Integrated Guide for Business Greenhouse Gas and Air Pollutant Emission Assessment

CLIMATE & CLEAN AIR COALITION
TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS
a UNEP convened initiative

SEI Stockholm Environment Institute

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Executive Summary

Air pollution and climate change are two of the biggest environmental issues that are faced globally.

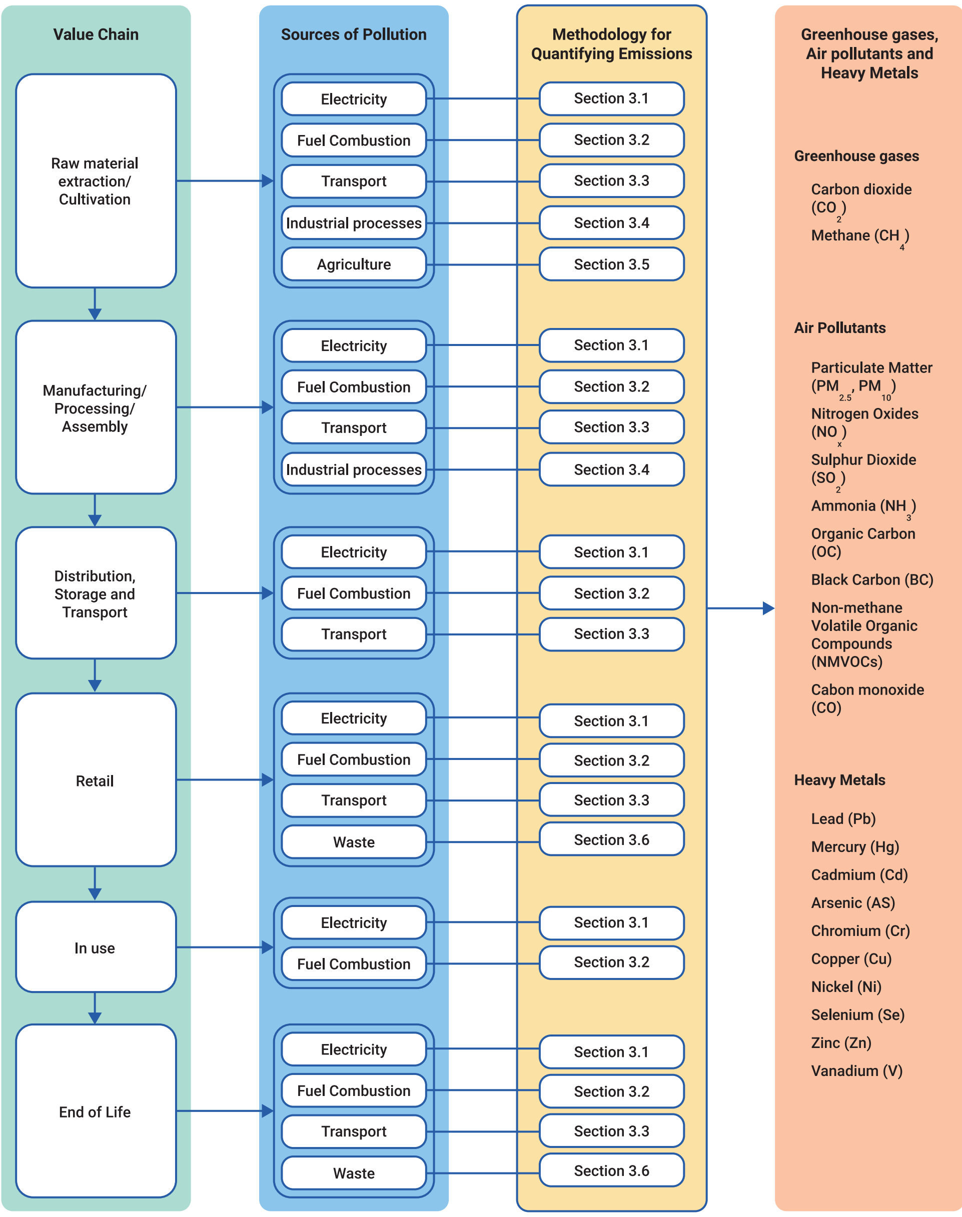
Air pollution is the largest environmental risk to public health globally. Exposure to indoor and outdoor fine particulate matter is associated with an estimated 7 million premature deaths each year (Murray et al. 2020) and is responsible for millions more non-fatal health outcomes such as an increase in emergency-room visits related to exacerbated asthma, and adverse pregnancy outcomes. Apart from the substantial impacts on human health, air pollution can also harm ecosystems and biodiversity reducing crop yields, impacting food security, physically damaging vegetation and reducing capacity to store carbon.

Air pollution and climate change are strongly linked. All major air pollutants have an impact on the climate and most share common sources with greenhouse gases (GHGs), especially related to the combustion of fossil fuels. The group of pollutants, called 'Short-Lived Climate Pollutants' (SLCPs), which include black carbon, ground-level ozone, methane, and hydrofluorocarbons (HFCs), are highly potent climate forcers and – in the case of ozone and black carbon – dangerous air pollutants. Air pollution also has huge economic costs related to human health, lost productivity, reduced crop yields and reduced competitiveness of globally connected cities. For example, the global cost of health damages from outdoor air pollution in 2019 was estimated to be US$8.1 trillion, an economic value equivalent to 6.1 percent of global Gross Domestic Product (GDP) in that year (World Bank 2022).

The private sector contributes to the emissions of greenhouse gases, Short-Lived Climate Pollutants, classical air pollutants and heavy metals (hereafter referred to as greenhouse gas and air pollutants) through the different activities that are taking place within their value chains. The combustion of fuel, consumption of electricity, disposal of waste and the transportation of goods, materials and passengers are some of the activities that could be substantially contributing to a company's greenhouse gas and air pollutant emissions. Specifically for air pollution, the contribution of the private sector has not been adequately quantified partly because there has been no guidance offering a comprehensive set of methods that would allow emissions from the various key sources along value chains to be identified and quantified. In this context, the Integrated Guide for Business Greenhouse Gas and Air Pollutant Emission Assessment (2025) is intended to be used for the development of integrated greenhouse gas and air pollutant emissions inventories of companies and businesses regardless of their size, product or service offered, and which industry they belong to. This version of the Guide is the first update to the 'Practical Guide for Business Air Pollutant Emission Assessment' (2022), the 'Integrated Guide for Business Greenhouse Gas and Air Pollutant Emission Assessment' (2025) hereafter referred to as 'the Guide' or 'the Guide 2.0'.

The Guide 2.0 uses two organising principles to develop a method for the comprehensive accounting of emissions from a particular business, the value chain of the business, and the sources of emissions that produce emissions at different points within the value chain, as illustrated in Figure i. The user can follow the six-step approach that is presented in this Guide in order to develop the air pollutant emission inventory: 1) mapping the value chain, 2) identifying key sources of pollution, 3) identifying the appropriate methodology for quantifying emissions, 4) identifying appropriate activity data, 5) choosing the appropriate emission factors, and 6) quantifying emissions. This Guide includes the appropriate methods and emission factors that allow the user to quantify air pollutant emissions from six key sources: electricity consumption, stationary fuel combustion, transport, industrial processes, agriculture and waste. This Guide focuses on quantifying the emissions of directly emitted Carbon dioxide (CO_2), Methane (CH_4), Particulate Matter ($PM_{2.5}$, PM_{10}), Black Carbon (BC), Organic Carbon (OC), Nitrogen Oxides (NO_x), Suphur Dioxide (SO_x), Ammonia (NH_3), Non-Methane Volatile Organic Compaounds (NMVOCs), Lead (Pb), Mercury (Hg), Cadmium (Cd), Arsenic (As), Cromium (Cr), Copper (Cu), Nickel (Ni), Selenium (Se), Zinc, Vanadium (V). The guide concentrates on these as they are the air pollutants identified as having the largest impact on human health by the World Health Organisation (WHO).

