_2O$ (kg/tonne of fuel) | 1.23 |
| Pb (kg/tonne of fuel) | 0.18 |
| Hg (kg/tonne of fuel) | 0.02 |
| Cd (kg/tonne of fuel) | 0.02 |

To proceed to a Tier 2 approach, the number of tonnes- km travelled by different types of locomotives needs to be calculated. Equation 3.3.3 is then applied separately for each locomotive type, using locomotive specific fuel consumption, and emission factors to estimate GHG and air pollutant emissions from freight transport for each type of locomotive. The IPCC (2006) and EMEP/EEA (2023) guidelines provide default emission factors for three types of locomotives (line haul locomotives, shunting locomotives, and railcars) to develop a Tier 2 estimate of rail freight transport GHG and air pollutant emissions. Emission factors for the Tier 2 method are included in the SI.

## Shipping

The emission estimation for $CO_2$ differs significantly from that of air pollutants as well as non-$CO_2$ GHGs, as it is not dependent on the combustion and emission control technology and is solely based on the type of fuel combusted. Therefore, the tier 1 method calculates $CO_2$ emissions from road transport based on the amount of fuel used. Table 3.3.1 provides the emission factors that can be used to estimate these emissions based on the type of fuel being used.

When estimating GHG and air pollutant emissions from freight transported by ships, the activity data (tonnes-km) should be disaggregated by fuel (e.g., diesel, fuel oil, gasoline). The development of tonnes-km estimates for ship transport using different fuels can be estimated either by

> i) disaggregating a total tonnes-km estimate for all marine freight transport into different fuel types based on the percentage of tonnes-km transport by ships using different fuels (a top-down approach) or ii) developing estimates of tonnes-km for different fuels independently (a bottom-up approach).

For the number of tonnes-km of freight transported by ships using different types of fuel, Equation 3.3.4 can be applied to estimate the GHG and air pollutant emissions associated with freight transport by ships:

Eq. 3.3.5

$$Emission_{k.f} = tkm_f * FC_f \times EF_{k,f}$$

where:

$tkm_f$ = tonnes-km travelled using vessels powered by fuel f (tonnes-km)

$EF_{k,f}$ = emission factor for pollutant k for vessel using fuel f (g kg fuel consumed-1)

$FC_f$ = Fuel consumption for vessel using fuel f (kg fuel tonne-km$^{-1}$)

The application of Equation 3.3.4 considers the number of tonnes-km transported using ships into the total fuel consumed to transport this freight, so that they can be combined with emission factors with units g pollutant emitted per kg fuel consumed for rail freight transport. Table 3.3.6 contains default values for energy consumption (MJ tonne-km$^{-1}$) derived from the IEA (2016). Dividing the energy consumption by the energy content of the fuel (diesel), fuel consumption (kg fuel tonne-km$^{-1}$) can be estimated.

**Table 3.3.6:** Default energy consumption (MJ tonne-km$^{-1}$) (Source: IEA 2016; (ADB, 2016) statistics for shipping and estimated values for fuel consumption using the energy content for heavy fuel.

| All Vessels | Energy Consumption (MJ/ tonnes km) | Energy Content (Diesel) (MJ/ kg) | Fuel consumption (kg fuel tonne-km$^{-1}$) |
|---|---|---|---|
| **All types (IEA)** | 0.08 | 40.19 | 0.0019 |
| **Domestic (ADB)** | 0.178 | 40.19 | 0.004 |
| **International (ADB)** | 0.1197 | 40.19 | 0.002 |

The EMEP/EEA Tier 1 emission factors are listed in Table 3.3.7 below.

**Table 3.3.7:** Tier 1 emission factors for shipping [Source: EMEP/EEA 2023]. Table S3.3.19, S3.3.20, and S3.3.21 should be referred for emission factors for the full list of GHG and air pollutants.

| Fuel category | CO (kg/ tonne of fuel) | NMVOCs (kg/ tonne of fuel) | $NO_x$ (kg/ tonne of fuel) | $PM_{10}$ (kg/ tonne of fuel) | BC (kg/ tonne of fuel) | $PM_{2.5}$ (kg/ tonne of fuel) | $SO_2$ (kg/ tonne of fuel) | $CO_2$ (kg/ tonne of fuel) | $CH_4$ (kg/ tonne of fuel) | $N_2O$ (kg/ tonne of fuel) | Pb (kg/ tonne of fuel) | Hg (kg/ tonne of fuel) | Cd (kg/ tonne of fuel) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bunker fuel oil** | 3.67 | 1.67 | 69.1 | 5.2 | 0.09 | - | 19.2 | 3150 | | | 0.1 | 0.01 | 0.01 |
| **Marine Diesel Oil/ Marine Gas oil** | 3.84 | 1.75 | 72.2 | 1.07 | 0.04 | - | 1.82 | 3186 | | | 0.1 | 0.005 | 0.005 |
| **LNG** | 13.8 | 2 | 4.92 | 1.24 E-03 | 2.49 E-05 | 1.06 E-03 | 0 | 2740 | | | | | |
| **Gasoline** | 573.9 | 181.5 | 9.4 | 9.5 | 0.051 | 9.5 | 202 | 3150 | | | | | |
| 1 (fraction of $PM_{2.5}$) | | | | | | | | | | | | | |
| 2 $SO_x$ instead of $SO_2$ | | | | | | | | | | | | | |

The emissions factors above represent an average ship, according to EMEP/EEA (2023). A Tier 2 approach to estimating GHG and air pollutant emissions from marine freight transport accounting for the specific engine types used in the ships that are used to move goods and materials within a company's value chain. Therefore, to proceed to a Tier 2 approach, the number of tonnes-km transported by different types of ships with different types of engines need to be calculated. Equation 3.4.4 is then applied separately for each engine/fuel type combination, using engine- and fuel- specific fuel consumption, and emission factors to estimate GHG and air pollutant emissions from marine freight transport. The IPCC (2006) and EMEP/EEA (2023) guidelines provide default emission factors and fuel consumption for 5 types of engines (Gas Turbine, High-speed diesel, Medium-speed diesel, slow-speed diesel, and steam turbine) to develop a Tier 2 estimate of marine freight transport GHG and air pollutant emissions.

The use of biofuels can have significant impact on emission of GHG and air pollutant emissions, therefore, it is important to estimate emissions using what is referred to as a 'corrected emission factor' when biofuel blends are used. The reduction in emissions is mainly due to the lower sulphur contents, ultimately reducing $SO_x$ and PM. Table 3.3.8 provides the reductions in emissions for different biofuel blends.

**Table 3.3.8:** Emission performance of Biofuels, compared to fuel oil as baseline (ICCT, 2020)

| Fuel Type | $SO_x$ | $NO_x$ | | PM | |
|---|---|---|---|---|---|
| | Decrease | Decrease | Increase | Decrease | Increase |
| **FAME** | 89-100% | 29% | 13% | 38-90% | |
| **HVO** | 100% | 0% - 20% | | 38% | 30% |
| **FT diesel** | 100% | 0% - 20% | | 24% | 18% |
| **Bio-methanol** | 100% | 30% - 82% | | 61% - 100% | |
| **DME** | 100% | | 20% - 26% | 23% - 58% | |

## Emission controls

In shipping, greenhouse gas and air pollutant emissions can be controlled by two mechanisms: control of the combustion technology, combined with exhaust gas treatment, and control of the fuel quality. According to the EMEP/EEA guidelines (2023) emission controls can include the following categories:

- Improved engine design, fuel injection systems, electronic timing, etc. to obtain optimum efficiency (optimising $CO_2$ emissions) reducing PM and VOC emissions

- Exhaust gas recirculation (EGR) where a portion of the exhaust gas is routed back to the engine charge air whereby the physical properties of the charge air are changed. For marine diesel engines, a typical $NO_x$ emission reduction of 10–30 % can be found. This technique has not yet been in regular service for ships

- Selective catalytic reduction (SCR) where a reducing agent is introduced to the exhaust gas across a catalyst. Hereby $NO_x$ is reduced to $N_2$ and H2O. However, this technology imposes severe constraints on the ship design and operation to be efficient. A reduction of 70–95 % in $NO_x$ can be expected applying this technology. The technology is in use in a few ships and is still being developed
- Selective non catalytic reduction (SNCR) where the exhaust gas is treated as for the SCR exhaust gas treatment technique, except the catalyst is omitted. The process employs a reducing agent, supplied to the exhaust gas at a prescribed rate and temperature upstream of a reduction chamber. Installation is simpler than the SCR but needs a very high temperature to be efficient. Reductions of 75–95 % can be expected. However, no installations have been applied yet on ships

- Scrubber (Exhaust Gas Cleaning System) is an emission control system that is used in order to reduce $SO_x$ and PM emissions by adding sea water or fresh water and chemical substances in the exhaust gas.

To account for the effect of the various emission control techniques used in shipping an additional step needs to be considered in order to quantify GHG and air pollutant emissions. Based on the emission reduction percentages which are achieved by the application of the control techniques, and which are presented in Table 3.3.9, the emission factors of ships can be multiplied by the reduction percentage of each emission control technology. The positive values indicate a reduction of pollutants through the emission control system, while the negative values indicate an increase of pollutants through the emission control system, categories marked as N/A are not applicable.

**Table 3.3.9:** **Emission reduction percentage of different emission control technologies. Source: EMEP/EEA (2019).**

| Emission control technology | Fuel | CO (%) | $NO_x$ (%) | $SO_2$ (%) | NMVOC (%) | PM (%) |
|---|---|---|---|---|---|---|
| **Wet scrubber** | Bunker fuel oil | -3.61 | 5.84 | 98.8 | 52.2 | 31.6 |
| | MDO/MGO | N/A | N/A | N/A | N/A | N/A |
| **SCR** | Bunker fuel oil | -63 | 89.6 | 23.5 | 68.6 | 34.8 |
| | MDO/MGO | -55.8 | 70.2 | 6.57 | 78.3 | 6.1 |
| **DOC** | Bunker fuel oil | 42.9 | -0.63 | -1.3 | 50 | 50 |
| | MDO/MGO | 99.2 | 20.4 | 0 | 97.2 | -113 |
| **DPF** | Bunker fuel oil | N/A | N/A | N/A | N/A | N/A |
| | MDO/MGO | 0 | 0 | -1.5 | 0 | 91.7 |
| **SCR+Scrubber** | Bunker fuel oil | -119 | 80.1 | 99.7 | 68.6 | 34.8 |
| | MDO/MGO | N/A | N/A | N/A | N/A | N/A |
| **SCR+DPF** | Bunker fuel oil | N/A | N/A | N/A | N/A | N/A |
| | MDO/MGO | -55.8 | 92 | 4 | 78.3 | 96 |
| **DPC + Scrubber** | Bunker fuel oil | 42.9 | 5.66 | 99.1 | 50 | 50 |
| | MDO/MGO | N/A | N/A | N/A | N/A | N/A |

Eq. 3.3.6

$$RevEF_{k,f,e} = \sum_c (EF_{k,f,e} (1-C_c) x f_c)$$

where:

$RevEF_{k,f}$ = revised fuel consumption-specific emission factor of pollutant k, fuel type f [kg/tonne] and engine type e

$EF_{k,m,e}$ = fuel consumption-specific emission factor of pollutant k, fuel type f [kg/tonne and engine type e

f = fuel type (bunker fuel oil, marine diesel oil, marine gas oil, gasoline)

e = engine type (slow-, medium-, and high-speed diesel, gas turbine, and steam turbine for large ships and diesel, gasoline 2S and gasoline 4S for small vessels).

Cc = correction factor for emission control technologies.

fc = distribution of emission control technology on the considered flee (estimated as fleet with specific emission technology divided by the total number of vessels in the fleet)

## Aviation

When estimating greenhouse gas and air pollutant emissions from freight transported by air, the activity data (tonnes-km) should be disaggregated by fuel (e.g., aviation gasoline, jet type kerosene). The development of tonnes-km estimates for air transport using different fuels can be estimated either by i) disaggregating a total tonnes-km estimate for all air passenger and freight transport into different fuel types based on the percentage of tonnes-km transport by aviation using different fuels (a top-down approach) or ii) developing estimates of tonnes-km for different fuels independently (a bottom-up approach). For the number of tonnes-km of passenger and freight transported by aviation, Equation 3.3.7 below can be used to estimate the associated GHG and air pollutant emissions:

Eq. 3.3.7

$$Emission_{k,f} = tkm_f * FC_f * EF_{k,f}$$

where:

kmf = tonnes-km travelled using air powered by fuel f (passenger-km or tonnes-km for freight transport, respectively)

EFk,f = emission factor for pollutant k for air travel using fuel f (g kg fuel consumed-1)

FCf = Fuel consumption for air travel using fuel f (kg fuel tonne-km$^{-1}$ or kg fuel tonne-km$^{-1}$ for freight transport, respectively)

Emissionsk,f = emissions of the specific pollutant k for air transport using fuel f (g)

The application of Equation 3.3.6 converts the number of tonnes-km transported using aviation into the total fuel consumed to transport this freight, so that they can be combined with emission factors with units g pollutant emitted per kg fuel consumed for aviation freight transport. Table 3.3.10 contains default values for energy consumption (MJ tonne-km$^{-1}$) derived from the IEA (2016) and ADB (2016). Dividing the energy consumption by the energy content of the fuel (diesel), fuel consumption (kg fuel tonne-km$^{-1}$) can be estimated.

**Table 3.3.10: Default energy consumption (MJ tonne-km$^{-1}$) (Source: IEA, 2016 and ADB, 2016) statistics for aviation and estimated values for fuel consumption using the energy content for jet kerosene.**

| Type of flight | Energy Consumption (MJ/ tonnes km) | Energy Content (Jet Kerosene) (MJ/kg) | Fuel consumption (kg fuel tonne-km$^{-1}$) |
|---|---|---|---|
| **All (IEA)** | 12.3 | 44.8 | 0.27 |
| **International (IEA)** | 10.9 | 44.8 | 0.24 |
| **All (ADB)** | 10.26 | 44.8 | 0.22 |

EMEP/EEA Tier 1 emission for aviation are listed in Table 3.3.11 below.

**Table 3.3.11: Tier 1 emission factors for aviation [Source: EMEP/EEA 2023; IPCC 2006]. Table S3.3.13, S3.3.14, and S3.3.14 should be referred for emission factors for the full list of GHG and air pollutants.**

| Fuel category | CO (kg/ tonne of fuel) | NMVOCs (kg/tonne of fuel) | $NO_x$ (kg/ tonne of fuel) | $SO_2$ (kg/ tonne of fuel) | $CO_2$ (kg/ tonne of fuel) | $CH_4$ (kg/ tonne of fuel) | $N_2O$ (kg/ tonne of fuel) | Pb (kg/ tonne of fuel) | Hg (kg/ tonne of fuel) | Cd (kg/ tonne of fuel) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Jet Gasoline and Aviation Gasoline** | 1200 | 19 | 4 | 1 | 3150 | 0.03 | 0.005 | 0.1 | 0.001 | 0.001 |

The emissions factors above represent an average aircraft, according to IPCC (2006) and EMEP/EEA (2023). A Tier 2 approach to estimating GHG and air pollutant emissions from freight transport by aviation using plane-specific emission factors that take into account the specific characteristics of the aviation fleet that is used to move goods and materials within a company's value chain. Therefore, to proceed to a Tier 2 approach, the number of tonnes-km taken by different types of aircraft need to be calculated. Equation 3.3.7 is then applied separately for each aircraft, using aircraft specific fuel consumption, and emission factors to estimate GHG and air pollutant emissions from freight transport for each type of aircraft. The EMEP/EEA (2023) guide provides default fuel consumption statistics for approximately 25 commonly used aircraft, which could be combined with company-specific data on the aircrafts used to move goods within their value chain to develop Tier 2 GHG and air pollutant emission estimates.

In contrast to other modes of transport, the GHG and air pollutant emissions from aviation are disaggregated into different stages of the plane journey, where the amount of fuel used, and the altitude of emissions are significantly different. Following the IPCC (2006) GHG inventory and EMEP/EEA (2023) air pollutant inventory guidance for national GHG and air pollutant emission inventories, estimation of aviation GHG and air pollutant emissions in company values chains should disaggregate between emissions occurring during take-off and landing cycles (LTO), and during climbing, cruising and descent (CCD).

## Passenger transport

The methods for quantifying greenhouse gas and air pollutant emissions from passenger (i.e., customer, employee) travel are outlined below separately for different transport modes (road, and rail), methods for passenger travel related to aviation are not provided in this document and will be developed in later stages of this work.

For both transport modes, the activity variable is the total number of passenger-km (fuel consumed for GHG emission estimation) transport using different transport modes. Hence a prerequisite for quantifying air pollutant emissions within a company's value chain is understanding the total number of customers travelling to retail stores or other company activities, and the average distance that these people travel to reach these destinations. The sub-sections below outline the level of disaggregation that is required to calculate passenger-km (i.e., by vehicle types, fuel types etc.), and how this activity variable can be combined with appropriate emission factors to quantify emissions of different pollutants.

### Road

As described under freight road transport, to quantify GHG and air pollutant emissions from road transport, there are two methods that can be used based on the information that is available to the user. The tier 1 method for air pollutants only requires information on the number of different types of vehicles and fuel consumed by each type of vehicle, and the tier 2 method, which type of vehicle, but also vehicle emission standard. The level of disaggregation for Tier 1 GHG emissions estimation requires data on fuel consumption, whereas Tier 2 method would require data on fuel consumption and vehicle type. It is up to the user to identify which method is best suited to calculate GHG and air pollutant emissions, based on the data that is available to them.

### ▸ *Tier 1*

#### a) Air Pollutants

As described under 'Freight transport' if the only information available is the type of fuel consumed by each type of vehicle, then approach to estimate air pollutant emissions from passenger transport can be simplified and modified to include the following steps:

1 **Step 1: Collect information on the number of different types of vehicles used.**

The user needs to identify the number of different types of vehicles used within their value chain. This should include the number of passenger cars (PC), and the number of vehicles described under the L-category (i.e., mopeds, motorcycles, mini-cars and all-terrain vehicles).

2 **Step 2: Disaggregate each type of vehicle by type of fuel used.**

Disaggregate each type of vehicle by type of fuel used. The user then needs to disaggregate each vehicle type by the different types of fuel used by each vehicle type. For passenger cars, the fuels that can be considered are petrol, diesel and LPG, and for the L-category it's petrol.

