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TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS
a UNEP convened initiative

Integrated Guide for Business Greenhouse Gas and Air Pollutant Emission Assessment

CHAPTER 3.3 Estimating Greenhouse Gas and Air Pollutant Emissions from Transport

SEI Stockholm Environment Institute

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Design and Layout
Biyoke (Ying) Madavisid

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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 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^{-1}vehicle-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

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