Figure i: **Generic value chain (from raw material extraction, through manufacturing, retail, use and disposal) and possible sources of greenhouse gas and air pollutant emissions (electricity generation associated with use, transport and process emissions) at different points in the value chain.**



Finally, the Guide introduces approaches to mitigation and implementation and how an emissions inventory can be used for decision making by different companies.

01 Introduction and Background

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This section of the Guide 2.0 gives introductory information regarding the sources and impacts 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) emissions.

1.1 Introduction

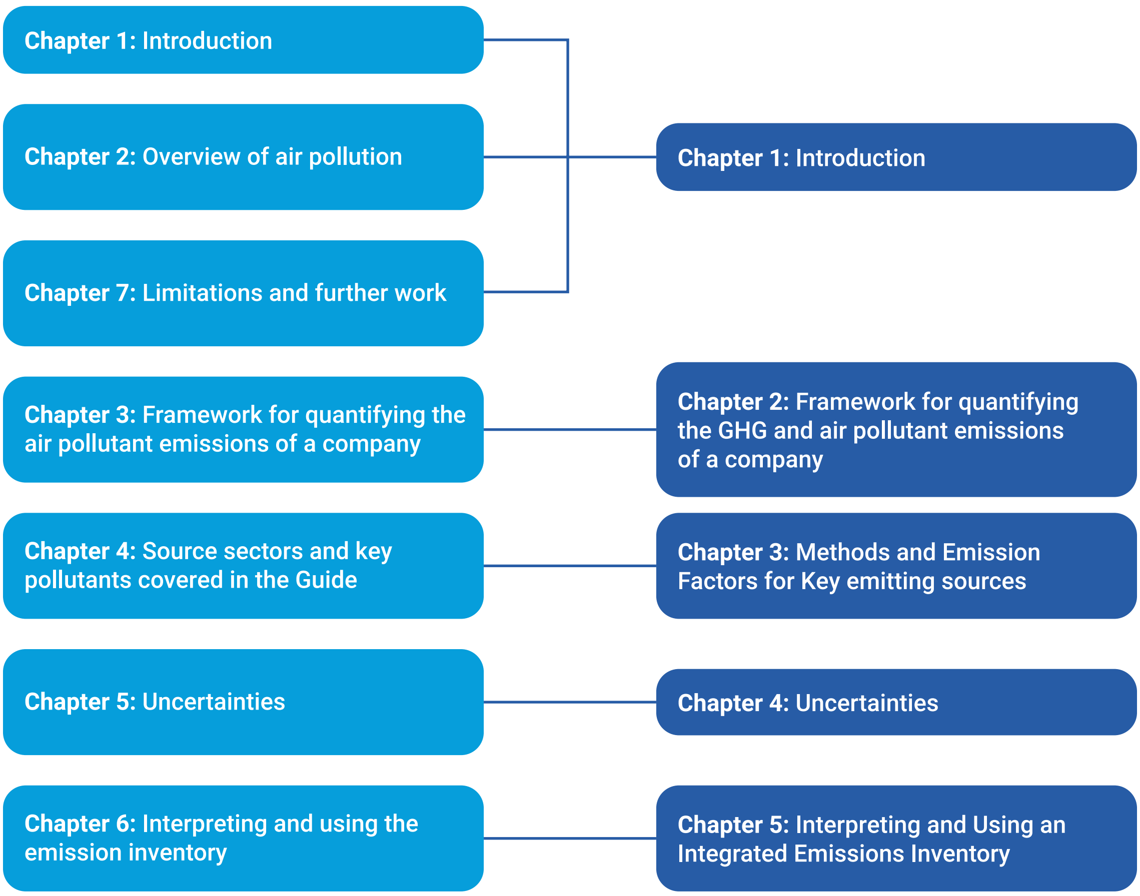
The 'Practical Guide for Business Air Pollutant Emission Assessment' (2022) was developed to enable private sector companies to quantify air pollutant emissions across their entire value chain. This version of the Guide is the first update to the 'Practical Guide for Business Air Pollutant Emission Assessment', the 'Integrated Guide for Business Greenhouse Gas and Air Pollutant Emission Assessment' (2025) hereafter referred to as 'the Guide' or 'the Guide 2.0'. The aim of the Guide 2.0 is to expand the scope of the previous version which only focused on air pollutants, and to provide businesses with practical guidance that will enable them to quantify i) greenhouse gas (GHGs), ii) short-lived climate pollutants (SLCPs), iii) classical air pollutants and iv) heavy metal (HM) emissions across their value chains. For brevity, the full set of emissions to the atmosphere covered by this Guide are referred to as 'greenhouse gas and air pollutant emissions' unless otherwise stated.

The Guide 2.0 provides methods and emission factors that allow for the consistent quantification of greenhouse gas and air pollutant emissions, therefore providing companies with the ability to develop integrated greenhouse gas and air pollutant emission inventories and enable them to report on these emissions (if they need to/choose to). The development of an integrated greenhouse gas and air pollutant emissions inventory is the initial step in understanding the magnitude of different emissions across a business and allows for specific parts of a value chain that simultaneously have emissions contributing to climate change and air pollution to be identified. The integration of these methods under one coherent framework further allows for integrated greenhouse gas and air pollutant emissions mitigation pathways to be developed as actions to reduce one type of emissions (e.g., greenhouse gases) will often also reduce other emissions as well (e.g., air pollutant emissions). The methodologies to estimate emissions presented in the Guide 2.0 (Chapter 3) provide the starting point for projecting how a company's emissions may change into the future, specific guidance for which will be developed as an additional part of the guide. This will allow companies to develop mitigation pathways that consider how their impact(s) on climate change, air quality and public health can be reduced at the same time.

The Guide 2.0 is sector agnostic, meaning that the methods described in the Guide are applicable to any industry and economic sector, and are designed both to be used by companies that currently have an existing GHG emission inventory system(s), to extend and integrate these systems to also quantify air pollutants, or to be used as a standalone Guide for quantification of greenhouse gas and air pollutant emissions across their value chain. It can be used by large, as well as small and medium enterprises (SMEs).

The Guide 2.0 contains several updates to the previous version of Chapters 1 to 6 such as the addition of carbon dioxide (CO_2), methane (CH_4), and heavy metals (e.g., cadmium, arsenic, lead and mercury). Changes to the chapters also include practical examples of the implementation of the methods outlined and the merging of certain chapters as per Figure 1.1 below. These changes were in part informed by user feedback, companies' needs and reporting requirements as well as changes in the regulatory landscape (including but not limited to the European Union's Corporate Sustainability Reporting Directive (CSRD)). No prior knowledge of the previous version of the 'Practical for Business Air Pollutant Emission Assessment' is required, as the Guide 2.0 contains all the information included in the previous version, and the Guide 2.0 is meant to be used as a standalone document. Figure 1.1 shows the summary of changes between the previous iteration of the guide and new Guide 2.0.