3 **Step 3: Multiply the amount fuel consumed (kg) for different types of vehicles by pollutant-specific emission factors.**

Steps 1-2 derive the activity data (kg of fuel consumed by type of vehicle) that will allow GHG and air pollutant emissions to be estimated for passenger transport within a company's value chain. These data are then required to be combined with emission factors that quantify the air pollutant emissions from this freight transport activity. The available emission factors, from IPCC (2006) and EMEP/EEA (2019) for all relevant air pollutants, have units of gram pollutant emitted per vehicle-km travelled.

Equation 3.3.8 shows how air pollutant emissions are estimated for freight transport for a particular vehicle type and fuel:

Eq. 3.3.8

$$Em_{k,v,f} = FC_{v,f} * EF_{k,v,f}$$

where:

$FC_{v,f}$ = fuel consumption of vehicle type v using fuel f (kg)

$EF_{k,v,f}$ = emission factor for pollutant k for vehicle type v, and fuel f (g vehicle-km$^{-1}$)

$Em_{k,v,f}$ = emissions of the specific pollutant k for vehicle type v, and fuel f (g)

### Tire, Brake, and Road Wear

The source for PM emissions is consistent in both freight and  passenger transport and should also be applied to passenger transport to estimate wear emissions. Tailpipe emissions occurring from combustion of fuel are a major source of air pollution from the transportation sector. However, non-exhaust emission in the form of tire, road, and brake wear emissions also contribute a significant amount of particulate matter ($PM_{10}$ and $PM_{2.5}$) air pollution. These particles released due to tire and brake wear can also have significant BC emissions. Airborne particles are produced because of the shear force generated due to interaction between a vehicle's tyres and the road surface, and also when the brakes are applied to decelerate the vehicle. Evaporation of material from surfaces at the high temperatures developed during contact can also lead to these forms of emissions. Various factors such as vehicle speed, driving behaviour and conditions, weather conditions, and road conditions can have impacts on the rate of release of these emissions.

Legislation that aims to control these emissions are not in force yet, however low friction tires to improve fuel economy and reduce $CO_2$ emissions, which are promoted currently can lower these emissions also.

These emissions can be calculated using eq. 4.7. Tier 1 default emission factors for tire, brake, and road wear are provided in the table 3.3.12.

**Table 3.3.12:** Tier 1 emission factor for tire, brake, and road wear (gkm-1vehicle-1) (EMEP/EEA 2023)

| Vehicle category | Pollutant | Tire and Brake wear combined | Road Wear |
|---|---|---|---|
| **Two-wheelers** | $PM_{10}$ | 0.0064 | 0.003 |
| | $PM_{2.5}$ | 0.0034 | 0.0016 |
| | BC (% of $PM_{2.5}$) | 0.12 | 0.12 |
| **Passenger cars** | $PM_{10}$ | 0.0184 | 0.0075 |
| | $PM_{2.5}$ | 0.0093 | 0.0041 |
| | BC (% of $PM_{2.5}$) | 0.10 | 0.10 |
| **Light duty trucks** | $PM_{10}$ | 0.0271 | 0.0075 |
| | $PM_{2.5}$ | 0.0139 | 0.0041 |
| | BC (% of $PM_{2.5}$) | 0.10 | 0.10 |
| **Heavy duty trucks** | $PM_{10}$ | 0.059 | 0.038 |
| | $PM_{2.5}$ | 0.0316 | 0.0205 |
| | BC (% of $PM_{2.5}$) | 0.10 | 0.10 |

a) GHG Emissions

b) $CO_2$ emissions

The emission estimation for $CO_2$ differs significantly from that of air pollutants as well as non-$CO_2$ ($CH_4$ and $N_2O$) GHGs, as it is not dependent on the combustion and emission control technology and is solely based on the type of fuel combusted. Therefore, the simplified method calculates $CO_2$ emissions from road transport based on the amount of fuel used. Table 3.3.1 provides the emission factors that can be used to estimate these emissions based on the type of fuel being used.

c) $N_2O$ and $CH_4$ emissions

$CH_4$ and $N_2O$ emission rates from vehicles can vary significantly based on the combustion and emission control technology available, therefore using default fuel-based emission factors that do not specify vehicle technology can be highly uncertain. Table 3.3.2 provides tier 1 emissions factors for road transportation vehicles with their combustion and emission technology accounted.

Emissions of $CH_4$ and $N_2O$ are more difficult to estimate accurately than those for $CO_2$ because emission factors depend on vehicle technology, fuel and operating characteristics. Both distance-based activity data (e.g. vehicle kilometres travelled) and disaggregated fuel consumption may be considerably less certain than overall fuel combustion. $CH_4$ and $N_2O$ emissions are significantly affected by the distribution of emission controls in the fleet. Thus, higher tiers use an approach considering different vehicle types and their different pollution control technologies.

## *Tier 2*

This option should be selected if there is information available on the different types of vehicles used, the different types of fuels consumed by each vehicle type and emission standards. When estimating GHG and air pollutant emissions from the road transport sector, the activity data (passenger- km) should be disaggregated by vehicle type, fuel used, and vehicle emission standard (e.g., Euro standard). The following steps should be taken to derive passenger-km estimates disaggregated at this level, and then combined requires information on the vehicle type, fuel used by each with emission factors to estimate GHG and air pollutant emissions.

a) GHG Emissions

1 **Step 1: Estimate passenger-km for different vehicle types.**

The development of passenger-km estimates for different vehicle types can be estimated either by i) disaggregating a total passenger-km estimate for all vehicle types into different vehicle categories based on the percentage of passenger-km transport by different types of vehicles or ii) developing estimates of passenger-km for different vehicle types independently.

The categorization of vehicles differs across jurisdictions, reflecting variations in regulatory frameworks, vehicle fleets, and data collection practices. For example, some countries may classify vehicles simply as light-duty or heavy-duty, while others may have more detailed categories such as passenger cars, light commercial vehicles, heavy-duty trucks, and buses, each with further subdivisions based on fuel type or engine technology. These differences can affect emission estimation methods and comparability of data across regions. As the Guide 2.0 considers emission factors from the EMEP/EEA (2023) guidelines for air pollutants, the Guide adopts the disaggregation of vehicles according to the EME/EEA categorization and these categories are aligned to vehicle categories available in IPCC (2006; 2019) guidance used for greenhouse gas emissions. For customer travel, the three vehicle types in the EMEP/EEA guidebook are 'passenger cars', which can include private vehicles and taxis, 'buses' and 'motorcycles'. The development of passenger-km estimates for different vehicle types using either approach described above requires company- specific data on the number of people travelling to retail stores, or other company destinations, and the distance that those customers travel to. These are highly specific to the value chain of the individual company being studied. For this reason, no default data is available and company- specific data is required on the number of passenger-km travelled by different vehicles.

2 **Step 2: Disaggregate passenger-km for different vehicles by fuel.**

Similarly for estimating emissions of GHGs, it is also necessary to disaggregate passenger-km taken by different vehicles by the fuel used in these vehicles when estimating GHG and air pollutant emissions. This is done by multiplying the total number of passenger-km taken using heavy duty vehicles or light duty vehicles by the fraction of those passenger- km taken in these vehicle types which use different fuels. The types of fuels where GHG and air pollutant emissions can be estimated include gasoline, diesel, liquified petroleum gas (LPG), and compressed natural gas (CNG), which result in exhaust emissions when used in transport.

The total number of passenger-km that are taken using electric vehicles in a company's value chain should also be estimated, by multiplying the total passenger-km taken by each vehicle type by the fraction of those journeys taken in electric vehicles. No exhaust emissions result from electric vehicles, and therefore the GHG and air pollutant emissions from electric vehicles are only those resulting from the generation of electricity. The reader should therefore use the methods outlined in Section 3.2 to estimate the GHG and air pollutant emissions associated with electric vehicle use in a value chain, as with other sources of electricity consumption within a company.

3 **Step 3: Disaggregate passenger-km by technology/vehicle emission standards.**

For fossil fuel powered cars, different countries and regions have progressively introduced more stringent vehicle emission standards to reduce the emissions of key GHG and air pollutants in their vehicle fleets. For example, since the early 1990s in Europe, the 'Euro' standards, now in their early 1990s in Europe, the 'Euro' standards, now in their 6th iteration, have provided emission limits for new vehicles introduced to the vehicle fleet in Europe, for both passenger and freight vehicles. The Euro standards reflect the use of different technologies to control vehicle GHG and air pollutant emissions. Other regions have adopted Euro standards, or similar in their national vehicle emission standards. In other cases, e.g., in the United States, a different set of vehicle emission standards have been introduced, with GHG and air pollutant emission limits ranging from Tier 1 (least stringent) to Tier 4 (most stringent). To robustly estimate emissions from the freight transport within a company's value chain, it is therefore necessary to disaggregate the passenger-km for heavy duty vehicles, and light duty vehicles, for different fuel types, by vehicle emission standard. The most commonly used emission standard globally is the Euro standard, and therefore they are reflected in this methodology. However, other emission standards can be used. Similarly for Step 2 above, to estimate the number of passenger-km taken by vehicles meeting different Euro standards (disaggregated by fuel), the number of passenger-km taken by, e.g. heavy duty vehicles using diesel, which are calculated by applying Steps 1 and 2 above, should be multiplied by the fraction of passenger-km transport in vehicles that are either Uncontrolled, or meet Euro 1, Euro 2, Euro 3, Euro 4, EURO 5, or Euro 6 standards.

4 **Step 4: Multiply passenger-km for different vehicles, fuels and emission standards by pollutant-specific GHG and air pollutant emission factors.**

Steps 1-3 derive the activity data (passenger-km) in a sufficient level of detail to allow GHG and air pollutant emissions to be estimated for freight transport within a company's value chain. These data are then required to be combined with emission factors that quantify the air pollutant emissions from this freight transport activity. The available emission factors, from IPCC (2006) and EMEP/EEA (2019) for all relevant GHG and air pollutants, have units of gram pollutant emitted per vehicle-km travelled. Therefore, to apply in company value chain, it is necessary that a conversion is made so that they can be combined with passenger-km data.

Equation 3.3.9 shows how GHG and air pollutant emissions are estimated for freight transport for a particular vehicle type, fuel, and emission standard:

Eq. 3.3.9

$$Emissions_{k,v,f,s} = (pkm_{v,f,s} / Occupancy) * EF_{k,v,f,s}$$

where:

$pkm_{v,f,s}$ = passenger-km travelled using vehicle type v, fuel f, and emission standard s (passenger-km)

$EF_{k,v,f,s}$ = emission factor for pollutant k for vehicle type v, fuel f, and emission standard s (g vehicle-km$^{-1}$)

Occupancy = occupancy of the vehicle (passengers / vehicle m)

$Emissions_{k,v,f,s}$ = emissions of the specific pollutant k for vehicle type v, fuel f, and emission standard s (g)

Equation 3.3.9 takes passenger-km estimates for different vehicle types, fuels and emission standards and divides it by i) an occupancy rate, multiplies it and ii) emission factors for different pollutants with units g vehicle-km$^{-1}$. The occupancy rate is the conversation factor that allows the emission factors to be combined with passenger-km estimates for a company's value chain. The occupancy rate is the average number of people that are within one vehicle transport at one time. Dividing the passenger-km by the occupancy rate converts the passenger-km to vehiclekm estimates, consistent with the default emission factors available in international GHG and air pollutant emission inventory guidebook such as EMEP/EEA (2019). In the absence of company specific data, then the default average occupancy rates included in Table 3.3.13 below could be used with company-specific passenger-km data. As these values are default averages and occupancy rates can differ substantially between different countries and regions, the user is highly encouraged to use region and/or country specific values where available and appropriate.

**Table 3.3.13:** Default average occupancy rates (people per vehicle) for different types of vehicles (Source: The International Council on Clean Transport Roadmap, 2017)

| Vehicle type | Occupancy (passengers/vehicle) |
|---|---|
| **Passenger car** | 1.7 |
| **Motorcycle** | 1 |
| **Bus** | 20 |
| **Truck** | 1 |

The EMEP/EEA (2019) default emission factors for each pollutant, fuel and Euro standard are reproduced in SI and can be applied using Equation 3.4.8 above, along with occupancy data and passenger-km to estimate the GHG and air pollutant emissions from a company's customer travel.

### a) GHG Emissions

Greenhouse gas emissions using a Tier 2 approach are estimated using fuel consumed by vehicles disaggregated by fuel, vehicle, and emission control technology specific categories. The emissions should be estimated using equation 3.3.10.

Eq. 3.3.10

$$E = \sum_{a,b,c} FC_{a,b,c} \times EF_{a,b,c}$$

Where:

Emission = emission in kg.

$EF_{a,b,c}$ = emission factor (kg/TJ)

$Fuel_{a,b,c}$ = fuel consumed (TJ) (as represented by fuel sold) for a given mobile source activity

a = fuel type (e.g., diesel, gasoline, natural gas, LPG)

b = vehicle type

c = emission control technology (such as uncontrolled, catalytic converter, etc)

## Rail

When estimating GHG and air pollutant emissions from passenger or customer travel by rail, the activity data (passenger-km) should be disaggregated by fuel (e.g., diesel, electricity). The development of passenger-km estimates for rail transport using different fuels can be estimated either by i) disaggregating a total passenger-km estimate for all rail freight transport into different fuel types based on the percentage of passenger-km transport by rail using different fuels (a top-down approach) or ii) developing estimates of passenger-km for different fuels independently (a bottomup approach).

The total number of passenger-km that are taken using electric rail should also be estimated, and GHG and air pollutant emissions from the electricity generation accounted for. The user should therefore use the methods outlined in Section 3.1 to estimate the GHG and air pollutant emissions associated with electric rail transport in a value chain, as with other sources of electricity consumption within a company. For the number of passenger-km taken by diesel rail, there are direct emissions of GHG and air pollutants as the freight is transported. Equation 3.3.11 below can be used to estimate the GHG and air pollutant emissions associated with freight transport by rail:

Eq. 3.3.11

$$Emissions_{k,f} = tkm_f * FC_f * EF_{k,f}$$

where:

tkmf = passenger-km travelled using rail powered by fuel f (passenger-km)

$EF_{k,f}$ = emission factor for pollutant k for rail using fuel f (g kg fuel consumed-1)

$FC_f$ = Fuel consumption for rail using fuel f (kg fuel tonne-km$^{-1}$)

$Emissions_{k,f}$ = emissions of the specific pollutant k for rail transport using fuel f (g)

The application of Equation 3.3.11 first converts the number of passenger-km taken using rail into the total fuel consumed for transport, so that they can be combined with emission factors with units g pollutant emitted per kg fuel consumed for rail transport. The energy consumption of different types of fuel is very different and needs to be accounted for. However, detailed default data for the different types of technologies, fuel and fuel consumption are sparse. An example of default data is included in Table 3.3.14 which contains default values for energy consumption (MJ tonne-km$^{-1}$) derived from the Railway Handbook (2012, 2015, 2017). Dividing the energy consumption by the energy content of the fuel (e.g., diesel), fuel consumption (kg fuel tonne-km$^{-1}$) can be estimated. These values are not representative of all types of locomotives and all types of fuel and technologies. The user is highly encouraged to include fuel and technology specific values.

**Table 3.3.14:** Example of default energy consumption (MJ passenger-km$^{-1}$) (Source: Railway Handbook 2012; 2015; 2017) statistics for diesel rail transport and estimated values for fuel consumption using the energy content for diesel.

| Locomotive (all types) | Energy Consumption (MJ/ passenger km) | Energy Content (Diesel) (MJ/kg) | Fuel consumption |
|---|---|---|---|
| **Diesel** | 1.15 | 42.91 | 0.02 |

EMEP/EEA Tier 1 emission factors for rail transport using diesel are listed in Table 3.3.15.

**Table 3.3.15:** Tier 1 emission factors for railways [Source: EMEP/EEA, 2023]. Table S3.3.31, S3.3.32, and S3.3.33 should be referred for emission factors for the full list of GHG and air pollutants.

| Pollutant | Gas oil/Diesel |
|---|---|
| **CO (kg/ tonne of fuel)** | 10.7 |
| **NMVOCs (kg/tonne of fuel)** | 4.65 |
| **$NO_x$ (kg/tonne of fuel)** | 52.4 |
| **$PM_{10}$ (kg/tonne of fuel)** | 1.44 |
| **$PM_{2.5}$ (kg/tonne of fuel)** | 1.36 |
| **BC % of $PM_{2.5}$** | 0.65 |
| **$NH_3$ (kg/tonne of fuel)** | 0.007 |
| **$CO_2$ (kg/tonne of fuel)** | 3186.3 |
| **$CH_4$ (kg/tonne of fuel)** | 0.1785 |
| **$N_2O$ (kg/tonne of fuel)** | 1.23 |
| **Pb (kg/tonne of fuel)** | 0.18 |
| **Hg (kg/tonne of fuel)** | .02 |
| **Cd (kg/tonne of fuel)** | .02 |

To proceed to a Tier 2 approach, the number of passenger- km taken by different types of locomotives needs to be calculated. Equation 3.3.11 is then applied separately for each locomotive type, using locomotive specific fuel consumption, and emission factors to estimate GHG and air pollutant emissions from freight transport for each type of locomotive. The IPCC (2006) and EMEP/EEA (2023) guidelines provide default emission factors for three types of locomotives (line haul locomotives, shunting locomotives, and railcars) to develop a Tier 2 estimate of rail freight transport air pollutant emissions.

NB: The following part will be applicable to both Freight and Passenger Transportation

## Non-road mobile machinery

The IPCC (2006; 2019) and EMEP/EEA (2023) guidelines provide methods to estimate greenhouse gas and air pollutant emissions occurring from combustion and evaporative emissions for selected non-road mobile machinery sources.

As per IPCC (2006) guidelines, the off-road category (1.A.3.e.ii) includes vehicles and mobile machinery used within the agriculture, forestry, industry (including construction and maintenance), residential, and sectors, such as airport ground support equipment, agricultural tractors, chain saws, forklifts, snowmobiles.

The types of equipment covered by the EME/EEAP (2023) guidelines include the following NFR categories:

- 1.A.2.g vii: Mobile combustion in manufacturing industries and construction
- 1.A.4.a.ii: Commercial and institutional mobile machinery
- 1.A.4.b ii: Mobile combustion used in residential areas; household and gardening mobile machinery
- 1.A.4.c ii: Off-road vehicles and other machinery used in agriculture and forestry

The engines used in these categories of other mobile sources include diesel engines, four-stroke and two-stroke petrol engines or LPG engines.
The activity variable for this emission source is the total amount of fuel consumed, but it needs to be disaggregated by the different types of mobile machinery, the different types of fuel consumed and the different types of engines (if possible).
The methods for quantifying greenhouse gas and air pollutant emissions from non-road mobile machinery are outlined below.