Figure 1.1: Summary of the changes between the previous and current version of the Guide



The Guide 2.0 has also been updated to include the following resources:

- Excel sheets with emission factors for each key emitting source
- Excel sheets with preloaded methodologies and default data (when and if needed) for each key emitting source
- Guidance videos

1.2 Background concepts

The Guide 2.0 is focusing on emissions of greenhouse gas and air pollutants from activities taking place across the value chains of different companies. These activities can be a set of actions (e.g., starting or running a vehicle) and/or processes (e.g., industrial or chemical) with the potential to emit greenhouse gas and/or air pollutant emissions. The activities and the emissions resulting from them can be grouped under specific sources of emissions and the Guide 2.0 is focusing on six different types of sources, electricity consumption, stationary fuel combustion, transport, industrial processes, agriculture, and waste (treatment and management). These sources can emit both greenhouse gas and air pollutant emissions at the same time. Table 1.1 (Glossary of terms) contains a full list of the terms and their definitions, used in this document.

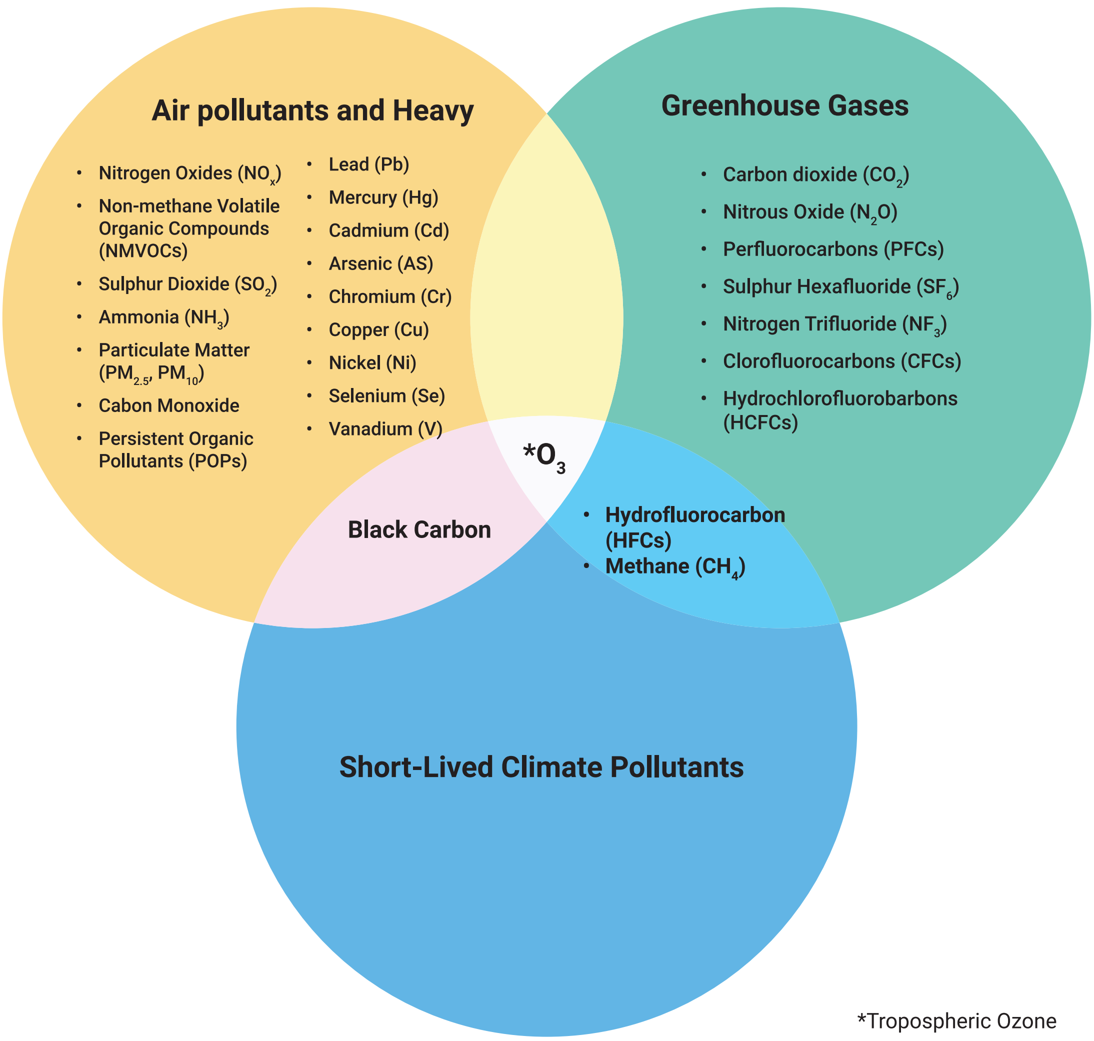
Table 1.1: **Glossary of terms related to quantification of greenhouse gas and air pollutant and definitions of how they are used in this document.**

Term	Definition
Air pollutant	Suspended particles (including heavy metals) and gases in the atmosphere that have negative impacts on human health and the environment.
Greenhouse gas	A gas in the atmosphere that traps heat by absorbing and emitting infrared radiation, contributing to the Earth's greenhouse effect and global warming.
Heavy metal	A specific type of air pollutant that can become toxic.
Emission	The production and discharge of a substance into the atmosphere.
Source	The type of activity/process which gives rise to the emission.
Sector	The area of the economy which contains the emission source.
Process	A structured set of operations, often industrial or chemical, such as fuel combustion in a power plant or cement production.
Action	A discrete or individual occurrence, such as starting a vehicle, applying fertilizer, or burning crop residue.
Activity	A broader category that can encompass both processes and actions over time, like road transportation, agricultural tilling, or residential heating.
Value Chain	The full range of activities undertaken by a company required to produce a product or service
Supply Chain	The network and activities between the company and its suppliers to produce and distribute a product or provide a service to a customer
Activity Variable	The quantitative measure of the size of a particular process, action or other activity that is a driver of air pollutant emissions.
Emission Factor	The quantity of a pollutant released in the atmosphere per unit of activity. To estimate the magnitude of emissions, the activity variable is multiplied by the corresponding emission factor that is specific to the activity that is the source of emissions

Term	Definition
Scope 1 Emissions	Direct emissions that occur from sources controlled and owned by the organization
Scope 2 Emissions	Indirect emissions associated with the purchase of electricity, heat, steam or cooling
Scope 3 Emissions	The result of activities from assets not controlled or owned by the reporting organization

Overall, air pollutants are emitted as particles and gases and include several different substances. Black carbon (BC) and tropospheric ozone (O_3) are air pollutants that affect health and ecosystems and warm the climate but are short-lived in the atmosphere and so are included also as Short-Lived Climate Pollutants (SLCPs). Unlike other pollutants, tropospheric (lower atmosphere) ozone is not emitted but formed in the atmosphere from precursor emissions (nitrogen oxides (NO_x), Non-Methane Volatile Organic Compounds (NMVOCs), methane (CH_4) and carbon monoxide (CO)). Greenhouse gases (e.g., carbon dioxide (CO_2) are the main cause of climate change and have different atmospheric lifetimes, but methane and hydrofluorocarbons (HFCs), and together with tropospheric ozone, are also short-lived in the atmosphere and are therefore SLCPs (Figure 1.2).

Figure 1.2: Summary of pollutants that are classified as air pollutants, short-lived climate pollutants and greenhouse gases (Adapted from CCAC SNAP 2019)



While greenhouse gas and air pollutant emissions can occur naturally, they are mostly the result of anthropogenic activities such as the combustion of fossil fuels or biomass burning, processes including fossil fuel extraction and transport, and different manufacturing processes. These activities are very prominent in the private sector and give rise to a large part of global emissions.

Within this document, the two key organising principles that are used to develop a method for the comprehensive accounting of emissions from a particular business are:

- the **value chain** of the business, and
- the **sources** that produce emissions at different points within the value chain.

The value chain maps the full set of activities that are undertaken by a business to create a product from start ('cradle') to finish ('grave') describing a chain of inter-connected processes. The term 'source' refers to the specific emission sources that can be identified and assigned to the different activities undertaken within the value chain. Chapter 2 outlines the methodological approaches that can be used to map the value chain, identify emission sources within the value chain, and finally demonstrates how the magnitude of emissions from each source identified in the value chain can be quantified and accounted for.

The user of this document, (e.g., an inventory compiler or preparer working within or for a company), will need to make some key decisions that will define how, and at what level of detail, greenhouse gas and air pollutant emissions can be quantified for their value chain and/or particular needs. These key decisions relate to the availability of data to estimate the emissions, but they also relate to which parts of the value chain the user wants to include in their quantification and/or reporting of these emissions. The Guide 2.0 outlines a six-step process for the development of the greenhouse gas and air pollutant emission inventory for a particular business (Sections 2.2 – 2.7). It then guides the user through the methods and emission factors that need to be used as part of the quantification and provides information of the appropriate boundary that will include the emissions specific to their value chain. In the Guide 2.0, the boundary is not determined by whether the emissions are under Scopes 1, 2 or 3 but rather by whether specific sources of emissions are present within a company's value chain regardless of these activities being controlled and/or owned by the company.

1.3 Aim of this Guide

The overall aim of this Guide is to provide a practical framework with detailed methodologies explaining how companies can develop an integrated greenhouse gas and air pollutant emission inventory. These inventories can be used by companies as part of their sustainability (or other types of) reports and can also facilitate reporting under requirements such as the EU's Corporate Sustainability Reporting Directive (CSRD). The objectives of this Guide are to:

- Provide a harmonised basis for quantification of greenhouse gas and air pollutant emissions to facilitate consistency, transparency and comparability in emission estimates between companies, and link the methods to existing systems that companies may have in place already to estimate GHG emissions, to capitalize on existing work and expertise on emission estimation within the private sector.

- Provide different methods for estimating emissions from companies' value chains, focusing on the six most important greenhouse gas and air pollutant emission sources: electricity generation, fuel combustion, transport, industrial processes, agriculture and waste (treatment and management). The Guide 2.0 describes the data required and, where possible, provides default data that can be used in the absence of company-specific information. As far as possible, methods are aligned with those used to estimate GHG emissions from a company's value chain in international guidance (e.g., GHG Protocol).

- Show how the information developed on the magnitude of emissions from a company's value chain can inform decision making to reduce these emissions. The Guide 2.0 gives an overview of how the greenhouse gas and air pollutant emission estimates can be extended to evaluate different mitigation options associated with a particular emission source.

Developing an emissions inventory is an essential part of greenhouse gas and air quality management as it is a fundamental step in understanding the key sources of emission of the different greenhouse gases and air pollutants. Essentially, an emissions inventory is a database that lists, by key emission source, the amount of greenhouse gas and air pollutants discharged into the atmosphere during one (or more) years. The key emitting sources discussed in this document can emit both greenhouse gases and air pollutants, so developing an integrated emissions inventory is important both in that it allows the user to quantify and understand the magnitude of different types of pollutants from the same source, but also different mitigation actions (e.g., electrification of transport, fuel or technology changes) will impact the magnitudes of the different types of greenhouse gases and air pollutants. More information on this is given in Chapter 5.

1.3.1 Greenhouse gases, short-lived climate pollutants, air pollutants and heavy metals covered

Section 1.2 provided a brief overview of the different sources covered in the Guide 2.0 that can be emitting different greenhouse gas and air pollutant emissions. The full list of pollutants covered in this version of the Guide are:

Greenhouse gases:

Carbon Dioxide (CO_2):

Carbon dioxide (CO_2) is the dominant anthropogenic greenhouse gas. It contributed about 66% of the radiative forcing from long-lived greenhouse gases in 2019 (IPCC 2021). It is naturally present in the atmosphere as part of the Earth's carbon cycle. However, human activities are altering the carbon cycle–both by adding more CO_2 to the atmosphere and by influencing the ability of natural sinks, like forests and soils, to remove and store CO_2 from the atmosphere. While CO_2 emissions come from a variety of natural sources, human-related emissions are responsible for the increase that has occurred in the atmosphere since the industrial revolution (from about 280 parts per million (ppm) in 1750 to more than 420 ppm now (Marvel, K et al 2023). Major sources of CO_2 emissions can include transportation, electricity generation, industry, and agriculture and livestock. Most of the anthropogenic increases in emissions are from fossil fuel combustion.

Methane (CH_4):

Methane (CH_4) is another important greenhouse gas and can result from a variety of human activities such as leaks from natural gas systems and livestock. CH_4 is also emitted by natural sources, such as termites and wetlands. In addition, natural processes in soil and chemical reactions in the atmosphere help remove CH_4 from the atmosphere. CH_4's lifetime in the atmosphere is much shorter (about 12 years) than carbon dioxide (about 100 years on average) (Alterskjaer et al. 2021), but CH_4 is more efficient at trapping radiation than CO_2, leading to climate warming. Agricultural emissions are significant – mainly from rice paddies and ruminant livestock farming. Livestock produce CH_4 as part of their normal digestive process. Storage or management of animal manure can also produce CH_4. Emissions of CH_4 also occur because of land use and land management activities. CH_4 is emitted to the atmosphere during the production, processing, storage, transmission, distribution, and use of natural gas, and the production, refinement, transportation, and storage of crude oil. CH_4 is generated in landfills as waste decomposes and in the treatment of wastewater.

Air pollutants:

The term 'air pollutant' covers a wide range of different chemicals that are emitted to the atmosphere and that contribute to negative impacts, including on human health through inhalation, or on vegetation as discussed above. The World Health Organisation (WHO) defines a list of 'classical air pollutants' for which ambient air quality guideline values have been defined for the protection of human health. These pollutants are particulate matter (PM_{10}, and $PM_{2.5}$, particles with diameter less than 10 and 2.5 µm, respectively), ozone, nitrogen oxides and sulphur dioxide (WHO 2021). These pollutants are both directly emitted (primary pollutants) and formed in the atmosphere through chemical reactions from directly emitted precursor pollutants (secondary pollutants). In terms of impacts on human health, primary and secondary pollutants are both important in determining the impact of air pollution on human health. A further category of air pollutants are the heavy metal emissions that affect human health and the environment.

Particulate Matter ($PM_{2.5}$ and PM_{10}):

Particulate matter (with aerodynamic diameter less than 2.5 µm ($PM_{2.5}$) and 10 µm (PM_{10})) are small particles suspended in the atmosphere. They make the largest contribution to air pollution effects on human health through effects on the cardiovascular and respiratory systems. The methods to estimate emissions of $PM_{2.5}$ and PM_{10} presented here represent the direct emissions to the atmosphere of primary particulate matter only. These emitted primary particles are made up of different substances, including black carbon (BC), organic carbon (OC), and mineral particles. Other gaseous pollutant emissions, like nitrogen oxides, sulphur dioxide, ammonia and volatile organic compounds, also contribute to the $PM_{2.5}$ and PM_{10} concentrations that people are exposed to, through chemical reactions in the atmosphere that convert gaseous pollutants into secondary particulate matter – but these are not part of primary $PM_{2.5}$ emissions – and their contribution to impacts needs to be assessed using chemical transformation and transport models.