### 1 Step 1: Estimate the total number of non-road mobile machinery used.

The user first needs to identify and estimate the total number of non-road mobile machinery used throughout the company's value chain. As these methods need company specific data, no default data can be used to estimate the total number of non-road vehicles. The user is encouraged to consider the different stages of the value chain that are presented in Chapter 2 and map the different types of non-road mobile machinery related to every stage of the value chain. For example, under the stage 'Raw materials/ Extraction/Cultivation' the types of non-road mobile machinery used will be mostly related to agriculture and commercial or construction types of machinery.

### 2 Step 2: Disaggregate the total number of non-road mobile machinery by type.

Once the total amount of non-road mobile machinery has been estimated for every stage of the value chain, the user needs to disaggregate this amount by the different types of machinery according to the EMEP/EEA guidelines, namely:

- 1.A.2.g vii: Mobile combustion in manufacturing industries and construction
- 1.A.4.a.ii: Commercial and institutional mobile machinery
- 1.A.4.b ii: Mobile combustion used in residential areas; household and gardening mobile machinery
- 1.A.4.c ii: Off-road vehicles and other machinery used in agriculture and forestry

## 3 Step 3: Disaggregate by type of fuel, and engine.

Once the user has identified the total number of non-road machinery used for the different NFR categories, they will need to disaggregate by type of fuel and type of engine. The types of fuel and engines considered in the IPCC and EMEP/EEA guidelines for the different NFR categories are Diesel, LPG, Gasoline (two-stroke), Gasoline (four-stroke) and Gasoline.

## 4 Step 4: Estimate the total amount of fuel used, by NFR category, and by engine type

Once the user has estimated the total amount of non-road mobile machinery is used under the different NFR categories and these have been disaggregated by type of fuel and type of engine, the total amount of fuel needs to be estimated.

## 5 Step 5: Estimate emissions from non-road mobile machinery

### Tier 1

Finally, the total amount of fuel consumed by the non-road mobile machinery by NFR category, type of fuel and type of engine, will be multiplied by an NFR category-, fuel-, engine, and pollutant specific emission factor according to the Equation 3.3.12:

Eq. 3.3.12

$$Emissions_{k,v,f,s} = FC_{c,f,}e * EF_{k,v,f,s}$$

$FC_{v,f,s}$= Fuel consumed per NFR category c, fuel type f, and engine type e (tonnes of fuel)

$EF_{k,v,\ f,s}$ = emission factor for pollutant k for NFR category c, fuel type f, and engine type e (µg/kg of fuel)

$Emissions_{k,v,\ f,s}$ = emissions of the specific pollutant k for NFR category c, fuel type f, and engine type e (kg)

The estimation of GHG emissions by tier 1 method only requires data in fuel categories and does not depend on engine type (IPCC, 2006). The Tier 1 emission factors for non-road mobile machinery are included in the Table S3.3.37.

### ▸ *Tier 2*

To advance to a Tier 2 methodology, the user also needs to identify the age of the off-road equipment technology and further disaggregate the fuel consumed by the different off- road mobile machinery into the different years and stages. The EMEP/EEA (2023) guidelines are separating the different types of machinery for the following years and stages < 1981, 1981–1990, 1991–Stage I, Stage I, Stage II, Stage IIIA, Stage IIIB, Stage IV, Stage V where Stages IIIB, IV and V are the diesel engine emission technology stages which enter into the fleet between 2011-2013, 2014-2015 and 2019-2020. The IPCC guidelines suggest using a tier 2 method where the information required is disaggregated in fuel and equipment type (IPCC, 2006).

Eq. 3.3.13

$$Ek = \sum_{f} \sum_{y} FC_{j,c,e,y} * EF_{k,e,y}$$

where:

FCv,f,s = Fuel consumed per NFR category c, fuel type f, engine type e, and equipment technology y (tonnes of fuel)

EFk,v, f,s = emission factor for pollutant k for NFR category c, fuel type f, engine type e, and equipment technology y (μg/kg of fuel)

Ek = emissions of the specific pollutant k (kg) The Tier 2 emission factors for non-road mobile machinery are included in the Table S3.3.38.

## 3.3.3 Example

### Case 1(b): When a common vehicle is being used to transport material for more than one business and load factors are available.

**Heavy-duty vehicles (HDVs):**

Material transported = 5000 tonnes
Distance travelled = 200 km

Total tonnes-km: 1,000,000

Diesel: 80%
CNG: 20%
Emission standards: Euro IV (30%), Euro V (50%), Euro VI (20%)

### Light commercial vehicles (LCVs):

Material transported = 1000 tonnes
Distance travelled = 500 km

Total tonnes-km: 500.000
Diesel: 70%
Gasoline: 30%

Emission standards: Euro IV (40%), Euro V (40%), Euro VI (20%)

Step-by-Step Estimation

1

**Step 1: Estimate tonnes-km for different vehicle types.**

HDVs: 1,000,000 tonnes-km
LCVs: 500,000 tonnes-km

2

**Step 2: Disaggregate tonnes-km for different vehicles by fuel.**

### For HDVs:

Diesel: 1,000,000 tonnes-km * 80% = 800,000 tonnes-km
CNG: 1.000.000 tonnes-km * 20% = 200.000 tonnes-km

### For LCVs:

Diesel: 500.000 tonnes-km * 70% = 350,000 tonnes-km
Gasoline: 500.000 tonnes-km * 30% = 150.000 tonnes-km

3

**Step 3: Disaggregate tonnes-km by technology/vehicle emission standards.**

### For HDVs using Diesel:

Euro IV: 800.000 tonnes-km * 30% = 240.000 tonnes-km
Euro V: 800,000 tonnes-km * 50% = 400,000 tonnes-km
Euro VI: 800,000 tonnes-km * 20% = 160,000 tonnes-km

### For HDVs using CNG:

Euro IV: 200.000 tonnes-km * 30% = 60,000 tonnes-km
Euro V: 200,000 tonnes-km * 50% = 100,000 tonnes-km
Euro VI: 200.000 tonnes-km * 20% = 40.000 tonnes-km

### For LCVs using Diesel:

Euro IV: 350.000 tonnes-km * 40% = 140.000 tonnes-km
Euro V: 350,000 tonnes-km * 40% = 140,000 tonnes-km
Euro VI: 350,000 tonnes-km * 20% = 70,000 tonnes-km

### For LCVs using Gasoline:

Euro IV: 150.000 tonnes-km * 40% = 60,000 tonnes-km
Euro V: 150.000 tonnes-km * 40% = 60.000 tonnes-km
Euro VI: 150.000 tonnes-km * 20% = 30.000 tonnes-km

## 4 Step 4: Multiply tonnes-km for different vehicles, fuels and emission standards by pollutant-specific emission factors.

Using the EMEP/EEA (2019) default emission factors for PM2.5 (g/vehicle-km) and converting to tonnes-km using the load factors provided in Table 4.7, we can calculate emissions.

### Load Factors:

For HDVs: Assuming average load factor = 10 tonnes/vehicle
For LCVs: Assuming average load factor = 0.2 tonnes/vehicle

vehicle-km = tonnes-km/load factor

*Assuming the following emission factors for PM2.5 (g/vehicle-km):*

HDVs (Diesel): Euro IV = 0.3, Euro V = 0.2, Euro VI = 0.1
HDVs (CNG): Euro IV = 0.1, Euro V = 0.08, Euro VI = 0.05
LCVs (Diesel): Euro IV = 0.1, Euro V = 0.07, Euro VI = 0.05
LCVs (Gasoline): Euro IV = 0.08, Euro V = 0.06, Euro VI = 0.04

### For HDVs (Diesel):

Euro IV:
Emissions = (240,000 tonnes-km/10 tonnes/vehicle) × 0.3 g/vehicle-km = 7,200 g

Euro V:
Emissions = (400,000 tonnes-km/ 10 tonnes/vehicle) × 0.2 g/vehicle-km = 8,000 g

Euro VI:
Emissions = (160,000 tonnes-km/ 10 tonnes/vehicle) × 0.1 g/vehicle-km = 1,600 g

### For HDVs (CNG):

Euro IV:
Emissions = (60,000 tonnes-km/10 tonnes/vehicle) × 0.1 g/vehicle-km = 600 g

Euro V:
Emissions = (100,000 tonnes-km/10 tonnes/vehicle) × 0.08 g/vehicle-km = 800 g

Euro VI:
Emissions = (40,000 tonnes-km/10 tonnes/vehicle) × 0.05 g/vehicle-km = 200 g

### For LCVs (Diesel):

Euro VI:
Emissions = (140,000 tonnes-km/.2 tonnes/vehicle) × 0.1 g/vehicle-km = 70000 g

Euro V:
Emissions = (140,000 tonnes-km/.2 tonnes/vehicle) × 0.07 g/vehicle-km = 49000 g

Euro VI:
Emissions = (70,000 tonnes-km/.2 tonnes/vehicle) × 0.05 g/vehicle-km = 17500 g

### For LCVs (Gasoline):

Euro IV:
Emissions = (60,000 tonnes-km/.2 tonnes/vehicle) × 0.08 g/vehicle-km = 24000 g

Euro V:
Emissions = (60,000 tonnes-km/.2 tonnes/vehicle) × 0.06 g/vehicle-km = 18000 g

Euro VI:
Emissions = (30,000 tonnes-km/.2 tonnes/vehicle) × 0.04 g/vehicle-km = 6000 g

## 3.3.4 Reference

EMEP/EEA. (2019). EMEP/EEA air pollutant emission inventory guidebook 2019: Technical guidance to prepare national emission inventories (EEA Report No. 13/2019). European Environment Agency. https://www.eea.europa.eu/publications/emep-eea-guidebook-2019

European Environment Agency. (2023). EMEP/EEA air pollutant emission inventory guidebook 2023. https://www.eea.europa.eu/en/analysis/publications/emep-eea-guidebook-2023

Intergovernmental Panel on Climate Change. (2006). 2006 IPCC guidelines for national greenhouse gas inventories. IGES. https://www.ipcc-nggip.iges.or.jp/public/2006gl/

Intergovernmental Panel on Climate Change. (2019). 2019 refinement to the 2006 IPCC guidelines for national greenhouse gas inventories. https://www.ipcc-nggip.iges.or.jp/public/2019rf/

International Energy Agency, Energy and Air Pollution, World Energy Outlook Special Report, 2016, Energy and Air Pollution - World Energy Outlook 2016 Special Report (windows.net)

International Energy Agency & International Union of Railways. (2012). Railway handbook 2012: Energy consumption and $CO_2$ emissions. https://www.uic.org/com/IMG/pdf/iea-uic_2012final-lr.pdf

International Energy Agency & International Union of Railways. (2017). Railway handbook 2017: Energy consumption and $CO_2$ emissions. https://uic.org/IMG/pdf/handbook_iea-uic_2017_web3.pdf

Asian Development Bank. (2016). Transport databank model: User guide. https://transportdata.net/upload_file/docs/User_Guide.pdf

International Council on Clean Transportation (ICCT). (2020). Biofuels for shipping: Fuel quality and emissions. https://theicct.org/publications/biofuels-shipping-fuel-quality-emissions

# 3.4 Estimating Greenhouse Gas and Air Pollutant Emissions from Industrial Processes

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**URL:** https://www.ccacoalition.org/resources/integrated-guide-business-greenhouse-gas-and-air-pollutant-emission-assessment

This section of the Guide 2.0 explains how the emissions of greenhouse gas (GHGs), Short-Lived Climate Pollutants (SLCPs), classical air pollutants and heavy metals (HM) (hereafter referred to as greenhouse gas and air pollutants as defined in Chapter 1) that are related to industrial processes (covering manufacturing and construction activities but excluding fuel combustion) at different parts of a company's value chain can be quantified.

This section is structured by first describing the source, then describing the methods, which includes Tier 1 emission factors. The Tier 2 methods are explained in this document, but the Tier 2 (as well as the Tier 1) emission factors are linked to a database where these default values can be found (https://www.ccacoalition.org/resources/integrated-guide-business-greenhouse-gas-and-air-pollutant-emission-assessment). The section then includes an example calculation using the methods and then provides the references for the methods and data.

## 3.4.1 Description of the source

Emissions from industrial processes cover greenhouse gas and air pollutant emissions that are emitted during specific manufacturing or construction activities, but which do not result from the combustion of fuels during these industrial processes. The combustion of fuel during industrial processes accounts for using the methods outlined in Section 3.2 for the category 'Stationary Fuel Combustion'. Industrial processes which emit non-fuel combustion-related GHG, and air pollutant emissions include:

- Mineral industries such as cement production, lime production, glass production
- Chemical industries including soda ash, ammonia, nitric acid, adipic acid, and carbide production
- Metal production, including iron and steel, magnesium, ferroalloys, aluminium, magnesium, lead, zinc, copper and nickel production
- Chemical Products
- Pulp and paper production
- Food and Beverage Production
- Other solvent and product used
- Construction and demolition

The source of greenhouse gas and air pollutant emissions for each of these sub- sectors differs, and the magnitude of emissions also depends on whether specific abatement technologies are in place for that particular industrial process. For example, in the mineral industry, cement production and other mineral industries emit particulate matter ($PM_{10}$ and $PM_{2.5}$), predominantly mineral dust, during the grinding and crushing processes necessary to produce clinker and cement. In food processing, emissions of non-methane volatile organic compounds, and other pollutants may occur from the cooking of meat and fish, converting raw sugar into refined sugar, baking bread, cakes and other goods. The pollutants emitted from Industrial processes and product use are Carbon Dioxide ($CO_2$), Methane ($CH_4$), Nitrous Oxide ($N_2O$), Particulate Matter ($PM_{10}$, $PM_{2.5}$), Sulphur Dioxide ($SO_2$), Nitrogen Oxide ($NO_x$), Carbon Monoxide (CO), Non-methane volatile organic compounds (NMVOCs), Ammonia ( $NH_3$), Black Carbon (BC), Organic Carbon (OC), Lead (Pb), Mercury (Hg), Cadmium (Cd), Arsenic (As), Chromium (Cr), Copper (Cu), Nickel (Ni), Selenium (Se), Zinc (Zn).

It should be noted that, as stated in Chapter 1, this Guide focuses on the source of GHG and air pollutant emissions wherever they occur within a company's value chain. Therefore, emissions from Industrial Processes can be relevant even to companies that do not manufacture or produce these materials themselves but instead buy and use the materials as in the different parts of their value chains.

For the majority of these Industrial Process emission sub-sectors, a consistent methodology can be used to quantify emissions of greenhouse gas and air pollutants from each process. However, some variation can be found in both Tier 1 and Tier 2. While Tier 1 emissions for air pollutants can be estimated using material consumption or production specific emission factors, greenhouse gas emission estimation can also take into account the process used during production. The following sections describe the Tier 1 and Tier 2 methods that can be applied across Industrial Processes sub-sectors to quantify greenhouse gas and air pollutant emissions. Default emission factors specific to each industrial process, are also provided. Finally, where the methods for quantifying emissions from an industrial process differ, then this is specifically highlighted, and the alternative methodology outlined.

## 3.4.2 Methodologies for Quantifying Emissions

The methods to estimate greenhouse gas and air pollutant emissions from industrial processes, excluding combustion-related emissions (accounted for under "stationary fuel combustion"), are presented here. The methods cover emissions for pollutants such as $SO_2$, $NO_x$, CO, NMVOCs, $PM_{10}$, $PM_{2.5}$, Pb, Hg, Cd, As, Cr, Cu, Ni, Se, Zn, BC, $CO_2$, $CH_4$, and $N_2O$. Emission factor for $NH_3$ and OC are not available in the EMEP/EEA guidelines, their estimation of these emissions cannot be done following the methods provided below. The simplified Tier 1 methodology calculates emissions by multiplying default emission factors with the quantity of material used in a company's value chain. A more detailed Tier 2 approach can be used if information about the technologies involved in the process is available, allowing for more accurate estimation by incorporating technology-specific emission factors.

### ▸ Tier 1: Methodology for Industrial Processes

The Tier 1 method for quantifying greenhouse gas and air pollutant emissions from industrial processes along a company's value chain is based on the IPCC (2006; 2019) and EMEP/EEA (2023) guidelines. The Tier 1 method multiplies the annual production (or consumption/use) of a particular material in an Industrial Process by pollutant- and process-specific emission factors for that product and process. In applying this method to quantify greenhouse gas and air pollutant emissions within a company's value chain, the activity data (production) is substituted with the amount of product used in a company's value chain. The Tier 1 method is shown in Equation 3.4.1:

Eq. 3.4.1

$$Emissions_{k,p} = M_p * EF_{k,p}$$

where:

Mp = Quantity of material M used in (or produced by) a company's value chain produced using process p (tonnes, litres)

$EF_{k,p}$ = emission factor for pollutant k for process p (g unit production-1)

$Emissions_{k,p}$ = emissions of the specific pollutant k for process p (g)

In applying the Tier 1 approach for quantifying greenhouse gas and air pollutant emissions from Industrial Processes, it is necessary to obtain company-specific data on the number of materials that are used within their value chain, e.g. within the manufacture of particular products. Default emission factors for all greenhouse gases and air pollutants emitted from particular Industrial Processes are available for all Industrial Processes listed above. These emission factors can be combined with company-specific data on the use of different industrial products to apply Equation 3.4.1 to estimate greenhouse gas and air pollutant emissions from industrial processes along a company's value chain. The default emission factors for air pollutants from EMEP/EEA (2023) and GHGs from IPCC (2006) are summarised in Table 3.4.1 and 3.4.2, respectively.

**Table 3.4.1: Summary of default emission factors for Tier 1 method for quantifying air pollutant emissions from industrial processes [Source: EMEP/EEA, 2023]. Table S3.4.1 and S3.4.3 should be referred for emission factors for the full list of air pollutants.**

| Sector | Sub-sector | Units | CO | $NO_x$ | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | BC % of $PM_{2.5}$ | OC | NMVOCs | $NH_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mineral** | Cement | g/Mg clinker | | | | 234 | 130 | | | | |
| | Lime | g/Mg Lime | | | | 3500 | 700 | 0.46 | | | |
| | Glass | g/Mg Glass | | | | 270 | 240 | 0.06 | | | |
| | Quarrying and mining of miners | g/Mg mineral | | | | 50 | 5 | | | | |
| **Chemical Industry** | Ammonia production | kg/t of $NH_3$ | 0.1 | 1 | | | | | | | |
| | Nitric acid production | g/Mg produced, 100% acid | | 10000 | | | | | | | |
| | Adipic acid production | kg/Mg | 0.4 | 8 | | | | | | | |
| **Metal** | Iron and steel | g/Mg steel | | | | 180 | 140 | 0.36 | | 150 | |
| | Ferroalloys Production | g/Mg alloy produced | | | | 850 | 600 | 10 | | | |
| | Aluminium Production | kg/Mg aluminium | 120 | 1 | 4.5 | 0.7 | 0.6 | 2.3 | | | |
| | Lead Production | g/Mg Lead | | | 2050 | 5 | 2.5 | | | | |
| | Zinc Production | g/Mg Zinc | | | 1350 | 13 | 12 | | | | |
| | Copper production | g/Mg Copper | | | | 250 | 190 | | | | |
| | Nickel Production | kg/Mg Nickel | | | 18 | | | | | | |

| Sector | Sub-sector | Units | CO | $NO_x$ | $SO_2$ | $PM_{10}$ | $PM_{2.5}$ | BC % of $PM_{2.5}$ | OC | NMVOCs | $NH_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Copper production | g/Mg Copper | | | | 250 | 190 | | | | |
| | Nickel Production | kg/Mg Nickel | | | 18 | | | | | | |
| **Other Industry Production** | | | | | | | | | | | |
| | Pulp and paper | kg/Mg air dried pulp | 5.5 | 1 | 2 | 0.8 | 0.8 | 2.6 | | | |
| | Food and Beverages | kg/Mg of Product | | | | | | | | 2 | |
| **Other Solvent And Product Use** | | | | | | | | | | | |
| | Domestic solvent use Including Fungicides | Kg/ per capita | | | | | | | | | |
| | | | | | | | | 1.2 | | | |
| | Road paving | | | | | | | | | | |
| | with asphalt | g/Mg asphalt | | | | 3000 | 400 | 5.7 | | 16 | |
| | Asphalt roofing | g/Mg shingle | | | | 400 | 80 | 0.013 | | 130 | |
| | Decorative | | | | | | | | | | |
| | Coating | | | | | | | | | | |
| | Application | g/kg paint applied | | | | | | | | 150 | |
| | Industrial Coating Application | g/kg paint applied | | | | | | | | 400 | |
| | Other coating Application | g/kg paint applied | | | | | | | | 200 | |
| | Degreasing | g/kg cleaning products | | | | | | | | 460 | |
| | Dry cleaning | g/kg textile treated | | | | | | | | 40 | |
| | Printing | g/kg ink | | | | | | | | 500 | |

Tier 1 emissions for GHG also follow similar method, however some of the sectors also depends on processes employed for production. Therefore, the production or consumption data should be disaggregated in further processes and relevant emission factors should be applied.

**Table 3.4.2:** **Summary of default emission factors for Tier 1 method for quantifying GHG emissions from industrial processes [Source: IPCC (2006; 2019). Table S3.4.3 should be referred for emission factors for the full list of GHGs.**

| Sector | Sub-sector | Units | CO | $NO_x$ | $SO_2$ | $PM_{10}$ |
|---|---|---|---|---|---|---|
| **Mineral** | Cement | | tonnes/tonne clinker | 0.52 | | |
| | Lime | High-calcium lime | tonnes per tonne lime | 0.75 | | |
| | | Dolomitic lime | tonnes per tonne lime | 0.86 | | |
| | Glass | Hydraulic lime | tonnes per tonne lime | 0.59 | | |
| **Chemical industry** | Ammonia production | Modern plants – Europe Conventional reforming – natural gas | tonnes/tonne $NH_3$ | 1.694 | | |
| | | Excess air reforming – natural gas | tonnes/tonne $NH_3$ | 1.666 | | |
| | | Autothermal reforming – natural gas | tonnes/tonne $NH_3$ | 1.694 | | |
| | | Partial oxidation | tonnes/tonne $NH_3$ | 2.772 | | |
| | | Derived from European average values for specific energy consumption (Mix of modern and older plants) Average value – natural gas | tonnes/tonne $NH_3$ | 2.104 | | |
| | | Average value – partial oxidation | tonnes/tonne $NH_3$ | 3.273 | | |
| | Nitric acid Production | Plants with NSCRa (all processes) | kg/tonne nitric acid | | 2 | |
| | | Plants with process-integrated or tailgas $N_2O$ destruction | kg/tonne nitric acid | | 2.5 | |

| Sector | Sub-sector | Units | CO | $NO_x$ | $SO_2$ | $PM_{10}$ |
|---|---|---|---|---|---|---|
| | | Atmospheric pressure plants (low pressure) | kg/tonne nitric acid | | 5 | |
| | | Medium pressure combustion plants | kg/tonne nitric acid | | 7 | |
| | | High pressure plants | kg/tonne nitric acid | | 9 | |
| | Adipic acid production | Nitric Acid Oxidation | kg/tonne adipic acid | | 300 | |
| **Metal** | iron and steel | Sinter Production | tonne/tonne sinter produced | 0.2 | | 0.07 |
| | | Coke Oven | tonne/tonne coke produced | 0.56 | | 0.1 |
| | | Iron Production | tonne/tonne pig iron produced | 1.35 | | |
| | | Direct Reduced Iron production | tonne/tonne DRI produced | 0.7 | | 1 kg /TJ (on a net calorific basis) |
| | | Pellet production (tonne $CO_2$ per tonne pellet produced) | | 0.03 | | |
| | | Basic Oxygen Furnace (BOF) | tonne/tonne of steel produced | 1.46 | | |
| | | Electric Arc Furnace (EAF) ** | tonne/tonne of steel produced | 0.08 | | |
| | | Open Hearth Furnace (OHF) | tonne/tonne of steel produced | 1.72 | | |
| | | Global Average Factor (65% BOF, 30% EAF, 5% OHF)* | tonne/tonne of steel produced | 1.06 | | |
| | Ferroalloy production | Ferrosilicon 45% Si | tonnes/tonne product | 2.5 | | |
| | | Ferrosilicon 65 % Si | tonnes/tonne product | 3.6 | | |
| | | Ferrosillicon 75% Si | tonnes/tonne product | 4 | | |
| | | Ferrosillicon 90% Si | tonnes/tonne product | 4.8 | | |
| | | Ferromanganeses (7% C) | tonnes/tonne product | 1.3 | | |

| Sector | Sub-sector | Units | CO | $NO_x$ | $SO_2$ | $PM_{10}$ |
|---|---|---|---|---|---|---|
| | | Ferromanganeses (1% C) | tonnes/tonne product | 1.5 | | |
| | | Silicomanganese | tonnes/tonne product | 1.4 | | |
| | | Silicon metal | tonnes/tonne product | 5 | | |
| | | Ferrochromium | tonnes/tonne product | 1.3 (1.6 with sinter plant) | | |
| | Alluminium production | Prebake7 | tonnes/tonne Al | 1.6 | | |
| | | Søderberg | tonnes/tonne Al | 1.7 | | |
| | Lead production | From Imperial Smelt Furnace (ISF) Production | tonnes/tonne product | 0.59 | | |
| | | From Direct Smelting (DS) Production | tonnes/tonne product | 0.25 | | |
| | Zinc production | Waelz Kiln | tonne/ tonne zinc | 3.66 | | |
| | | Pyrometeallurgical (Imperial Smelting Furnace) | tonne/ tonne zinc | 0.43 | | |
| | | Electro-thermic | tonne/ tonne zinc | Unknown | | |
| | | Default Factor | tonne/ tonne zinc | 1.72 | | |

## ▸ Tier 2: Methodology for Industrial Processes

The greenhouse gas and air pollutant emissions from industrial processes can often be reduced from the application of particular abatement technologies within industrial processes, e.g., end of pipe technologies to remove pollutants before they are emitted to the atmosphere. To advance from a Tier 1 estimate of greenhouse gas and air pollutant emissions from Industrial Processes to a Tier 2 approach therefore requires that the technologies used in the production of industrial products used in a company's value chain is taken into account. Equation 3.4.2 below shows the Tier 2 method for quantifying Industrial Process emissions within a company's value chain. It is similar to the Tier 1 approach (Equation 3.4.1) but disaggregates the quantity of material used in a company's value chain (M) by the technology used in the process to produce it. The application of the Tier 2 approach therefore requires that not only is the quantity of different products used by companies known, but that the specific technologies in the processes that produce it are also identified. For each Industrial Process, pollutant-, process-, and technology-specific emission factors are included in the SI and taken from EMEP/EEA (2023).

Eq. 3.4.2

$$Emissions_{k,p,t} = M_{p,t} * EF_{k,p,t}$$

where:

$M_{p,t}$ = Quantity of material M used in (or produced by) a company's value chain produced using process p and technology t (tonnes, litres)

$EF_{k,p,t}$ = emission factor for pollutant k for process p and technology t (g unit production-1)

$Emissions_{k,p,t}$ = emissions of the specific pollutant k for process p and technology t (g)

## 3.4.3 Examples

### Industrial processes and product use

**Example:**
To estimate sulfur oxides ($SO_x$) emissions example from production of cement.

*Tier 1 method:*

1 **Step 1: Industry: Cement production**

Material used: Clinker (a primary component in cement production)
Annual production: 50,000 Mg (50,000,000 kg) of clinker
Emission factor for $SO_x$ (from Table 4.18): 3 g/Mg clinker

2 **Step 2: Apply the Tier 1 Methodology**

The Tier 1 methodology estimates emissions using the following equation:

$$\text{Emissions } SO_x = M_p \times EFS_{ox}$$

Where:

$M_p$ = Quantity of material used (in this case, clinker) = 50,000 Mg
$EFSO_x$ = Emission factor for $SO_x$ for cement production = 3 g/Mg

3 **Step 3: Calculate the $SO_x$ Emissions**

$\text{EmissionsSO}_x$ = 50,000 Mg x 3 g/Mg
**$\text{EmissionsSO}_x$ = 150000 g = 150 kg**

This example used the Tier 1 method, which is straightforward and uses default emission factors. If more detailed information were available about specific abatement technologies used in the cement production process, the Tier 2 methodology could be applied for a more precise estimate.

### *Tier 2 method:*

Industry: Cement production
Material used: Clinker
Annual production: 50,000 Mg (50,000,000 kg) of clinker
Technology 1: Standard process without $SO_x$ abatement
Emission factor for $SO_x$: 3 g/Mg clinker (as in Tier 1)
Proportion of production: 40% of total production
Technology 2: Process with advanced $SO_x$ abatement (e.g., flue gas desulfurization)
Emission factor for $SO_x$: 0.5 g/Mg clinker
Proportion of production: 60% of total production

1

**Step 1: Apply the Tier 2 Methodology**

The Tier 2 methodology estimates emissions using the following equation:

$$EmissionsSO_{x,p,t} = M_{p,t} \times EFSO_{x,p,t}$$

Where:

$M_{p,t}$ = Quantity of material produced using process p and technology t

$EFSO_{x,p,t}$ = Emission factor for $SO_x$ for process p and technology t

2

**Step 2: Disaggregate Production Data**

Standard process without ab atem ent:
Production: 50,000 x 0.40 = 20,000 Mg
Emission factor: 3 g/Mg
Process with advanced abatement:
Production: 50,000 x 0.60 = 30,000 Mg
Emission factor: 0.5 g/Mg

3

**Step 3: Calculate the $SO_x$ Emissions for Each Technology**

1. Emissions from the Standard Process (without abatement):
   $EmissionsSO_x$,Standard = 20,000 Mg x 3 g/Mg = 60,000 g = 60 kg

2. Emissions from the Process with Advanced Abatement:
   $EmissionsSO_x$,Abatement = 30,000 Mg x 0.5 g/Mg = 15,000 g
   $EmissionsSO_x$,Abatement ent =30,000Mg x 0.5g/Mg = 15,000g = 15 kg

5

**Step 5: Sum the Total SOx Emissions**

Total $EmissionsSO_x$ = $EmissionsSO_x$, Standard + $EmissionsSO_x$ ,Abatement
Total $EmissionsSO_x$ = 60 kg + 15 kg = 75 kg

## 3.4.4 Sub-sector specific methods

This section covers the categories of Construction and Demolition, and Solvent use that are included under Industrial Processes according to the EMEP/EEA (2023) guidelines, but their methods are different compared to the methods described in Section 3.4.2 and are also only applicable to estimation of air pollutant emissions.

### 3.4.4.1 Other solvent and product use

The Solvent and Product Use category, primarily covers NMVOC emissions that occur from processes and products that use solvents and other volatile organic chemicals. The EMEP/EEA (2023) Guidelines describe nice sub- divisions of emission sources under this emission source:

- Fat, edible and non-edible oil extraction
- Preservation of wood
- Creosote preservatives
- Water-born preservatives
- Organic solvent-borne preservatives
- Underseal treatment
- Vehicle dewaxing
- Lubricant use
- Application of adhesives
- Adhesive tapes
- Tobacco combustion
- Aircraft de-icing

The term 'solvent' is used to refer to all volatile organic chemicals that are used under the other solvent and product used source.

A key challenge when it comes to estimating air pollutant emissions from this source is that emissions from this source include emissions that occur by the general use of any of a huge range of consumer products, and it also extends to a wide range of processes that are carried out in practically every branch of industry (EMEP/ EEA Guidebook, Additional Guidance: 2D3 Solvent and Product Use, 2019). Furthermore, the use of solvents can often be a relatively minor element of the activity carried out by a business. For example, solvents are used in the paints for motor vehicles, but this may be regarded as a very minor aspect of a company's activities.

The Tier 1 method that will be used in order to estimate air pollutant emissions from this source sector (Equation 3.4.3) is similar to one described under Industrial Processes (Equation 3.4.2). However, in this case, there is one key difference. Equation 3.4.3 refers to the total amount of solvents used within a company's value chain.

Further to that difference, particular care needs to be taken by the user because solvents will often pass through several different businesses before they are ultimately released as NMVOC emissions, for example:

- Solvent made and sold by solvent manufacturer
- Solvent incorporated into a product by a manufacturer
- Product used by another manufacturer.

Industries can have very specific definitions for what is a solvent and can even have different ideas about what is a solvent in a particular type of product. For example, data from industry on solvents supplied for use in aerosols therefore might not include propellants so it is important to check the detail of the input data.

## ▸ Tier 1: Methodology for other solvent and product use

The Tier 1 method for quantifying air pollutant emissions from other solvent and product use along a company's value chain is based on the EMEP/EEA (2023) methods for developing national air pollutant emission inventories from Industrial Processes. The EMEP/EEA (2023) Tier 1 method multiplies the annual use of solvents (kg) by a pollutant emission factor. The Tier 1 method is shown in Equation 3.4.3:

Eq. 3.4.3

$$Emissions = S * EF$$

where:

S = Quantity of solvent S used in a company's value chain (kg)

$EF_k$ = emission factor for pollutant k (g/Mg product used)

$Emissions_k$ = emissions of the specific pollutant k (g)

**Table 3.4.3:** **Tier 1 emission factors for other solvent and product use (EMEP/EEA, 2023)**

| | NMVOCs |
|---|---|
| **Other solvent and product use** | 2 |

## ▸ Tier 2: Methodology for Other solvent and product use

To advance from a Tier 1 estimate of air pollutant emissions from other solvent and produce use to a Tier 2 approach therefore requires that nice sub-divisions of the emission source are taken into consideration. The air pollutant emissions from these sub-divisions can often be reduced from the application of particular abatement technologies to remove pollutants before they are emitted to the atmosphere. Equation 3.4.4 below shows the Tier 2 method for quantifying 'Other solvent and product use' emissions within company's value chain. It is similar to the Tier 1 approach (Equation 3.4.3) but disaggregates the amount of solvent used in a company's value chain (M) by the specific emission source (i.e., wood preservation, vehicle dewaxing). The application of the Tier 2 approach therefore requires that not only is the quantity of different products used by companies known, but that the specific sub-divisions of the emission source are identified. For each of these sub-divisions a, pollutant-, process- and technology-specific emission factors are summarised in SI and taken from EMEP/EEA (2023).

Eq. 3.4.4

$$Emissions_{k,i,t} = S_{i,t} * EF_{k,i,t}$$

where:

$S_{i,t}$ = Quantity of solvent S for the different technology t and sub-divisions i used in a company's value chain (kg)

$EF_{k,i,t}$ = emission factor for pollutant k, technology t and sub-division i (g/Mg product used)

$Emissions_{k,i,t}$ = emissions of the specific pollutant k for technology t and sub-division i (g)

Tier 2 emission factors for other solvent and product use are included in the SI.

### 3.4.4.2 Construction and Demolition

Construction and demolition of infrastructure and buildings can contribute significantly to the emissions of particulate matter, $PM_{10}$ and $PM_{2.5}$. The methods strictly focus on particulate matter air pollution and does not include estimation of GHG emissions. To estimate particulate matter emissions from construction and demolition the EMEP/EEA (2023) Guidelines provide a Tier 1 method for national inventories. This method can also be used to estimate emissions that occur from this source for the value chains as well. It should be highlighted that a Tier 3 method also exists (US EPA) but this method requires very detailed local data and is not presented in this guide. Tier 2 methods to estimate emissions from this source are not currently available.