Nitrogen Oxides (NO_x):

An air pollutant which is a precursor to the formation of small particulate matter (i.e., $PM_{2.5}$) and tropospheric ozone, NO_x is made up of two pollutants, nitrogen oxide (NO) (a primary gas emitted from combustion) and nitrogen dioxide (NO_2) (which forms when NO interacts with oxygen in the atmosphere)(DEFRA 2012). NO_X emissions occur through any high temperature combustion, often associated with using fossil fuels. NO_2 gas is also a harmful pollutant to health, in the high concentrations that are usually found closer to emission sources, like traffic. When NO_X is oxidized to nitrate it forms an aerosol that is part of $PM_{2.5}$.

Sulphur dioxide (SO_2):

An air pollutant which is a precursor to the formation of $PM_{2.5}$ particulate matter and comes from the Sulphur contained in fossil fuels, biomass and from industrial processes such as smelting. SO_2 is a harmful air pollutant that primarily affects health near its emission sources but can also contribute to regional air pollution through the formation of fine particles and acid rain. When SO_2 is oxidized to sulphate it forms an aerosol that is part of $PM_{2.5}$ which also has significant impacts on health (DEFRA 2012).

Ammonia (NH_3):

An air pollutant which is a precursor to the formation of particulate matter (once reduced to ammonium) which is mostly emitted from agriculture from inorganic fertilizer application and manure.

Organic Carbon (OC):

A component of directly emitted particulate matter (PM) emissions that contributes to the negative effects of air pollution on human health, and like BC is emitted due to incomplete combustion (Fang, GC et al 2008).

Black carbon (BC):

A component of primary particulate matter (PM) emissions that contributes to the negative effects of air pollution on human health. Emissions of black carbon also warm the atmosphere through direct absorption of incoming solar radiation, and through indirect effects such as deposition on snow and ice and cloud interactions. With an atmospheric lifetime of a few days, it is a short-lived climate pollutant. It is mainly emitted through incomplete combustion (Climate and Clean Air Coalition 2024).

Non-methane volatile organic compounds (NMVOCs):

A collection of different organic molecules emitted from a range of emission sources (such as, combustions, biomass burning, use of solvents in industrial process etc). NMVOCs are precursors to the formation of tropospheric ozone and secondary organic particulate matter (part of $PM_{2.5}$ pollution). Some of the NMVOCs, such as benzene, are also toxic to humans as gases (EEA 2023).

Carbon monoxide (CO):

A gaseous air pollutant which contributes to the formation of tropospheric ozone, and which is toxic in its own right in high concentrations (Das 2020).

Heavy metals:

Lead (Pb):

Lead is a harmful heavy metal, that can accumulate in human body, especially bones. major sources of lead in the air are ore and metals processing and piston-engine aircraft operating on leaded aviation fuel (EEA 2023). Other sources are waste incinerators, utilities, and lead-acid battery manufacturers. Depending on the level of exposure, lead can adversely affect the nervous system, kidney function, immune system, reproductive and developmental systems and the cardiovascular system. Lead exposure also affects the oxygen carrying capacity of the blood. Lead exposures have developmental and neurobehavioral effects on fetuses, infants and children, and elevate blood pressure in adults (WHO 2024).

Mercury (Hg):

Mercury is toxic in the elemental and inorganic forms, but the main concern is associated with the organic compounds, especially methylmercury that accumulates in the food-chain, the main route of human exposure. The main sources in 2021 are coal use in public electricity and heat production and industrial combustion, iron and steel production processes, cremation, and emissions from the disposal of products containing mercury (EEA 2023).

Cadmium (Cd):

Cadmium exposures are associated with kidney and bone damage. Cadmium has also been identified as a potential human carcinogen, causing lung cancer. Effects of acute inhalation exposure to cadmium consist mainly of effects on the lung, such as pulmonary irritation. Chronic effects via inhalation can cause a build-up of cadmium in the kidneys that can lead to kidney disease. The main sources are the residential sector (e.g., burning of treated, painted or contaminated wood or waste such as painted materials or plastics) and industrial use of wood and other biomass fuels (Timonem et al 2021). Historically, non-ferrous metal manufacture and municipal solid waste incineration were very significant sources (EEA 2023).

Arsenic (As):

Arsenic is a toxic substance commonly emitted into the air from the burning of coal, smelting of metal ores, and waste incineration. It is a known human carcinogen, causing lung and skin cancers upon long-term exposure. Airborne arsenic particles can deposit onto soil and water, leading to contamination of ecosystems. Inhalation of arsenic-contaminated air poses significant health risks, especially in close proximity to the sources of emissions, such as industrial regions (EEA 2023; WHO 2010).

Chromium (Cr):

Chromium is a metal used extensively in stainless steel production and other industrial processes and is released into the atmosphere mainly through metal smelting, fossil fuel combustion, and waste incineration. Chromium compounds can persist in the environment and bioaccumulate in organisms (EEA 2023; WHO 2017).

Copper (Cu):

Copper is an essential trace metal but becomes a pollutant when released in excess through industrial activities such as metal refining, brake and tire wear, and fossil fuel combustion. Copper particles in air can deposit into soils and water bodies, potentially causing toxicity to plants and aquatic life. Human exposure occurs primarily via inhalation in industrial areas, potentially leading to respiratory irritation (EEA 2023; UNEP 2019). Nickel (Ni): Nickel is emitted mainly from the combustion of oil and coal, metal refining, and waste incineration and is known to cause allergic reactions and respiratory problems, and some nickel compounds are classified as carcinogenic to humans. Nickel particles can travel long distances in the atmosphere, contaminating soils and water, with adverse effects on both ecosystems and human health(EEA 2023; WHO 2000).

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Selenium (Se):

Selenium is a trace element that enters the air primarily from fossil fuel combustion and certain industrial processes. While Selenium is essential in small amounts for human and animal health, excessive selenium exposure can cause toxicity, including respiratory and neurological effects. Airborne selenium can deposit onto soils and water, affecting plant and aquatic life, with bioaccumulation potential in food chains (EEA 2023; WHO 2001).

Zinc (Zn):

Zinc is released into the atmosphere mainly from industrial processes such as metal smelting, waste incineration, and from vehicle tire and brake wear. Although zinc is an essential nutrient, elevated levels in the environment can be toxic to plants, aquatic organisms, and soil microorganisms. Human exposure through inhalation is generally low but can cause respiratory irritation in occupational settings (EEA 2023; AMAP 2019).

Vanadium (V):

Vanadium is a metal mainly emitted through the combustion of heavy oils and coal. It often occurs in the form of vanadium pentoxide (V_2O_5), which is toxic and can cause respiratory irritation, lung inflammation, and other health issues upon inhalation. Vanadium particles can travel long distances, contributing to regional air pollution and potentially affecting ecosystems through deposition (EEA 2023; WHO 2000).