#### ▸ *Tier 1:* *Methodology for Construction and Demolition*

The Tier 1 methodology to quantify emissions from construction and demolition requires information on the types of structures being constructed and/or demolished. The user needs to identify either the number or percentage of the following types of structures: houses, apartments, non-residential construction and road construction. Once the different types of structures are identified, the user needs to multiply a structure specific emission factor (Table 3.4.5), with the total area affected by the construction and/ or demolition of the specific structure and the average duration, according to Equation 3.4.5:

Eq. 3.4.5

$$EM_{PM10} = EF_{PM10} * A_{affected} *d * (1\text{-}CE) * (24/PE) * (s/9\%)$$

Where:

$EM_{PM10}$ = $PM_{10}$ emission (kg of $PM_{10}$)

$EF_{PM10}$ = the emission factor for this pollutant emission (kg $PM_{10}$/[m² · year])

$A_{affected}$ = area affected by construction activity ($m^2$) d = duration of construction (year)

CE = efficiency of emission control measures (-)

PE = Thornthwaite precipitation-evaporation index (-)

s = soil silt content (%)

To estimate emissions from this source, the user should have country specific information on a number of parameters such as the area affected by the construction activity, the duration of the construction, the control efficiency of any applied emission reduction measures, the Thornthwaite precipitation-evaporation index, and the soil silt content(s) because these parameters can vary significantly depending on the country. However, if country specific data are not available the EMEP/EEA (2023) guidelines provide default data for some of these parameters as shown in Table 3.4.2 below:

**Table 3.4.4:** **Default data for key parameters needed for the Tier 1 approach for Construction and Demolition [Source: EMEP/EEA, 2023].**

| | Duration (months) | Fractional overall control efficiency | Total affected area |
|---|---|---|---|
| **Construction of houses (all types)** | 6 | 0 | |
| Detached (single family) | | | 300 (m2/house) |
| Detached (two family) | | | 188(m2/house) |
| Terraced | | | 120(m2/house) |
| **Construction of apartment buildings** | 9 | 0 | |
| Apartment, building basis | | | 585(m2/building) |
| Apartment, unit basis | | | 65(m2/building) |
| **Non-residential construction** | 10 | 0.5 | |
| **Construction of roads** | 12 | 0.5 | |

**Climate and PE Index:** a) Wet: More than 128, b) Humid: 64 -127, c) Sub-humid: 32 -63, d) Semi-arid: 16 -31, e) Arid: Less than 16

**Table 3.4.5:** Tier 1 emission factors (kg/($m_2$ * year)) for the different types of construction Source: EMEP/EEA 2019].

| | $PM_{2.5}$ kg/($m^2$ * year) | Total affected area |
|---|---|---|
| **Construction of houses** | 0.086 | 0.0086 |
| **Construction of apartment buildings** | 0.30 | 0.030 |
| **Non-residential construction** | 1.0 | 0.1 |
| **Construction of roads** | 2.3 | 0.23 |

## Detailed Methodology for Construction sector

The simplified Tier 1 methodology may be appropriate for national emission inventories, where aggregated data is sufficient to meet the needs of policymakers. However, when estimating emissions for a specific company, greater accuracy is essential, often requiring more detailed data and higher-tier methods. Therefore, whenever detailed data on individual activities is available, a Tier 3 approach should be employed to produce more representative emission estimates. A more comprehensive methodology for analysing emissions from construction and demolition activities is provided by the US EPA (2011) in "AP-42, Compilation of Air Pollutant Emission Factors". The following sections discuss the detailed methodology across various phases of construction.

Equation 3.4.6 represents the fundamental method used to estimate particulate matter emission from construction processes.

Eq. 3.4.6

$$E_i = \sum_i A_i \times EF_i$$

Where, E is the annual emission load, A is the amount of annual activity, EF is the emission factor, and i is the individual construction process.

Therefore, to estimate emission from all construction activities, the user will need to gather information on individual construction activities taking place in various phases of construction. The US EPA guidance categorises the construction activities in three phases, described in detail further.

### Demolition and debris removal

Demolition and land clearing activities can generate air pollution through various sources, such as the demolition process, heavy machinery usage, and the loading and unloading of debris. The dust and particulate matter generated during these activities can pose significant health risks to workers and the surrounding community. The extent of air pollution depends on several factors, including the size of the demolition site, weather conditions, and dust control measures (USEPA 1995).

### Site preparation (Earth removal)

Excavation during construction can cause particulate matter air pollution as dust and other airborne particles are generated during the activity (U.S. EPA 1995; Chiu & Rao 2010; Qian et al. 2008). The size of the excavation site, type of soil, weather conditions, and dust control measures (U.S. EPA 1995; Qian et al. 2008; Jena et al. 2019). In addition, soil moisture content can significantly impact the generation of dust during excavation, while dry soil can produce more dust, as higher soil moisture leads to reduction in PM generation (Jena et al. 2019).

The excavation process can generate dust and other airborne particles, while excavator operation can create additional emissions from the engine and hydraulic systems (Liu et al. 2019). Loading and unloading of excavated material can also produce dust from the handling and transport of the material (U.S. EPA 1995). Contrary to demolition activity, during excavation both activities excavation and loading are done simultaneously, therefore separate estimation of loading time is not required. Finally, to effectively estimate PM emissions from excavation activities, all sources should be considered in the estimation process.

### General construction

General construction encompasses the active phase of building and infrastructure development following demolition and site preparation. It includes the use of heavy machinery, movement of materials, and operation of portable processing plants, all of which contribute to particulate matter (PM) emissions. The key dust-generating activities during this phase include:

- Vehicular traffic on unpaved and paved roads, which resuspends silt and soil particles due to vehicle weight and frequency.
- Material crushing and fines crushing, where coarse and fine construction materials are broken down, releasing fine dust.
- Screening and fines screening, involving the sorting of materials, which disperses particulate matter, particularly from finer aggregates.
- Material transfers, such as loading/unloading of aggregates or soil, which generate dust, especially under dry and windy conditions.

Accurate quantification of $PM_{2.5}$ and $PM_{10}$ emissions from these sources requires activity-specific data and the use of emission factors that account for local environmental conditions such as silt load, moisture content, wind speed, and vehicle weight.

The activity data required for these estimation methods would vary greatly depending upon the construction type, location, and weather conditions. Therefore, it is suggested that accurate primary data should be used for emission estimation. The emissions factors for these construction activities also depend on a variety of local factors such as silt content, wind speed, vehicle weight etc. Therefore, it is advisable to use these factors for local conditions. The emission factors suited to local conditions for individual construction activity during varying construction phases can be estimated using the methods provided in table 3.4.6.

**Table 3.4.6:** Activity specific emission factors, emission factor equations, and activity data requirements

| Dust-Generating Activities | Activity Data Required (Unit) | Unit | $PM_{2.5}$ Emission Factor | $PM_{10}$ Emission Factor |
|---|---|---|---|---|
| **Demolition and Debris Removal Phase** | | | | |
| **Drilling and blasting of soil** | Holes by drilling and blasting (Number) | g/hole | 590 | 590 |
| **General land clearing** | Hours of operation | kg/hr | (2.6 × S^1.2)/M^1.3 × 0.105 | (0.45 × S^1.5)/M^1.4 × 0.75 |
| **Loading of debris into trucks** | Debris Loaded (Mg) | kg/Mg | 0.0000848 × (U/2.2)^1.2 / (M/2)^1.4 | 0.00056 × (U/2.2)^1.2 / (M/2)^1.4 |
| **Truck transport of debris - Unpaved Road** | VKT during transport (VMT) | g/VKT | k × 366.52 × (s/12)^a × (W/3)^b | k × 366.52 × (s/12)^a × (W/3)^b |
| **Truck transport of debris - Paved Road** | VKT during transport (VKT) | g/VKT | 0.15 × (sL)^0.91 × (W)^1.02 | 0.62 × (sL)^0.91 × (W)^1.02 |
| **Truck unloading of debris** | Debris unloaded (Mg) | kg/Mg | 0.0000848 × (U/2.2)^1.2 / (M/2)^1.4 | 0.0000848 × (U/2.2)^1.2 / (M/2)^1.4 |
| **Earth Moving Phase** | | | | |
| **Bulldozing** | Total Bulldozer operation (hrs) | kg/hr | (2.6 × S^1.2) / M^1.3 × 0.105 | (0.45 × S^1.5) / M^1.4 × 0.75 |
| **Scrapers unloading topsoil** | Total topsoil unloaded (ton) | lb/ton | 0.058 | - |
| **Scrapers in travel - Unpaved roads** | Scrapers travel (VMT) | g/VKT | k × 366.52 × (s/12)^a × (W/3)^b | k × 366.52 × (s/12)^a × (W/3)^b |
| **Scrapers removing topsoil** | Scrapers travel (VKT) | kg/VKT | 5.7 | - |
| **Loading of excavated material into trucks** | Total excavated material loaded (Mg) | kg/Mg | 0.0000848 × (U/2.2)^1.2 / (M/2)^1.4 | 0.00056 × (U/2.2)^1.2 / (M/2)^1.4 |
| **Truck dumping of fill material, road base, or materials** | Total excavated material unloaded (Mg) | kg/Mg | 0.0000848 × (U/2.2)^1.2 / (M/2)^1.4 | 0.00056 × (U/2.2)^1.2 / (M/2)^1.4 |

| Dust-Generating Activities | Activity Data Required (Unit) | Unit | $PM_{2.5}$ Emission Factor | $PM_{10}$ Emission Factor |
|---|---|---|---|---|
| **Compacting** | Total soil compacting (hrs) | kg/hr | (2.6 × S^1.2) / M^1.3 × 0.105 | (0.45 × S^1.5) / M^1.4 × 0.75 |
| **Motor grading** | Motor grader travel (VKT) | kg/VKT | 0.001054 × S^2.5 | 0.00336 × S^2.0 |
| **General Construction** | | | | |
| **Vehicular traffic - Unpaved Road** | Vehicle travel - Unpaved roads (VKT) | g/VKT | k × 366.52 × (s/12)^a × (W/3)^b | k × 366.52 × (s/12)^a × (W/3)^b |
| **Vehicular traffic - Paved Road** | Vehicle travel - paved roads (VKT) | g/VKT | 0.15 × (sL)^0.91 × (W)^1.02 | 0.62 × (sL)^0.91 × (W)^1.02 |
| **Portable plants** | | | | |
| **Crushing** | Material crushed (Mg) | kg/Mg | 0.0027 | - |
| **Fines Crushing** | Fines crushed (Mg) | kg/Mg | 0.0195 | - |
| **Screening** | Material screened (Mg) | kg/Mg | 0.0125 | - |
| **Fines Screening** | Fines screened (Mg) | kg/Mg | 0.15 | - |
| **Material transfers (Aggregate handling and storage)** | Material transferred (Mg) | kg/Mg | 0.0000848 × (U/2.2)^1.2 / (M/2)^1.4 | 0.00056 × (U/2.2)^1.2 / (M/2)^1.4 |

Where,

S= Silt Content of the debris or material (%)

M= Moisture content of debris or material (%)

U= Average wind speed (m/s)

s= Surface material silt content (%)

W= Mean vehicle weight (ton)

sL= Silt load ($g/m^2$)

### 3.4.4.3 Example (construction and Demolition)

## Construction and Demolition

Let's go through an example to calculate the $PM_{2.5}$ emissions for one of the activities, using assumed values for the required variables. We'll use the loading of debris into trucks activity from the demolition and debris removal phase.

**Assumptions:**

Debris Loaded (Mg) = 100 Mg (metric tons)
Average wind speed (U) = 5 m/s
Moisture content of debris (M) = 15%
Silt content of the debris (S) = 20%
Vehicle weight (W) = 20 tons
Using these values, let's calculate the $PM_{2.5}$ emissions for this activity.

**Emission Estimation:**

The formula for $PM_{2.5}$ emission during loading of debris into the truck is:
$PM_{2.5}$ emissions = 0.0000848 X (U/2.2)12 / (M/2)1.4

**Step-by-step Calculation:**

$PM_{2.5}$ Calculation:

1 **Step 1: Emission factor quantification**

First, calculate the factor for wind speed:
(U/2.2) = 5/2.2 = 2.27

Now raise it to the power of 1.2:
2.2712=2.77

Next, calculate the factor for moisture content:
(M/2) = 15/2= 7.5

Now raise it to the power of 1.4:
7.51.4 = 14.29

Now calculate the emission factor for $PM_{2.5}$:
$PM_{2.5}$ = 0.0000848 X 2.77/14.29 = 0.0000168 kg/Mg

2 **Step 2: Emission quantification**

$PM_{2.5}$ Emission for 100 Mg of debris:
$PM_{2.5}$ emissions = 100 X 0.0000168 = 0.00168 kg

## 3.4.5 References

EMEP/EEA. (2019). EMEP/EEA air pollutant emission inventory guidebook 2019: Technical guidance to prepare national emission inventories (EEA Report No. 13/2019). European Environment Agency. https://www.eea.europa.eu/publications/emep-eea-guidebook-2019

European Environment Agency. (2023). EMEP/EEA air pollutant emission inventory guidebook 2023. https://www.eea.europa.eu/en/analysis/publications/emep-eea-guidebook-2023

Intergovernmental Panel on Climate Change. (2006). 2006 IPCC guidelines for national greenhouse gas inventories. IGES. https://www.ipcc-nggip.iges.or.jp/public/2006gl/

Intergovernmental Panel on Climate Change. (2019). 2019 refinement to the 2006 IPCC guidelines for national greenhouse gas inventories. https://www.ipcc-nggip.iges.or.jp/public/2019rf/

General Guidance on Estimating and Reporting Air Pollutant Emissions" report from EU contract No 070201/2020/831771/SFRA/ENV.C.3 - Capacity building for Member States regarding the development of national emission inventories

Chiu, K., & Rao, K. (2010). Investigation of excavation-induced ground vibrations and airborne dust at a construction site. Environmental Monitoring and Assessment, 170(1-4), 439-449. doi: 10.1007/s10661-009-1247-6

Qian, J., Ferro, A. R., & Fowler, J. F. (2008). Dust emission from construction sites in the United States. Journal of the Air & Waste Management Association, 58(11), 1547-1553. doi: 10.3155/1047-3289.58.11.1547

Jena, S. K., Mishra, R. K., & Das, S. K. (2019). Effect of moisture content on fugitive dust emissions from an opencast coal mining site in India. Environmental Monitoring and Assessment, 191(6), 347. doi: 10.1007/s10661-019-7452-2

Liu, C., Zhao, Q., Jiang, Y., Liu, H., Xu, Z., & Zhang, H. (2019). Characteristics of particulate matter emission from construction sites in a suburban area of Beijing, China. Environmental Pollution, 246, 505-513. doi: 10.1016/j.envpol.2018.12.019

U.S. Environmental Protection Agency (EPA). (n.d.). AP-42: Compilation of air pollutant emission factors. Retrieved June 1, 2025, from https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emission-factors

U.S. Environmental Protection Agency. (1995). Compilation of air pollutant emission factors, Volume I: Stationary point and area sources, Fifth edition, Chapter 13: Miscellaneous sources (AP-42, Report No. EPA-454/R-95-012). https://www.epa.gov/sites/default/files/2020-09/documents/13misc.pdf

# 3.5 Estimating Greenhouse Gas and Air Pollutant Emissions from Agriculture

**Quote as:** CCAC and SEI (2025). Section 3.5 Estimating Greenhouse Gas and Air Pollutant Emissions from Agriculture, in Integrated Guide for Business Greenhouse Gas and Air Pollutant Emission Assessment. Climate and Clean Air Coalition and Stockholm Environment Institute, Paris.

URL: https://www.ccacoalition.org/resources/integrated-guide-business-greenhouse-gas-and-air-pollutant-emission-assessment

This section of the Guide 2.0 explains how the emissions of greenhouse gas (GHGs), Short-Lived Climate Pollutants (SLCPs), classical air pollutants and heavy metals (HM) (hereafter referred to as greenhouse gas and air pollutants as defined in Chapter 1) that are related to agricultural activities at different parts of a company's value chain can be quantified. This section is structured by first describing the source, then describing the methods, which includes Tier 1 emission factors. The Tier 2 methods are explained in this document, but the Tier 2 (as well as the Tier 1) emission factors are linked to a database where these default values can be found (https://www.ccacoalition.org/resources/integrated-guide-business-greenhouse-gas-and-air-pollutant-emission-assessment). The section then includes an example calculation using the methods and then provides the references for the methods and data.

## 3.5.1 Description of the Source

Agriculture is a source of greenhouse gas and air pollutants from both main types of agricultural activity, livestock and crop production. Agriculture is the main source of ammonia ($NH_3$) emissions globally but can also contribute to emissions of nitrogen oxides ($NO_x$), methane ($CH_4$), as well as particulate matter, volatile organic compounds and other GHG and air pollutant emissions. The pollutants emitted from the agriculture sector are Carbon Dioxide ($CO_2$), Methane ($CH_4$), Nitrous Oxide ($N_2O$), Particulate Matter ($PM_{10}$, $PM_{2.5}$), Nitrogen Oxide ($NO_x$), Non-methane volatile organic compounds (NMVOCs), Ammonia ( $NH_3$). Within agriculture, the following specific sources of greenhouse gas and air pollutant emissions are covered in this Section:

**Livestock**

- Manure Management
- Livestock Housing
- Enteric Fermentation

**Crop production**

- Manure application to fields
- Synthetic fertiliser application to fields
- Open burning of agricultural residues
- Rice Cultivation
- Lime & Urea fertilization
- Land Use and Land Use Change

Land Use and Land Use Change (LULUC) are significant sources of greenhouse gas (GHG) emissions, particularly for companies in sectors such as agriculture, forestry, real estate, mining, and infrastructure. These emissions primarily arise from deforestation, land conversion, soil carbon loss, and biomass burning, and can involve releases of $CO_2$, $CH_4$, and $N_2O$. For companies aiming to measure or report LULUC emissions, the IPCC Guidelines for National Greenhouse Gas Inventories (2006), particularly Volume 4: Agriculture, Forestry and Other Land Use (AFOLU), provide internationally recognized methodologies. These guidelines categorize land use into six broad classes (forest land, cropland, grassland, wetlands, settlements, and other land) and offer three tiers of methodological rigor:

- **Tier 1:** Basic method using global default emission factors and carbon stock values. Suitable for companies with limited data.

- **Tier 2:** Uses country- or region-specific data and is more representative of local conditions.

- **Tier 3:** Employs detailed models, site-specific measurements, and higher-resolution data. Appropriate for companies with large land footprints or advanced monitoring capabilities.

While the IPCC methods were originally designed for national inventories, they can be adapted by companies—particularly those with direct land holdings or influence over land-use decisions in their supply chain. Given the technical complexity, data requirements, and variability across geographies and sectors, a detailed treatment of IPCC LULUC methodologies is beyond the scope of this version of the Guide 2.0. Comprehensive methods for estimating GHG emissions from this source will be provided in a future edition of the guide.

In the **livestock sector,** manure management refers to the emissions that occur during the different process for the collection and storage of manure. There are multiple different manure management systems that are employed on farms for dealing with manure. These different manure management systems include:

- **Pasture/Range/Paddock (Grazing):** Deposition of manure to pastureland while livestock are grazing is allowed to lie as deposited and is not managed
- **Daily spread:** Manure is removed from a confinement facility and applied to cropland or pasture within 24 hours of excretion
- **Solid Storage (Heaps):** Storage of manure for a period of months, in unconfined piles or stacks. Solid storage can be covered with a plastic sheet to reduce the surface of manure exposed to air and/or compacted to increase density (Covered/Compacted). Solid storage can include manure mixed with specific materials to provide structural support and enhanced decomposition (Bulking agent addition). Finally, solid storage can include the addition of substances to reduce gaseous emissions (Additives).
- **Dry lot:** A paved or unpaved open confinement area without any significant vegetation cover, without the addition of bedding to control moisture. Manure can be removed periodically and spread on fields.
- **Liquid/Slurry (Tanks):** Manure is stored as excreted or with minimal addition of water or bedding material in tanks or pods. It is removed and spread once or more in a year.
- **Uncovered anaerobic lagoon (Lagoon):** Liquid storage system.
- **Pit Storage below animal confinements (In-house slurry pit):** Collection and storage of manure with little or no added water typically below a slatted floor in an enclosed animal confinement facility.
- **Anaerobic digester (Biogas treatment):** Livestock manure with and without straw are collected and anaerobically digested in a containment vessel where co-digestion with other waste or energy crops may occur (Digesters of high quality and low leakage); Livestock manure with and without straw are collected and anaerobically digested in covered lagoon (Digesters with high leakage).
- **Burned for fuel:** Dung and urine are excreted on fields and the sun-dried dung is burned for fuel.
- **Deep bedding (In-house deep litter):** Bedding is added continually to absorb moisture of the accumulating manure over 6 to 12 months.
- **Composting:** In an enclosed channel with forced aeration and continuous mixing (In-vessel); In piles with forced aeration but no mixing with or without runoff containment (Static pile); Composting in windrows with daily mixing and aeration with or without runoff containment (Intensive windrow); Composting in windrows with infrequent mixing and aeration with or without runoff (Passive windrow).
- **Poultry manure with litter (laying hens – solid):** Used for all poultry breeder flocks and other fowl where litter and manure are left in place with added bedding.
- **Poultry manure without litter (laying hens – slurry):** Similar to open pits in enclosed animals where manure is dried as it accumulates.
- **Aerobic treatment:** Biological oxidation of manure collected as a liquid with forced or natural aeration.

The main pollutants produced from manure management are $NH_3$ and $NO_x$, which are emitted when manure and excreta that is collected and stored are exposed to the atmosphere, in livestock housing, from manure stores, after manure application to fields and from excreta deposited by grazing livestock. Significant emissions of NMVOCs from manure management in sold or slurry form have been measured from livestock production. In addition to manure management, silage stores are major sources and emissions occur during feeding with silage.

In crop production, manure and synthetic fertiliser application to soils refers to the emissions that occur as a result of the application of different kinds of fertiliser and livestock excreta to soils. This includes $NH_3$ and NO emissions that can occur during and after the application of N fertilisers to land (including urea), sewage sludge, organic fertilisers (e.g., digestate and compost), and urine and dung applied to soils. It also includes PM emissions from the handling and storage of agricultural products on farms (e.g., grain) but also emissions during the handling and storage of products produced elsewhere to be used on the farm such as fertilisers and livestock feeds.

The burning of crops refers to the emissions that occur from the practice of burning crop residues as a means of clearing land. Combustion in the field leads to the emissions of pollutants such as $NO_x$, CO, NMVOCs, PM and BC.

## 3.5.2 Methodologies for Quantifying Emissions

The GHG and air pollutant emissions from the agriculture sector that may exist within a company's value chain could result from the use of agricultural outputs within their products or services. For example, agricultural greenhouse gas and air pollutant emissions may result from the use of specific ingredients (meat, dairy, eggs or crop-based ingredients) within a company's food products or could result from the use of non-food products within a company's activities. Non-food products can also be made through livestock or crop production, and include, for example, wool and cotton for clothes manufacturing. This guide adapts the national greenhouse gas and air pollutant emission methods for the agriculture sector to estimate a company's emissions from agricultural sources, based on those methods outlined in the IPCC (2006; 2019) and EMEP/EEA (2023) guidelines respectively. These methods are used to estimate emissions for pollutants such as $NH_3$, $NO_x$, NMVOCs, $PM_{10}$, $PM_{2.5}$, $CO_2$, $CH_4$, and $N_2O$ and are described further in this section.

To apply these methods to a company's value chain, it is necessary to first estimate the number of livestock and crop products and land area that are used within that value chain. For livestock, the number of livestock used in the production of the meat, dairy, eggs and/or wool used in a company's value chain are calculated as shown in Equation 3.5.1:

Eq. 3.5.1

$$A_t = MP_{(product,t)} * 1000 / Y_{product,t}$$

Where:

At = The number of a specific type (t) of livestock (No of livestock)

MP = Amount of product (Meat, Dairy, Egg) from specific livestock equivalent (t) used in a company's value chain (in tonnes)

Y= Yield (kg/livestock) for product (Meat, Dairy, Egg) from specific livestock (t)

**Table 3.5.1:** Yield of meat (kg/livestock)

| Region | Yield (kg/livestock) | | | | |
|---|---|---|---|---|---|
| | Cattle | Chicken | Goat | Pig | Sheep |
| **Africa** | 158.9 | 1.3 | 11.2 | 50.8 | 15.2 |
| **Americas** | 284.7 | 2.1 | 13.4 | 91.1 | 18.1 |
| **Asia** | 144.2 | 1.3 | 13.0 | 76.5 | 16.5 |
| **Europe** | 258.2 | 1.6 | 11.4 | 90.0 | 16.1 |
| **Oceania** | 229.8 | 1.9 | 14.9 | 65.8 | 21.5 |

**Table 3.5.2:** Yield of milk (kg/livestock)

| Region | Yield (kg/livestock) | | | | |
|---|---|---|---|---|---|
| | Cattle | Chicken | Goat | Pig | Sheep |
| **Africa** | 1605 | 386 | 572 | 51 | 27 |
| **Americas** | - | - | 3883 | 93 | 33 |
| **Asia** | 1851 | 270 | 1831 | 107 | 37 |
| **Europe** | 936 | 147 | 6141 | 293 | 99 |
| **Oceania** | - | - | 4618 | 31 | - |

**Table 3.5.2:** Yield of Egg (kg/livestock)

| Region | Yield (kg/livestock) | |
|---|---|---|
| | Hen | Other Birds |
| **Africa** | 5667 | 268 |
| **Americas** | 13795 | 5979 |
| **Asia** | 9463 | 38345 |
| **Europe** | 13368 | 14554 |
| **Oceania** | 14340 | 7156 |

For crop production, the tonnes of crop used in a company's value chain should be identified from company specific statistics. A company may produce a variety of food products that each require a combination of different ingredients produced from different types of crop. The crop production GHG and air pollutant emissions are calculated based on the tonnes of crops produced. Therefore, to derive the tonnes of a particular crop required for a particular product within a company's value chain, Equation 3.5.2 should be used. For example, a food manufacturing company may produce 1000 loaves of bread per day, each weighing 500 g. Each loaf of bread may require 300g of wheat flour, and 200g of other ingredients, i.e., 60% of each bread loaf is made from wheat flour. The mass of wheat therefore required by this company to manufacture the bread product is 1000* 365 * 500 * 0.6 / 1,000,000 = 109.5 tonnes wheat per year.

Eq. 3.5.2

$$CP_t = Product_x * Frac_t$$

Where:

CP = Crop production for crop t (tonnes)

Productx = Production of product x within a company's value chain (tonnes)

Fract = Fraction by mass of Product x that is made of crop t

As shown in the methods outlined below, the tonnes of crop required should be calculated separately for different types of crops (e.g., wheat, rice, soy, etc.), and it is also necessary to apply these methods that either the crop yield (tonnes crop produced per hectare) and/or the land area used to produce these crops is calculated to estimate emissions from crop production. The crop production, land area, and yield are interrelated according to Equation 3.5.3:

Eq. 3.5.3

$$^{Land\ area}type\ of\ crop = Tonnes\ of\ product_{type\ of\ crop}{}^{/Yield}type\ of\ crop$$

Having calculated the number of livestock and tonnes of crop required within a company's value chain, the following methods can then be used to estimate the greenhouse gas and air pollutant emissions associated with the rearing of those livestock and production of those crops.

# Livestock

The GHG and air pollutant emissions from livestock category can be estimated using tier 1 and tier 2 methodologies for manure management and enteric fermentation. Both tier 1 and tier 2 methodologies for GHG and air pollutants follows significantly different methodologies and are therefore discussed separately in the following section. Due to complex nature of tier 2 methods for manure management and enteric fermentation, the methods in the guide do not include tier 2 methods here and IPCC (2019) guidelines can be referred if the user requires emission estimation using tier 2 methods.

## *Tier 1: Methodology for Manure Management*

The Tier 1 method for quantifying air pollutant emissions from manure management is based on the EMEP/EEA (2023) methods for developing national air pollutant emission inventories from Manure Management (3.B). The EMEP/EEA (2023) Tier 1 method multiplies the number of livestock in the different categories (e.g., Dairy cattle, pigs) separated by the different types of handling of manure (solid or slurry) by a pollutant specific emission factor. In applying this method to quantify air pollutant emissions within a company's value chain, the activity data (number of livestock within a country) is substituted with the number of livestock used (directly or indirectly) in a company's value chain.

1 **Step 1: Estimating the number of livestock.**

The livestock specific meat/dairy/eggs (tonnes) used in the value chain is multiplied by theyield of a specific type of livestock (tonnes/livestock) to estimate the number of a specific type of livestock (e.g., dairy cattle) (At) as shown in Equation 3.5.1.

2 **Step 2: Disaggregating the number of different livestock by the different ways manure is handled.**

Once the number of a specific type of livestock has been estimated, the manure type (e.g., solid, slurry) also needs to be accounted for and for each livestock category.

3 **Step 3: Estimating emissions from manure management.**

The number of the different types of livestock with different handling of manure (At,m) is multiplied by the pollutant specific emission factors that account for the different types of manure according to the equation (3.5.4)

Eq. 3.5.4

$$Emissions_{k,At,m} = A_{t,m} * EF_{t,p,m}$$

where:

$A_{t,m}$ = The number of a specific type of livestock with specific handling of manure (No of livestock separated by manure handling type)

$EF_{k,t}$ = emission factor for pollutant k for animal type t and for manure type m (g unit production-1)

$Emissions_{k,t}$ = emissions of the specific pollutant k for the animal type tm (g unit production-1)

The Tier 1 emission factors for manure management are included in the SI.

## Methane Emissions from Manure Management

During storage and treatment, methane is emitted due to decomposition of manure during anaerobic conditions storage and treatment. These conditions can arise when large numbers of animals are managed in a confined area. Hence, companies using produce from various animal categories should report their relevant $CH_4$ emissions occurring during management of manure produced by these animals.

Here, the method to estimate $CH_4$ produced during the storage and treatment of manure, and from manure deposited on pasture is discussed. The term 'manure' is used here collectively to include both dung and urine (i.e., the solids and the liquids) produced by livestock.

The main factors affecting $CH_4$ emissions are the amount of manure produced and the portion of the manure that decomposes anaerobically.

## ▸ *Tier 1:* *Methodology for $N_2O$ Emissions from Manure Management*

This section outlines the estimation method for the $N_2O$ produced, directly and indirectly, during the storage and treatment of manure before it is applied to land or otherwise used for feed, fuel, or construction purposes. Direct $N_2O$ emissions occur via combined nitrification and denitrification of nitrogen contained in the manure, whereas Indirect emissions result from volatile nitrogen losses that occur primarily in the forms of ammonia and $NO_x$.

**Direct $N_2O$ emissions:**

Direct $N_2O$ emissions estimation from manure management is based on the following equation 3.5.6:

Eq. 3.5.5

$$CH_4 manure = \sum_T \frac{N_T \times EF_T}{10^6}$$

$CH_4$ manure = $CH_4$ emissions from manure management, for a defined population, Gg $CH_4$ yr-1

EFT = emission factor for the defined livestock population, kg $CH_4$ head-1 yr-1

NT = the number of head of livestock species/category

T = species/category of livestock

## ▸ Tier 1: Methodology for $N_2O$ Emissions from Manure Management

This section outlines the estimation method for the $N_2O$ produced, directly and indirectly, during the storage and treatment of manure before it is applied to land or otherwise used for feed, fuel, or construction purposes. Direct $N_2O$ emissions occur via combined nitrification and denitrification of nitrogen contained in the manure, whereas Indirect emissions result from volatile nitrogen losses that occur primarily in the forms of ammonia and $NO_x$.

**Direct $N_2O$ emissions:**

Direct $N_2O$ emissions estimation from manure management is based on the following equation 3.5.6:

Eq. 3.5.6

$$N_2O_{D(Manure)} = [\sum_S [\sum_T N_T * Nex_T * M_{(T,S)}] * EFS] * \frac{44}{28}$$

Where:

$N_2OD$ (manure) = direct $N_2O$ emissions from Manure Management, kg $N_2O$ yr-1

NT= number of head of livestock species/category T

NexT = annual average N excretion per head of species/category T in the country, kg N animal[1] yr[1]

MT,S = fraction of total annual nitrogen excretion for each livestock species/ category T that is managed in manure management system S in the country, dimensionless

EFS = emission factor for direct $N_2O$ emissions from manure management system S in the country, kg $N_2O$-N/kg N in manure management system S

S = manure management system

T = species/category of livestock

44/28 = conversion of ($N_2O$-N) (manure management) emissions to $N_2O$ (manure management) emissions

**Indirect Emissions:**

Indirect $N_2O$ emissions estimation from manure management is based on the following equation 3.5.7:

Eq. 3.5.7

$$N_{volatalization\text{-}mms} = [\, \sum_S [\, \sum_T N_T * Nex_T * M_{T,S} ] * \frac{FRAC_{GasMS}}{100} \,]$$

Where:

Nvolatilization-MMS = amount of manure nitrogen that is lost due to volatilisation of $NH_3$ and $NO_x$, kg N yr-1

NT = number of head of livestock species/category T

NexT = annual average N excretion per head of species/category T , kg N animal-1 yr-1

MT,S = fraction of total annual nitrogen excretion for each livestock species/category T that is managed in manure management system S in the country, dimensionless

FracGasMS = percent of managed manure nitrogen for livestock category T that volatilises as $NH_3$ and $NO_x$ in the manure management system S, %

## ▸ Tier 2: Methodology for Manure Management

To advance to a Tier 2 method, there are additional steps that need to be taken and additional data that need to be identified by the user in comparison to the information used for the Tier 1 method. For the Tier 1 method, the EMEP/EEA (2023) guidelines do not consider the amount of time the different types of livestock spent being housed, or in uncovered yards or grazing. For the Tier 2 method, the user needs to estimate the amount of annual N excreted that is deposited when the livestock is house, in uncovered yards and during grazing, and they then need to estimate how much time (fraction of the year) the animals spend in these different setting. The full methods and equations required for the Tier 2 methodology are included in the SI. **Tier 2** estimation of $CH_4$ from manure management is also a complex method and should be used where a particular livestock species/category represents a significant share of a company's emissions. This method requires detailed information on animal characteristics and manure management practices, which is used to develop emission factors specific to the conditions of the various regions, these animals are raised. Due to these limitation the tier 2 method is beyond the scope of the Guide 2.0.

## ▸ Tier 1: Methodology for Methane Emissions from Enteric fermentation

The simplified tier 1 approach requires readily available animal population data from businesses based on their annual product use.

Methane emissions from enteric fermentation can be estimated using eqn:

Eq. 3.5.8

$$E_{Enteric\_Fermentation} = \sum N_t / 10^6 * EF_t$$

Where, $E_{CH4,enteric\_Fermentaion}$ is the total Methane emission from enteric fermentation in animals used for various products in a company's value chain, Nt is the livestock population in use resulting from product use, t is the livestock category, and EFt is the livestock category specific emission factor.

Default Tier 1 emission factors for methane emissions from enteric fermentation in animal categories except cattle in various regions are given in table 3.5.4.

**Table 3.5.4:** Tier 1 Enteric fermentation Emission Factors (kg $CH_4$ Head$^{1}$ Year$^{1}$) (IPCC, 2019)

| Animal Category | High Productivity Systems | Low Productivity Systems |
|---|---|---|
| **Chicken** | | |
| **Goat** | 9 | 5 |
| **Pig** | 1.5 | 1 |
| **Sheep** | 9 | 5 |

Tier 1 emission factors for dairy and other cattle species are provided in table 3.5.5.

**Table 3.5.5:** Default Enteric fermentation Emission Factors for cattle (kg $CH_4$ Head$^{1}$ Year$^{1}$) (IPCC, 2019)

| Region | Dairy | Other Cattle |
|---|---|---|
| **North America** | 138 | 64 |
| **Western Europe** | 126 | 52 |
| **Eastern Europe** | 93 | 58 |
| **Oceania** | 93 | 63 |
| **Latin America** | 87 | 78 |
| **Asia** | 78 | 54 |
| **Africa** | 76 | 52 |
| **Middle East** | 76 | 60 |
| **Indian Subcontinent** | 73 | 46 |

The Tier 2 approach can be used when more disaggregated data on livestock categories is available. Using this method requires estimation of emission factors for each animal category instead of using default values and would require collection of detailed activity data.

## Crop Production

### ▸ *Tier 1:* *Methodology for Methane Emissions from Enteric fermentation*

The Tier 1 method for quantifying GHG and air pollutant emissions from manure and synthetic fertiliser application to fields is based on the EMEP/EEA (2023) methods for developing national air pollutant emission inventories from Crop production (3.D). The EMEP/EEA (2023) Tier 1 method multiplies the amount of N applied in fertiliser or organic waste (e.g., N fertiliser, sewage sludge) by a pollutant specific emission factor. In applying this method to quantify GHG and air pollutant emissions within a company's value chain, the activity data (the amount of N applied in fertiliser or organic waste within a country) is substituted with the amount of N applied in fertiliser or organic waste used (directly or indirectly) in a company's value chain.

There are 5 steps that need to be followed in order for a Tier 1 method to be applied.

1

**Step 1: Estimating the crop production for the different types of crops.**

As mentioned above, company may produce a variety of food products that each require a combination of different ingredients produced from different types of crops. To estimate the crop production for the different types of crops, the production of a product (x) within a value chain is multiplied by the fraction by mass of product (x) that is made of a specific crop (t) to estimate the crop production for the different types of crops as shown in Equation 3.5.2.

2

**Step 2: Estimating the land area used for each type of crop.**

The crop production for the different types of crops (tonnes) is then divided by the yield for the different types of crops, to estimate the land area for each type of crop according to Equation 3.5.2:

3

**Step 3: Estimating NMVOC and PM emissions**

The land area covered by the specific type of crop is multiplied by a pollutant specific emission factor as shown in equation 3.5.9:

Eq. 3.5.9

$$Emission_{sk} = AR_{area} * EF_{k}$$

where:

$EF_k$= emission factor for pollutant k (g unit production-1)

$Emissions_{k,t}$ = emissions of the specific pollutant k (g)

AR(N_applied) = area covered by crop (ha)

Tier 1 emission factors for the Tier 1 methodology for manure and synthetic fertiliser are included in Table 3.5.6 below.