Short-lived Climate Pollutants:

A small number of air pollutants and GHGs that cause global and regional warming, but which are relatively short-lived in the atmosphere are called 'Short-Lived Climate Pollutants'. The SLCPs covered in the Guide 2.0 are:

- Black Carbon (BC)
- Methane (CH_4)

Finally, it must be noted that the Guide 2.0 does not cover methods to estimate secondary air pollutants, natural sources of greenhouse gas and air pollutants emissions as well as fugitive emissions. It is also important to note that methane emissions from Land Use and Land Use Change (LULUC) are currently outside the scope of this guide. These will be addressed in a future iteration of the document.

1.3.2 How to Use the Guide 2.0

This Guide provides a comprehensive set of methods and approaches for quantifying greenhouse gas and air pollutant emissions along a company's value chain. The intended users of the Guide 2.0 are technical officers, sustainability teams, or inventory compilers within companies or broader Environmental Social and Governance (ESG) preparers that are directly involved in the development of greenhouse gas and air pollutant emission quantification and estimates. It provides a framework for the quantification and categorization of greenhouse gas and air pollutant emissions associated with a company's activities that are organized around two key concepts:

1. **Value Chain:** The value chain describes the different activities that businesses undertake to produce and sell a product or service.
2. **Emission Source**: An emission source is a discrete activity, or process, that is located within a part of a company's value chain, that directly results in air pollutants being emitted to the atmosphere.

There are a diverse range of value chains across different types of businesses, and a large range of emission sources that may be contained within different parts of the value chain. In this Guide, a 6-stage generic value chain is used to describe a general set of activities that a business may undertake. Across this generic value chain, methods for the quantification of air pollutant emissions from 6 distinct sources are described. These sources are i) electricity generation, ii) fuel combustion, iii) transport, iv) industrial processes, v) agriculture and vi) waste. The proportion of selected greenhouse gases and key air pollutants to total global emissions by sources covered in the guide are presented in Table 1.2.

Table 1.2: **Proportion of global emissions of selected air pollutants that are covered by the six source categories that are included within this Guide (Source: EDGARv8.1, Air Pollution 2023; EDGAR_2024_GHG 2024)**

Term	$PM_{2.5}$	CO	NH_3	SO_2	NMVOC	OC	PM_{10}	CO_2	CH_4
Agriculture	13%	14%	3%	2%	3%	28%	9%	0.37%	46.60%
Energy	62%	50%	8%	77%	24%	65%	59%	38.42%	0.16%
Industrial Processes and Product Use (IPPU)	8%	13%	1%	7%	16%	0%	9%	8.42%	0.15%
Fuel Combustion	7%	11%	87%	5%	46%	2%	15%	16.27%	0.19%
Transport	10%	12%	1%	5%	9%	5%	7%	20.77%	0.31%
Waste	1%	0%	0%	3%	2%	0%	1%	0.05%	18.25%

The Guide 2.0 has been developed with close attention to the available Intergovernmental Panel on Climate Change (IPCC 2006; 2019) and European Monitoring and Evaluation Programme of the European Environmental Agency (EMEP/EEA) (EEA 2023) methodologies and emission factors for greenhouse gas and air pollutant emissions respectively. Particularly for the quantification of greenhouse gas emissions, and to the extent that it was possible, the Guide 2.0 has also considered other existing frameworks (e.g., Greenhouse Gas Protocol, the Global Logistics Emissions Council (GLEC)) and other methodologies currently used by companies to quantify their greenhouse gas emissions. The methods used by the Guide 2.0 are outlined in Chapter 3 (3.1 to 3.6) to facilitate the integrated greenhouse gas and air pollutant emission inventory development. The Guide 2.0 is divided into the following Sections:

Chapter 1 of the Guide provides a short introduction to the different emissions to the atmosphere, and their impacts on climate, human health and vegetation, and discusses how the integrated quantification of greenhouse gas and air pollutant emissions can be a useful tool to identify major sources and opportunities to improve air quality and human health at the same time as reducing the causes of climate change.

Chapter 2 then provides a framework and the suggested process for the development of an integrated GHG and air pollutant emission inventory. It outlines how a company can map its value chain, identify the emission sources at different stages of the value chain, and outlines the process for identifying the specific methods, data and assumptions needed to quantify greenhouse gas and air pollutant emissions from those sources.

Chapter 3 outlines the source-specific guidance and methods on how emissions can be calculated for each of the six sources that may occur along a value chain, alongside default data and approaches that can be used. Chapter 3 consists of Sections 3.1 to 3.6 reflecting the six key emitting sources covered under this iteration of the Guide.

Chapter 4 gives an overview of the uncertainties associated with the compilation of an emissions inventory and provides guidance on the sources of the uncertainties that need to be considered from the inventory compiler. These include uncertainties occurring from activity data and emission factors as well as approaches on how these uncertainties can be estimated for a specific year or a number of years within a category.

Chapter 5 provides high-level information on how to understand and interpret the results of an emissions inventory, how to move forward with decision making and considering mitigation options, and further approaches that can enhance the understanding of greenhouse gas and air pollutant emissions from a company’s value chain.

1.4 Emissions to the atmosphere and their impacts

Air pollution and climate change are caused when different greenhouse gases and air pollutants are emitted to the atmosphere. It is therefore important to quantify the magnitude of the emission of the different substances by developing an emission inventory. Once the emissions from the different processes and activities along a value chain have been quantified, they can be used to inform broader greenhouse gas and air quality management. This can happen either by evaluating which mitigation actions will help reduce emissions from the different key emitting sources (e.g., energy efficiency, fuel or technology changes) or by inputting the emissions into an atmospheric model to provide estimates for the concentrations of the different air pollutants and assess the change in radiative forcing and climate change from the different greenhouse gases and particles affecting warming. The concentrations and deposition of air pollutants can be used to estimate the level of impact on human health and ecosystems. They can also be used to estimate warming and changes to weather patterns, including rainfall. The chain of 'activity -> emissions -> concentrations ->impacts' is commonly used to understand the link between activities and the impacts caused and used to inform mitigation strategies.

Air pollution affects human health and is the largest cause of premature mortality caused by an environmentally mediated risk factor. The most important pollutant is $PM_{2.5}$ which is made up of small particles which can get into the lungs and bloodstream and affect the whole body. Ground-level ozone is the next most important air pollutant affecting human health, contributing to respiratory disease as it is an important oxidant affecting the lungs. Ozone is also the main air pollutant causing reductions in crop yields and forest growth. The heavy metals also have an impact on human and ecosystem health.

Emissions affect climate change in different ways. The greenhouse gases absorb infrared radiation emitted from the earth, preventing it from being radiated to space, thus warming the atmosphere through the 'greenhouse effect'. Black carbon absorbs sunlight directly and contributes to warming. Sulphate and organic carbon reflect sunlight and exert a cooling effect. The net warming of the atmosphere causes global and reginal impacts, related to impacts on the weather and dur to the overall warming of the planet. There are impacts on health due to additional heat, floods, increased intensity of storms, sea-level rise, droughts etc.

The main source of CO_2 emission is the combustion of fossil fuels. This combustion also creates air pollutant emissions such as nitrogen and sulphur oxides. This means that some, though not all, strategies to reduce emissions can reduce greenhouse gas and air pollutant emissions at the same time. But to ensure that these multiple benefits are realized, an integrated approach to addressing greenhouse gas and air pollution emission is necessary.

The pollution of terrestrial ecosystems with toxic heavy metals is a major environmental concern that has consequences for public health. Metals such as lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As) can be emitted into the atmosphere from activities including fossil fuel combustion, waste incineration, and metallurgical processes. Once airborne, these metals can be inhaled directly or deposited onto soil and water, entering the food chain. Chronic exposure to airborne heavy metals has been linked to respiratory illnesses, neurotoxicity, cardiovascular diseases, and developmental disorders, particularly in children (Manisalidis et al. 2020).

1.4.1 Air pollution: definition and sources

The term 'air pollutant' covers a wide range of different chemicals that are emitted to the atmosphere and that contribute to negative impacts, including on human health through inhalation. The World Health Organisation (WHO) defines a list of 'classical air pollutants' for which ambient air quality guideline values have been defined for the protection of human health. These pollutants are particulate matter (PM_{10}, and $PM_{2.5}$, particles with diameter less than 10 and 2.5 μm, respectively), ozone, nitrogen oxides and sulphur dioxide (WHO 2021). These pollutants are both directly emitted (primary pollution – e.g. SO_2, NO_2) and formed in the atmosphere through chemical reactions from directly emitted precursor pollutants (secondary pollution – e.g. sulphate and nitrate as well as ozone).

The key anthropogenic sources of air pollutant emissions include energy (which includes sources such as electricity generation, transport, industry, commercial and public services, and oil and gas), industrial processes and product use, agriculture and waste (treatment and management). For most of the world's population, human activities account for most of the air pollution they are exposed to. The magnitude of emissions of different pollutants varies by source. In cities, air pollutant concentrations are determined by emissions from sources both inside and outside city boundaries, some of it travelling over long distances, including internationally (transboundary air pollution). Many large sources, such as cement plants, steel plants and electricity generation, are located away from cities, but can still contribute to the urban air pollutant concentrations, due to being transported across long distances in the air. Agricultural sources, including burning vegetation to clear land for crops and forest fires, contribute a lot to urban and rural air pollution levels.

1.4.2 Impacts of Air pollution

Impacts on health and ecosystems

The World Health Organisation (WHO) categorises over 30 different chemicals as air pollutants based on their distribution, and linkage between exposure to them and associated health impacts. The air pollutants that contribute the most to health burdens are particulate matter ($PM_{2.5}$) and surface ozone (O_3). According to the WHO (2021), over 90% of people live in regions that exceed the WHO guidelines levels of $PM_{2.5}$. Those exposed to the highest levels of air pollutants are often in low- and middle-income countries. Indoor air pollution has a substantial impact on the health of women and children in the poorest countries as they cook using wood and other biomass. Over the past decades, air pollutant levels have decreased in some regions, such as Europe, North America, and recently in China, and other parts of East Asia. However, in many regions air pollutant concentrations continue to exceed national standards and international guidelines. In addition, the WHO has recently revised its ambient air quality guidelines and the guideline levels for all pollutants have been reduced (World Health Organisation 2021), for example, the new WHO guidelines for ambient $PM_{2.5}$ is 5 μg m^3, which is half of the previous value of 10.

Exposure to indoor and outdoor fine particulate matter is associated with an estimated 7 million premature deaths each year (WHO 2014). It is also linked with other non-fatal health impacts, such as adverse pregnancy outcomes (Malley et al. 2017), asthma (Anenberg et al. 2018), and emergency room visits (REVIHAAP 2013). In addition to substantial impacts on human health, air pollution also reduces crop yields, impacting food security, and other vegetation and ecosystems (Emberson et al. 2018). As per WHO's definition, indoor pollution is contamination of air within buildings, houses and enclosed spaces by various pollutants – which may can originate from building materials, household activities like cooking, cleaning, or heating, and even from the outside air entering the building. Whereas the outdoor air pollution is the contamination of outdoor atmosphere by harmful substances such as nitrogen dioxide, sulphur dioxide, carbon monoxide, heavy metals and ozone), particulate matter (PM_{10} and $PM_{2.5}$), and biological molecules that are harmful to human health, ecosystems, or the climate. The sources of outdoor air pollution are mainly anthropogenic but there are also natural sources (WHO 2024).

As a result, the WHO ambient air quality guidelines define both short-term (e.g., daily) and long-term (annual) exposure levels as important for the protection of human health. In terms of the overall burden of disease associated with exposure to air pollution, long-term exposure is responsible for a substantially larger fraction of health impacts compared to short-term exposure.

Impacts on ecosystems

Air pollution also significantly impacts several different ecosystems. Ozone pollution reduces crops and forest yields and this then reduces the carbon sequestration in the world's ecosystems thus making climate change worse. Acidification of soils due to pollutant deposition (sulphate, nitrate and ammonium) can cause damage to forests and sensitive lake ecosystems, altering the ecosystems and killing their fish populations. Nitrogen deposition resulting from air pollution presents a notable threat to plant health (Lovett et al. 2009). In a study conducted at three roadside locations in the United Kingdom, Bignal et al. (2007) assessed the effects of atmospheric pollutants on oak and beech trees. The research documented several adverse outcomes, including heightened leaf loss, discoloration, diminished crown vitality, and increased vulnerability to pest infestations. The findings suggest that vegetation situated within approximately 100 meters of major roadways may experience pronounced physiological stress, primarily attributed to nitrogen dioxide (NO_2) exposure. Air pollution also reduces atmospheric visibility with impacts on tourism and increases corrosion of materials, buildings, monuments, and cultural heritage sites.

Impacts on economy and the Sustainable Development Goals (SDGs)

Air pollution also has huge economic costs related to human health, lost productivity, reduced crop yields and reduced competitiveness of globally connected cities. For example, the global cost of health damages in 2016 alone from outdoor air pollution was estimated to be US$5.7 trillion, equivalent in magnitude to 4.8 percent of global Gross Domestic Product (GDP) that year (World Bank 2022). The links between air pollution and development, the economy and the environment mean that reducing air pollution is an important contribution to the achievement of the Sustainable Development Goals (SDGs) and directly affects the achievement of SDG 3: Good Health and Wellbeing, SDG 7: Affordable and Clean Energy, SDG 11: Sustainable Cities and Communities, and SDG 13: Climate Change. It indirectly impacts many other SDGs because of the multiple benefits that implementing actions to reduce air pollution can achieve (Haines et al. 2017).

A report published by OECD (2016) pointed out that every year outdoor exposure to air pollution impacts on workforce productivity and economic activity. They estimated that 1.2 billion work days are lost globally, and this is projected to reach 3.8 billion days lost by 2060. The same concern is reflected in the report published by the World Bank in 2025, which estimated that the health damage caused by air pollution costs $6 trillion a year due to health impacts, lost productivity and reduced life expectancy, which is a figure equivalent to 5% of global Gross Domestic Product (GDP). The Clean Air Fund in their report on, 'Air pollution and its impact on business' highlighted that, in India, due to the high level of outdoor air pollution, there is reduced productivity and an increase in work absences and premature deaths which cost the economy an estimated $95 billion – equivalent to 3% of the country's GDP in 2019. Despite remarkable reduction in emissions in recent decades, the levels of air pollution in EU still have a large impact; according to Oliu-Barton (2024), air pollution causes €600 billion in losses each year, an amount equivalent to 4% of its annual GDP of the EU.

1.4.3 Climate change and air pollution

Air pollution and climate change are two of the biggest environmental issues that are faced globally.