4

### Step 4: Estimating the total amount of fertiliser used for a specific type of crop

The land area for each type of crop is multiplied by a crop specific fertiliser application (synthetic and organic) rate to estimate the total amount of fertiliser used (tonnes/ha) for the specific type of crop according to Equation 3.5.10:

Eq. 3.5.10

$$\textit{Fertiliser applied}_{\textit{type of crop}} = \textit{Land area}_{\textit{type of crop}} * \textit{Application rate}_{\textit{type of crop}}$$

5

### Step 4: Estimating $NH_3$ and NO emissions

The amount of nitrogen applied the fertiliser or organic waste used is then multiplied by a pollutant specific emission factor to estimate GHG and air pollutant emissions according to equation 3.5.11.

Eq. 3.5.11

$$\textit{Emissions}_k = AR(N_{\textit{applied}})_{\textit{type of crop}} * EF_k$$

where:

$EF_k$= emission factor for pollutant k (g unit production-1)

$\text{Emissions}_{k,t}$ = emissions of the specific pollutant k (g)

$AR(N_{applied})$ = the N applied in fertiliser or organic waste (kg /a)

Tier 1 emission factors for the Tier 1 methodology for manure and synthetic fertiliser are included in Table 3.5.6 below.

**Table 3.5.6: Emission factors for the Tier 1 methodology for manure and synthetic fertiliser [Source: EMEP/EEA 2023; IPCC 2006]. Table S3.5.1, S3.5.2, and S3.5.3 should be referred for emission factors for the full list of GHG and air pollutants.**

| Pollutant | Value | Unit |
|---|---|---|
| **$NH_3$ from fertilizer** | 0.05 | kg $NH_3$ $kg^{1}$ fertiliser N applied |
| **$NH_3$ from sewage sludge** | 0.0068 or 0.13 | kg $NH_3$ $capita^{1}$ kg $NH_3$ (kg N $applied)^{1}$ |

| Pollutant | Value | Unit |
|---|---|---|
| **$NH_3$ emission from other organic wastes** | 0.08 | kg $NH_3$ (kg waste N applied)[1] |
| **NO from N applied in fertiliser, manure and excreta** | 0.04 | kg $NO_2$ kg1 fertiliser and manure N applied |
| **NO from sewage sludge** | 0.002 | kg $NO_2$ capita[1] |
| **NO emission from other organic wastes** | 0.04 | kg $NO_2$ kg[1] waste N applied |
| **NMVOC from standing crops** | 0.86 | kg ha[1] |
| **$CO_2$-C from Liming of Soil (Limestone)*** | 0.12 | tonne of C (tonne of limestone)[1] |
| **$CO_2$-C from Liming of Soil (Dolomite)*** | 0.13 | tonne of C (tonne of dolomite)[1] |
| **$CO_2$-C from Urea Fertilization*** | 0.20 | tonne of C (tonne of urea)[1] |
| ***The $CO_2$-C emissions are converted to $CO_2$ emissions by multiplying with 44/12** | | |

## Tier 1 — *Method for Methane Emissions from Rice Cultivation*

Anaerobic decomposition of organic material in flooded rice fields produces methane and it can escape to the atmosphere by transport through the rice plants. The amount of methane produced during cultivation is a function of various factors such as number and duration of crops grown, water regimes before and during cultivation period, and organic and inorganic soil amendments. The methane generated can also be impacted by the soil type, temperature, and rice cultivar. Therefore, corrections are made in the baseline emission factors using scaling factors for all these variations while accounting for methane emissions from rice cultivation. Rice cultivation can be a potential source of methane emissions across the value chain of a business depending on the annual consumption of rice by the company. Methane emissions can be estimated using Equation 3.5.12:

Eq. 3.5.12

$$E_{(CH4,Rice)}=\sum_{i,j,k} \left(EF_{i,j,k} \times t_{i,j,k} \times \frac{RC_{i,j,k}}{Y_{i,j,k}} \times 10^{(-6)} \right)$$

Where:

$CH_4$ Rice = annual methane emissions from rice cultivation, Gg $CH_4$ $yr^1$

$EF_{i,j,k}$ = a daily emission factor for i, j, and k conditions, kg $CH_4$ $ha^1$ $day^1$

$T_{i,j,k}$ = cultivation period of rice for i, j, and k conditions, day

$RC_{i,j,k}$ = total rice consumption for i, j, and k conditions, kg $yr^1$

$Y_{i,j,k}$ = rice yield for i, j, and k conditions, kg $ha^1$, the rice yields for country or region of operation can be availed from FAOSTAT (https://www.fao.org/faostat/en/#data/QCL)

i, j, and k = represent different ecosystems, water regimes, type and number of organic amendments, and other conditions under which $CH_4$ emissions from rice may vary

The baseline emission factor and scaling factor for correction depending on the varying factor of rice cultivation are available in IPCC (2019).

Table 3.5.7 provides the default yield of rice across various regions and these can be used to carry out the estimation. However, it is advisable to use country specific yields which are readily available.

**Table 3.5.7:** **Default rice yields across various regions [FAOSTAT (https://www.fao.org/faostat/en/#data/QCL)]**

| Region | Yield (kg/hectare) |
|---|---|
| **Africa** | 2313 |
| **Americas** | 6397 |
| **Asia** | 4992 |
| **Europe** | 6173 |
| **Oceania** | 9058 |

## Tier 1: Methodology for crop residue burning

The Tier 1 method for quantifying GHG and air pollutant emissions from Crop residue burning is based on the EMEP/EEA (2023) methods for developing national air pollutant emission inventories from Crop residue burning (3.F). The EMEP/EEA (2023) Tier 1 method multiplies the mass of residue burnt (kg of dry matter) by a pollutant specific emission factor. In applying this method to quantify GHG and air pollutant emissions within a company's value chain, the activity data (mass or burnt residue within a country) is substituted with the mass of burnt residue in a company's value chain. The following steps need to be taken in order to estimate GHG and air pollutant emissions from crop residue burning using the Tier 1 method:

1

**Step 1: Estimating crop production for different crops.**

As above, the production of a product (x) within a value chain is multiplied by the fraction by mass of product (x) that is made of a specific crop (t) to estimate the crop production for the different types of crops according to Equation 3.5.2.

2

**Step 2: Estimating the land area used for each type of crop.**

The crop production for the different types of crops (tonnes) is then divided by the yield for the different types of crops, to estimate the land area for each type of crop according to Equation 3.5.3.

3

**Step 3: Estimate the mass of residue burned**

To estimate the mass of residue burned, the user needs to multiply the crop production (tonnes) by the residue to crop ratio (Table 3.5.8) by a dry matter fraction (assumed constant, 85%) by the fraction burned in fields (assumed constant, 25%) and by the fraction oxidized (assumed constant, 90%) according to Equation 3.5.13.

Eq. 3.5.13

$$\text{Mass of residue burned} = \text{Crop production}i * \text{Residue to crop ratio}i * \text{Dry matter fraction} * \text{Dry matter fraction} * \text{Fraction oxidised}$$

**Table 3.5.8:** Residue to crop ratios [Source: EMEP/EEA, 2023] for the different types of crops.

| | |
|---|---|
| **Wheat** | 1.3 |
| **Barley** | 1.2 |
| **Maze** | 1 |
| **Oats** | 1.3 |
| **Rye** | 1.6 |
| **Rice** | 1.4 |
| **Peas** | 1.5 |
| **Beans** | 2.1 |
| **Soya** | 2.1 |

## 4 Step 4: Estimating GHG and air pollutant emissions

The amount of residue burnt (kg of dry matter) is multiplied by a pollutant specific emission factor to estimate GHG and air pollutant emissions according to Equation 3.5.14.

Eq. 3.5.13

$$Emissions_{k,t} = MR_{burned} * EF_{k,t}$$

where:

$MR_{burned}$= The mass of residue burned (kg)

EFk,t = emission factor for pollutant k (kg)

$Emissions_{k,t}$ = emissions of the specific pollutant k (kg)

The Tier 1 emission factors are included in the SI.

## 3.5.3 Example

# Agriculture

### Livestock: Manure Management

**Scenario:** Amount of cattle meat consumed by the company = 20000 kg

The farm uses a mixture of solid storage (60% of manure) and liquid/slurry storage (40% of manure). The cattle spend 70% of their time in housing. 20% in uncovered yards, and 10% grazing. The goal is to estimate $NH_3$ emissions using a Tier 2 approach.

1 **Step 1: Estimating the Number of Livestock**

Using equation 4.23 and assuming the company is operating in asia (Meat yield for cattle = 162.2) - Number of cattles used = 20000/ 162.2 = 123 cattle

2 **Step 2: Disaggregating the Number of Livestock by Manure Handling and Housing Time**

We calculate the amount of manure handled using solid storage and liquid/slurry storage systems.

**Solid storage:**

Time spent in housing: 70 % × 60 % = 42 %
Time spent in uncovered yards: 20 % × 60 % = 12 %
Grazing: 10% × 60% = 6%

**Liquid/slurry storage:**

Time spent in housing: 70% × 40% = 28%
Time spent in uncovered yards: 20% × 40% = 8%
Grazing: 10% × 40% = 4%

3 **Step 3: Estimating $NH_3$ Emissions from Manure Management**

We apply emission factors specific to each type of manure management and housing condition.

Assume the following emission factors for $NH_3$:
Solid storage (housing): 3 kg $NH_3$:/head/year
Solid storage (uncovered yards): 1.5 kg $NH_3$:/head/year
Grazing: 0.5 kg $NH_3$:/head/year
Liquid/slurry storage (housing): 4 kg $NH_3$:/head/year
Liquid/slurry storage (uncovered yards): 2 kg $NH_3$/head/year

Now, we calculate emissions for each condition:

### Solid Storage Emissions:

**Housing:**
$NH_3$: Emissions= 123 x 42% x 3= 155 kg

**Uncovered yards:**
$NH_3$: Emissions = 123 × 12% × 1.5 = 22 kg

**Grazing:**
$NH_3$: Emissions= 123 x6% x 0.5= 3.7 kg

### Liquid/Slurry Storage Emissions:

**Housing:**
$NH_3$: Emissions= 123 x 28% x 4= 138 kg

**Uncovered yards:**
$NH_3$: Emissions= 123 x 8% x 2= 20 kg

**Grazing:**
$NH_3$: Emissions= 123 x 4% x 0.5= 2.5 kg

## 3.5.4 References

EMEP/EEA. (2019). EMEP/EEA air pollutant emission inventory guidebook 2019: Technical guidance to prepare national emission inventories (EEA Report No. 13/2019). European Environment Agency. https://www.eea.europa.eu/publications/emep-eea-guidebook-2019

European Environment Agency. (2023). EMEP/EEA air pollutant emission inventory guidebook 2023. https://www.eea.europa.eu/en/analysis/publications/emep-eea-guidebook-2023

Intergovernmental Panel on Climate Change. (2006). 2006 IPCC guidelines for national greenhouse gas inventories. IGES. https://www.ipcc-nggip.iges.or.jp/public/2006gl/

Intergovernmental Panel on Climate Change. (2019). 2019 refinement to the 2006 IPCC guidelines for national greenhouse gas inventories. https://www.ipcc-nggip.iges.or.jp/public/2019rf/

# 3.6 Estimating Greenhouse Gas and Air Pollutant Emissions from Waste

**Quote as:** CCAC and SEI (2025). Section 3.6 Estimating Greenhouse Gas and Air Pollutant Emissions from Waste, in Guide for Private Sector Integrated Greenhouse Gas and Air Pollutant Emission Assessment. Climate and Clean Air Coalition and Stockholm Environment Institute, Paris.

URL: https://www.ccacoalition.org/resources/integrated-guide-business-greenhouse-gas-and-air-pollutant-emission-assessment

This section of the Guide 2.0 explains how the emissions of greenhouse gas (GHGs), Short-Lived Climate Pollutants (SLCPs), classical air pollutants and heavy metals (HM) (hereafter referred to as greenhouse gas and air pollutants as defined in Chapter 1) that are related to waste management activities at different parts of a company's value chain can be quantified.

This section is structured by first describing the source, then describing the methods, which includes Tier 1 emission factors. The Tier 2 methods are explained in this document, but the Tier 2 (as well as the Tier 1) emission factors are linked to a database where these default values can be found (https://www.ccacoalition.org/resources/integrated-guide-business-greenhouse-gas-and-air-pollutant-emission-assessment). The section then includes an example calculation using the methods and then provides the references for the methods and data.

## 3.6.1 Description of the Source

As shown in Chapter 2, waste treatment and management can be a source of greenhouse gas and air pollutant emissions at different stages of a value chain. Waste generation has been substantially increasing over the last decade with waste generated in cities having increased from 680 million tonnes to 1.3 billion tonnes per year from 2000-2012. The pollutants emitted from various waste treatment and management practices Carbon Dioxide ($CO_2$), Methane ($CH_4$), Nitrous Oxide ($N_2O$), Particulate Matter ($PM_{10}$, $PM_{2.5}$), Carbon Monoxide (CO), Non-methane volatile organic compounds (NMVOCs), Ammonia ( $NH_3$), Black Carbon (BC), Lead (Pb), Mercury (Hg), Cadmium (Cd), Arsenic (As), Chromium (Cr), Copper (Cu), Nickel (Ni), Selenium (Se), Zinc (Zn). Emissions of greenhouse gases and air pollutants and short-lived climate pollutants from waste, depend on the waste composition and how the different types of waste are disposed of and treated. Different waste management practices include landfill disposal, recycling, composting, and burning of waste.

The burning of different types of waste (e.g., food, paper, plastic) is a large source of greenhouse gas and air pollutants such as black carbon, a key component of particulate matter air pollution, but also carbon monoxide, non-methane volatile organic compounds, nitrogen oxides, sulphur dioxide, organic carbon and ammonia. However, emission levels can vary substantially depending on whether the waste is openly burned or if it is incinerated using clean technologies that promote efficient controlled combustion. With composting, it is the organic waste (e.g., food, garden waste) that is a key source of ammonia.

In national GHG and air pollutant emission inventory guidance, the methodologies used for quantifying GHG and air pollutant emissions from waste broadly consider two key variables: the percentage of different types of waste generated on a national level, and the different waste treatment processes used within the country. However, waste generation rates, waste composition and waste treatment practices will vary substantially between different countries depending on income levels, consumption models and infrastructure. This is a key difference between a national GHG and air pollutant emission inventory and the Guide 2.0. The user of this Guide will need to consider the waste generation rates, composition of waste and waste treatment processes in the different locations where these occur.

For example, for the waste that is burned (or incinerated) the EMEP/EEA (2023) methods are as follows:

1. Multiplying the amount of waste that is incinerated or openly burned by pollutant specific emission factors. This 'Tier 1' method is described in EMEP/EEA (2023)
2. The 'Tier 2' methodology, described in detail in EMEP/ EEA (2023) is very similar to the 'Tier 1' method as it uses the same principle, multiplying the amount of waste by a pollutant specific emission factor, but the equation can also account for the different types of technology (e.g., abatement) used.

However, both the amount of waste that is burned, and the processes that are used to burn the waste, so whether it is incinerated using different technologies or is openly burned, can be different depending on the stage of the value chain but also the location where the waste occurs.

The methods described below use the same principles presented in the IPCC and EMEP/EEA guidelines but are modified to consider the different stages of the value chain. For the different stages of the value chain, the user needs to have (or to be able to obtain) data on the amount of waste that is generated, then to disaggregate the amount of waste generated into different types of waste, which then needs to be disaggregated further into the different types of waste disposal and management.

## 1 Step 1: Estimating waste generated at different stages of the value chain.

The user first needs to estimate how much waste is generated (tonnes) in the different stages of the value chain. Depending on the level of information that is available and the data that is collected from the different companies, the total amount of waste generating in the different stages of the value can be estimated using different methods.

a. Direct collection of the amount of waste generated during different stages of the value chain.
b. Estimating waste generated in the different processes using production data where waste is estimated by multiplying the amount of material used (tonnes) by the fraction of material wasted according to Equation 3.6.1.

Eq. 3.6.1

$$Waste = Material\ used * Fraction\_Waste$$

For example, if 2500 kg of wood are required to make a specific product (e.g., chair, table) and 20% is the fraction that is wasted in process A, then 500 kg of waste has been generated through that specific process.

c. Estimating the total amount of waste using (a) or (b) and considering waste that is diverted to be reused and recycled.

The user will have company specific data that is collected throughout the different parts of the value chain, or for a specific part of the value chain (e.g., retail), or will be able to obtain information from suppliers and external partners such as waste treatment companies.

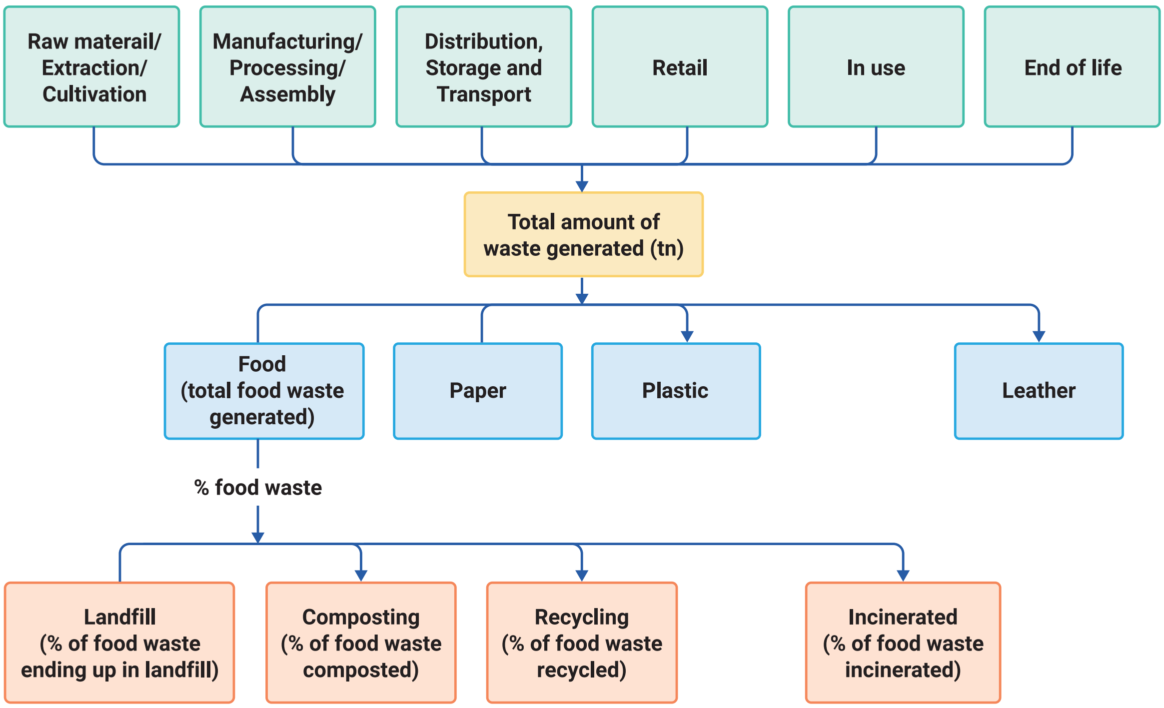
## 2 Step 2: Disaggregating the total amount of waste generated by different types of waste.

Waste composition is one of the key factors influencing emissions from solid waste treatment. Waste composition is dependent on several factors like the level of economic development, climate, cultural norms etc. Waste can be classified as organic and inorganic. The organic waste (e.g., food, paper) is primarily composed of biodegradable carbon but may also contain small amounts of non-biogenic or synthetic carbon due to the presence of materials like coating, inks, and packaging. Overall, different types of waste contain varying amounts of non-biogenic carbon and Degradable Organic Carbon (DOC). The total amount of waste generated therefore, then needs to be disaggregated by type of waste. This means that the user needs to identify the percentage of waste (fraction of the total waste generated) for each of the categories below.

- food waste
- garden waste
- paper and cardboard
- wood
- textiles
- rubber and leather
- plastics
- metal
- glass
- other (e.g., ash, dirt, dust, soil, electronic waste).
- Industrial (hazardous waste and sewage sludge)
- Clinical waste

An example flowchart of the different levels of disaggregation is shown in Figure 3.6.1.

**Figure 3.6.1:** Flowchart demonstrating the different levels of disaggregation required for the Tier 1 methodology for waste.



## 3.6.2 Methodologies for Quantifying emissions

Both forms of waste management i.e solid waste management as well as liquid waste discharge can lead to GHG emissions. However, air pollutant emissions are associate with management of solid waste. Therefore, in addition to discussing methods for GHG and air pollutant emissions from solid waste management, this section also covers methods to estimate GHG emissions from liquid waste discharge. The pollutants covered under these methods are NMVOCs, CO, $PM_{10}$, $PM_{2.5}$, $NH_3$, Pb, Hg, Cd, As, Cr, Cu, Ni, Se, Zn, BC, $CO_2$, $CH_4$, and $N_2O$.

### Solid Waste Management

▸ *Tier 1:*

#### *Methodology for Solid Waste*

The Tier 1 method for quantifying air pollutant emissions from waste is based on the EMEP/EEA (2023) methods for developing national air pollutant emission inventories from waste. EMEP/EEA (2023) Tier 1 method multiplies the total amount of waste generated by pollutant- specific emission factors for the different types of waste treatment. In applying this method to quantify air pollutant emissions within a company's value chain, the activity data (production) used is the total amount of the different types of waste generated in the different stages of a company's value chain. The Tier 1 method is shown in Equation 3.6.2:

Eq. 3.6.2

$$Emissions_{k,t,c} = WD_c * EF_{k,t}$$

where:

WDt = The tonnes of the total amount of the different types of waste (c) (tonnes) that is disposed using the different types of waste disposal

EFk,t = emission factor for pollutant k for type of treatment t (g unit production-1)

Emissionsk,t = emissions of the specific pollutant k for type of treatment t (g)

The default emission factors, from EMEP/EEA (2023) are summarised in Table 3.6.1 below.

**Table 3.6.1: Summary of default emission factors for Tier 1 method for quantifying air pollutant emissions from waste [Source: EMEP/EEA, 2019]. Table S3.6.1 and S3.6.3 should be referred for emission factors for the full list of air pollutants.**

| Waste treatment | Units | $PM_{10}$ | $PM_{2.5}$ | BC %of $PM_{2.5}$ | NMVOCs | CO | $NH_3$ | $NO_x$ | $SO_2$ | Pb | Hg | Cd |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Biological treatment of waste - Solid waste disposal on land** | kg/Mg of waste | 0.033 | 0.219 | - | 1.56 | - | - | - | - | | | |
| **Biological treatment of waste- Composting** | kg/Mg of waste | - | - | - | - | 0.56 | 0.66 | - | - | | | |
| **Municipal waste incineration** | g/Mg of waste | 3 | 3 | 3.5 | 5.9 | 41 | 3 | 1071 | 87 | | | |
| **Open burning of waste** | kg/Mg of waste | 4.51 | 4.19 | 42 | 1.23 | 55.83 | - | 3.18 | 0.11 | | | |
| **Industrial waste incineration** | kg/Mg of waste | 0.007 | 0.004 | 3.5 | 7.4 | 0.07 | - | 0.87 | 0.047 | | | |

## Tier 1: Methodologies for $CH_4$ and $N_2O$ emissions

Biological treatment of waste such as composting and anaerobic digestion are common practices in waste treatment in both developed and developing regions. Biological treatment gives certain advantages ranging from reduction in waste material volume, stabilization of waste, destruction of pathogens in the waste, and producing energy in the form of biogas. Additionally, the end products can be used as fertilizers and soil amendment or can be disposed of in solid waste disposal systems. However, biological treatment of waste can emit $CH_4$ and $N_2O$ and these should be reported while estimating greenhouse gas emissions from waste sector.

Estimating $CH_4$ and $N_2O$ emissions from biological treatment of solid waste would involve collection of data on amount and composition of solid waste while also disaggregating the waste according to their disposal and treatment category as discussed earlier in this section.

## $CH_4$ emissions from biological treatment of waste

Eq. 3.6.3

$$E_{CH4} = \sum_i (M_i * EF_i) * 10^3 - R$$

Where,

$E_{CH4}$= Total $CH_4$ emission from biological treatment of waste Gg $CH_4$

Mi= Organic waste mass by treatment type i, Gg

EF = emission factor for treatment i, g $CH_4$/kg waste treated

i = Biological treatment category

R = total amount of $CH_4$ recovered, Gg $CH_4$

While reporting $CH_4$ emissions from anaerobic digestion, the amount of recovered gas that is used in a flare or an energy device should be subtracted from the amount of $CH_4$ generated and is expressed as R in the equation 3.6.4. The emissions from combustion of recovered gas are not significant.

## $N_2O$ emissions from biological treatment of waste

Eq. 3.6.4

$$E_{N2O} = \sum_i (M_i * EF_i) * 10^3 - R$$

Where,

$E_{CH4}$= Total $CH_4$ emission from biological treatment of waste Gg $N_2O$

Mi= Organic waste mass by treatment type i, Gg

EF= emission factor for treatment i, g N2O/kg waste treated

i= Biological treatment category

Table 3.6.2 provides default emission factors for $CH_4$ and $N_2O$ emissions from biological treatment of waste. It should be noted that these emissions factors assume 25-50% DOC in dry matter, 2% N in dry matter, moisture content 60%. The emission factors for dry waste are estimated from those for wet waste assuming a moisture content of 60% in wet waste. For Tier 2 estimation of $CH_4$ and $N_2O$, the emissions factors should be based on representative measurements that cover relevant biological treatment options applied in the country.

**Table 3.6.2:** **Default tier 1 emission factors for $CH_4$ and $N_2O$ emissions from biological treatment of waste (IPCC, 2019)**

| Type of biological treatment | $CH_4$ Emission Factors (g $CH_4$/kg waste treated) | | $N_2O$ Emission Factors (g $N_2O$/kg waste treated) | |
|---|---|---|---|---|
| | Dry weight basis | Wet weight basis | Dry weight basis | Wet weight basis |
| **Composting** | 10 (0.08 - 20) | 4 (0.03 - 8) | 0.6 (0.2 - 1.6) | 0.24 (0.06 - 0.6) |
| **Anaerobic digestion at biogas facilities** | 2 (0 - 20) | 0.8 (0 - 8) | Assumed negligible | Assumed negligible |

Note: Default emission factors for CH4 for anaerobic digestion already account for CH4 recovery.

## *$CH_4$ emission from Solid Waste Disposal*

Significant $CH_4$ emissions can result from treatment disposal of municipal, industrial, and other solid waste. Solid waste disposal sites can also emit biogenic carbon dioxide and small amounts of nitrous oxide. $CH_4$ produced at solid waste disposal sites contributes a major fraction of annual anthropogenic greenhouse gas emissions and should be reported while reporting emissions from a company's value chain.

The estimation of $CH_4$ emissions from solid waste disposal sites follows a First Order Decay (FOD) method. The method assumes that the degradable organic component (degradable organic carbon, DOC) in waste decays slowly throughout a few decades, during which $CH_4$ and $CO_2$ are formed. In case, the conditions are assumed constant the $CH_4$ production is solely based on amount of carbon remaining in the waste. It can be inferred that $CH_4$ emissions from waste deposited on disposal sites are high during first few years of deposition and reduced gradually in following years as degradable carbon in the waste is consumed by the bacteria responsible for decay.

Significant $CH_4$ emissions from solid waste disposed in past years warrants the need to estimate current emissions from solid waste deposited during these preceding years. Therefore, it is suggested that good quality historical data on solid waste disposal during past 10 year or more should be used during emission estimation.

The methane generation potential of the disposed waste will decrease gradually; therefore, methane generation is estimated using the amount of Degradable Organic Matter (DOCm) in the deposited waste material. The methodology followed to estimate methane generation in specific year and the amount of Decomposable DOCm is provided in IPCC, 2019 and should be followed for the estimation process. The $CH_4$ recovered must be subtracted from the amount $CH_4$ generated. Only the fraction of $CH_4$ that is not recovered will be subject to oxidation in the Solid Waste Disposal Sites cover layer.

# Liquid Waste Discharge

## ▸ Tier 1: Methodology for wastewater treatment and discharge

**Methane emissions from Industrial wastewater**

Industrial wastewater is either treated onsite or releases into the domestic wastewater sewer. The current section discusses the methane emissions from wastewater treated onsite and if it is released in domestic sewers, the emission estimation is carried out assuming it is as domestic wastewater. Methane is produced from industrial wastewater with significant carbon loading that is treated under anaerobic conditions.

Assessment of $CH_4$ production potential from industrial wastewater streams is based on the concentration of degradable organic matter in the wastewater, the volume of wastewater, and the propensity of the industrial sector to treat their wastewater in anaerobic systems.

The general equation to estimate methane emissions from industrial wastewater is provided in equation 3.6.6.

Eq. 3.6.5

$$E_{N2O} = \sum_i (M_i * EF_i) * 10^3 - R$$

Where,

$E_{CH4}$= $CH_4$ emissions, Gg $CH_4$/year

TOWi = total organically degradable material in wastewater from industry i in inventory year, kg COD/yr

i = industrial sector

Si = organic component removed from wastewater (in the form of sludge) in inventory year, kg COD/yr

EFi = emission factor for industry i, kg $CH_4$/kg COD for treatment/discharge pathway or system(s) used in inventory year

If more than one treatment practice is used in an industry this factor would need to be a weighted average.

Ri = amount of $CH_4$ recovered or flared in inventory year, kg $CH_4$/yr

10-6 = conversion of kg to Gg

Table 3.6.3 provides default emission factors industrial wastewater based on type of wastewater treatment and discharge system.

**Table 3.6.3:** Emission factors for industrial wastewater based on type of wastewater treatment and discharge system.

| Type of treatment and discharge pathway or system | EF (kg $CH_4$/kg BOD) | EF (kg $CH_4$/kg COD) |
|---|---|---|
| **Discharge to aquatic environments (Tier 1)** | 0.068 | 0.028 |
| **Discharge to aquatic environments other than reservoirs, lakes, and estuaries (Tier 2)** | 0.021 | 0.009 |
| **Discharge to reservoirs, lakes, and estuaries (Tier 2)** | 0.114 | 0.048 |
| **Anaerobic reactor (e.g., upflow anaerobic sludge blanket digestion (UASB))** | 0.48 | 0.2 |
| **Anaerobic shallow lagoon and facultative lagoons** | 0.12 | 0.05 |
| **Anaerobic deep lagoon** | 0.48 | 0.2 |

## *Nitrous oxide emissions from industrial wastewater*

Nitrous oxide emissions can occur as emissions from Wastewater Treatment Plants (WWTPs) or as emissions from receiving aquatic environments following the disposal of untreated or treated wastewater effluent. More recent research and field surveys have revealed that emissions in sewer networks and from nitrification or nitrification-denitrification processes at WWTPs, previously judged to be a minor source, may in fact result in more substantial emissions. $N_2O$ is generated as a by-product of nitrification, or as an intermediate product of denitrification. There are many factors affecting $N_2O$ emissions from wastewater treatment systems such as the temperature and dissolved oxygen concentration of the wastewater, and the specific operational conditions. Emissions can be calculated using Equation 3.6.7.

Eq. 3.6.6

$$E_{(TP,N2O)} = [\sum_i (T_{i,j} \times EF_i \times TN_{INDi})] \times \frac{44}{28}$$

Where:

$E_{TP,N_2O}$ = $N_2O$ emissions from industrial wastewater treatment plants in inventory year, kg

$N_2O$/yr $TN_{INDi}$ = total nitrogen in wastewater from industry i in inventory year, kg N/yr.

$T_{i,j}$ = degree of utilisation of treatment/discharge pathway or system j, for each industry i in inventory year

i = industryj = each treatment/discharge pathway or system

EFj = emission factor for treatment/discharge pathway or system j, kg $N_2O$-N/kg N.

The factor 44/28 is for the conversion of kg $N_2O$-N into kg $N_2O$.
The activity data for this source category is the amount of total nitrogen (TN) in the industrial wastewater entering treatment (TNIND). This parameter is a function of industrial output (product) P (tonnes/yr), wastewater generation W ($m^3$/ton of product), and total N concentration in the untreated wastewater (kg TN/$m^3$).

Eq. 3.6.8

$$TN_{INDi} = P_i \times W_i \times TN_i$$

Where:

$TN_{INDi}$ = total nitrogen in wastewater entering treatment for industry i, kg TN/yr i = industrial sector

$P_i$ = total industrial product for industrial sector i, t/yr

$W_i$ = wastewater generated for industrial sector i, $m^3$/t product

$TN_i$ = total nitrogen in untreated wastewater for industrial sector i, kg TN/$m^3$

It is also required to estimate $N_2O$ emissions from wastewater treatment effluent that is discharged into aquatic environments. The emissions can be calculated using Equation 3.6.9.

Eq. 3.6.7

$$E_{effluent,N2O} = N_{effluent} \times EF_{effluent} \times \frac{44}{28}$$

Where:

$N_2O_{effluent}$ = $N_2O$ emissions from industrial wastewater effluent in inventory year, kg $N_2O$/yr

$N_{effluent}$ = nitrogen in the industrial wastewater effluent discharged to aquatic environments, kg N/yr.

$EF_{effluent}$ = emission factor for $N_2O$ emissions from wastewater discharged to aquatic systems, kg $N_2O$-N/kg N

The factor 44/28 is for the conversion of kg $N_2O$-N into kg $N_2O$.

The emission factor for $N_2O$ emissions from wastewater discharged to aquatic systems are provided in table 3.6.4.

**Table 3.6.4:** $N_2O$ emissions from industrial wastewater treatment plants and effluent discharge

| Type of treatment and discharge pathway or system | EF (kg $N_2O$ -N/kg N) | Range |
|---|---|---|
| **Discharge from treated or untreated system, EFEFFLUENT** | | |
| **Freshwater, estuarine, and marine discharge (Tier 1)** | 0.0052 | 0.0005 – 0.075 |
| **Nutrient-impacted and/or hypoxic freshwater, estuarine, and marine environments (Tier 3, if needed)** | 0.0192 | 0.0041 – 0.091 |
| **Wastewater treatment system, EFplants** | | |
| **Centralised, aerobic treatment plant** | 0.0161 | 0.00016 – 0.045 |
| **Anaerobic reactor** | 0 | 0 – 0.001 |
| **Anaerobic lagoons** | 0 | 0 – 0.001 |
| **Septic tank** | 0 | 0 – 0.001 |
| **Septic tank + land dispersal field** | 0.0045 | 0 – 0.005 |
| **Latrine** | 0 | 0 – 0.001 |

## 3.6.3 Example

# Waste

### Example Scenario:

A company operates in multiple stages of a value chain and generates a total of 1,500 tonnes of waste annually. The waste composition is as follows:

**Food waste:** 20%; Plastic waste: 15%; Paper waste: 25%; Wood waste: 10%; Other waste: 30%

Of this total waste, 30% is openly burned. We will calculate the $PM_{2.5}$ emissions from the open burning of this waste.

1

### Step 1: Calculate the Total Waste Openly Burned

First, calculate the total amount of waste that is openly burned:

Total Waste Openly Burned = Total Waste × Percentage Openly Burned
Total Waste Openly Burned = 1,500 tonnes × 30 % = 450 tonnes

2

### Step 2: Disaggregate Waste by Type

Next, we need to disaggregate the waste into different types for calculating emissions. We'll assume that the percentage of each type of waste burned matches the overall waste composition.

Food waste burned: 45 0tonnes × 20% = 90tonnes
Plastic waste burned: 450 tonnes × 15% = 67.5 tonnes
Paper waste burned: 450 tonnes × 25% = 112.5 tonnes
Wood waste burned: 450 tonnes × 10% = 45 tonnes
Other waste burned: 450 tonnes × 30% = 135 tonnes

3

### Step 3: Calculate PM2.5 Emissions Using Tier 1 Method

Using the default emission factor for $PM_{2.5}$ from open burning of waste (from Table 4.25):
$PM_{2.5}$ Emission Factor (Open Burning) = 4.19kg/Mg of waste

(Note: 1 Mg = 1 tonne)

Now, calculate the $PM_{2.5}$ emissions for the entire waste:

$PM_{2.5}$ Emissions = Total Waste Openly Burned × $PM_{2.5}$ Emission Factor

$PM_{2.5}$ Emissions = 450 tonnes × 4.19kg/tonne

$PM_{2.5}$ Emissions = 1,885.5 kg (or 1.89 tonnes)

## 3.6.4 References

EMEP/EEA. (2019). EMEP/EEA air pollutant emission inventory guidebook 2019: Technical guidance to prepare national emission inventories (EEA Report No. 13/2019). European Environment Agency. https://www.eea.europa.eu/publications/emep-eea-guidebook-2019

European Environment Agency. (2023). EMEP/EEA air pollutant emission inventory guidebook 2023. https://www.eea.europa.eu/en/analysis/publications/emep-eea-guidebook-2023

Intergovernmental Panel on Climate Change. (2006). 2006 IPCC guidelines for national greenhouse gas inventories. IGES. https://www.ipcc-nggip.iges.or.jp/public/2006gl/

Intergovernmental Panel on Climate Change. (2019). 2019 refinement to the 2006 IPCC guidelines for national greenhouse gas inventories. https://www.ipcc-nggip.iges.or.jp/public/2019rf/

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