Climate change and air pollution are deeply interconnected, most major air pollutants share common sources with GHGs, especially related to the combustion of fossil fuels, the primary cause of climate change. Furthermore, the interactions between air pollutants and GHGs can amplify environmental and health risks. For instance, higher temperatures enhance ozone formation and increase the frequency and intensity of wildfires, which release large quantities of particulate matter (PM) into the atmosphere (Afifa et al. 2024). To prevent the most catastrophic impacts of climate change, global leaders signed the Paris Agreement setting the goal of limiting global average temperature increases to 'well below 2°C', and ideally to 1.5°C (United Nations 2015). The annually averaged global mean near-surface temperature in 2024 was recorded 1.55 °C ± 0.13 °C above the 1850–1900 average used to represent pre-industrial conditions (WMO 2025). Current climate change commitments are estimated to be consistent with over 3°C of warming by 2100 (Jeffery et al. 2018), and therefore more action is needed to meet the goals of the Paris Agreement and meet these temperature goals. Impacts of climate change include increased frequency of extreme weather events, such as storms, floods, droughts and heatwaves, impacts on agriculture and food security, impacts on human health, and on biodiversity (IPCC 2019; 2018).

Most of the warming to date has been caused by emissions of carbon dioxide and addressing this is vital to reduce the level of warming that we will see this century, especially since CO_2 is long-lived with an average lifetime in the atmosphere of about 100 years. Since 2012 there has been an additional focus on Short-Lived Climate Pollutants (SLCPs) which include black carbon, ozone, methane, and hydrofluorocarbons (HFCs), as these are highly potent positive climate forcers; these pollutants have high global warming potentials (GWPs) and strong radiative forcing effects yet are relatively short lived in the atmosphere in comparison to CO_2 (CCAC 2025). The increased efforts to reduce these substances is driven by the fact that their mitigation holds out the prospect to reduce near-term warming – up to about a reduction of about half a degree by mid-century (Shindell et al. 2012) and implementing SLCP measures also has been shown to significantly reduce the impact of air pollution as the they address many of the sources of ozone and $PM_{2.5}$. Integrated actions, addressing the common sources of greenhouse gas and air pollutants and promoting actions that target SLCPs, can therefore provide triple-win scenarios, by achieving multiple real-world benefits for human health, agriculture and the climate. Table 1.3 gives examples of certain actions and which greenhouse gases and/or air pollutants these can help reduce.

Table 1.3: Integrated action to reduce greenhouse gas emissions and air pollution

Integrated Action	Greenhouse gases and air pollutants Addressed	Key Benefits
Clean Transport (e.g., EVs, public transit)	CO_2, NO_x, PM, BC	Lower urban air pollution, climate mitigation, improved public health
Waste Management Improvements (e.g., landfill gas capture, composting, reducing the burning of waste)	Methane, PM, odorous gases	Climate benefits, improved sanitation, reduced urban air pollution
Improved Livestock and Manure Management	Methane, ammonia, N_2O	Reduced agricultural emissions, improved fertilizer efficiency, better water quality
Eliminating Open Agricultural Burning	Methane, black carbon, PM, CO	Improved air quality, reduced respiratory illness, better soil health
Energy Efficiency & Clean Energy (e.g., solar, wind, efficient buildings)	CO_2, SO_2, NO_x, PM	Energy savings, lower emissions, cleaner air, climate co-benefits

Global and regional studies have shown that there are a variety of strategies and actions that can be taken to target the major sources of SLCPs and simultaneously improve air pollution locally while reducing global climate change (Kuylenstierna et al. 2020; Nakarmi et al. 2020; Shindell et al. 2012; Stohl et al. 2015; UNEP/WMO 2011; UNEP 2019 2018)

In the corporate value chain, climate action and mitigation have been increasingly becoming a central component of sustainability and other types of strategies. Traditionally, most of the efforts were focused on reduction of greenhouse gases, but with recent research and evidence of economic loss due to air pollution, the private sector is starting to also focus on mitigating air pollution. Therefore, companies that have existing greenhouse gas reduction plans, or intend to develop one, have the opportunity to consider co-benefits and trade-offs associated with air pollution. Integrating air pollutant and climate strategies provides the opportunity for companies to quantify and report on how their actions are reducing both air pollution impacts on health, thus helping economic growth, and the emissions causing climate change.

To improve air quality and reduce air pollution, the first requirement is an understanding of the contribution of different sources to the emissions of different air pollutants from activities within the value chain of a company. This might include upstream raw material extraction, manufacturing, logistics, distribution, and end-of-life product disposal. The aim of this Guide is to provide a practical framework and methods that can be applied by a diverse range of businesses to quantify emissions. Companies are often the organisations that are best positioned to achieve ambitious mitigation goals. They have scale, flexibility, resources, influence, expertise and can reap direct benefits from improvements in value chain efficiency while simultaneously delivering air quality improvements in the locations covered by the value chains, and globally. These locations include emission sources within high-, middle- and low-income countries within a company's value chain and are particularly relevant to reducing the inequalities in air pollution health burdens occurring in low- and middle- income countries due to consumption of goods in high- income countries that are often produced in the lower income countries (Zhang et al. 2017).

Companies with existing plans and strategies to rapidly reduce GHG emissions therefore have the opportunity to integrate actions to reduce air pollutants. As more companies are now setting out to develop GHG emission reduction plans, or net-zero pathways, the application of the Guide 2.0 allows consideration of the effects of these strategies on air pollutant emissions and provide benefits to human health.

1.5 Private sector and its contribution to GHG and air pollutant emissions

The private sector includes businesses that encompass industry, manufacturing, hospitality, retail, etc. These businesses can be of different sizes with only a few or thousands of employees and can exist in just one region of the world or span across several countries and continents. Regardless of their size and location, companies engage in activities that are required to run and maintain their businesses, and which can result in emissions of greenhouse gas and air pollutants. Examples of sources of emissions that may be present within a company's value chain include:

- Electricity consumption and fuel consumption (e.g., in stationary or mobile sources)
- Industrial processes and solvent use (e.g., chemical and mining industries)
- Agriculture
- Waste treatment

The energy consumed by the industrial sector is used for a wide range of purposes, such as process and assembly, motive power, steam and cogeneration, process heating and cooling, lighting, heating, and air conditioning for buildings. Some industries are more energy intensive than others. Table 1.4 is adapted from the International Energy Outlook report (IEA 2016) and shows the industrial sector, broken down into major groupings and their representative industries and categorized under 'Energy-intensive manufacturing, non-energy intensive manufacturing, non-manufacturing'. In addition to the energy intensity of an industry of business, the other determinant of the air pollutant emissions that the business emits is the types of fuel consumed, and technologies used to provide the energy required for the companies. GHGs mitigation often focusses on energy efficiency and switching to non-fossil fuels and these strategies will also reduce air pollution substantially – examples of integrated approaches to air pollution and climate change. In contrast, end-of-pipe techniques can be used to reduce specific air pollutants but may not impact the GHG emissions. For example, particle filters fitted to stationary machinery and/or vehicles can substantially reduce particulate matter emissions from those activities within a company's value chain, but CO_2 emissions will remain. Switching to electric vehicles or running machinery using renewable electricity will reduce both CO_2 and air pollution emissions.

Table 1.4: Industrial sector: major groupings and representative industries (Source: IEA International Energy Outlook, 2016)

Industry grouping	Representative industries
Energy-intensive manufacturing	
Food	Food, beverage, and tobacco product manufacturing
Pulp and paper	Paper manufacturing, printing and related support activities
Basic chemicals	Inorganic chemicals, organic chemicals (e.g., ethylene propylene, resins and agricultural chemicals.
Refining	petroleum refineries and co products manufacturing, including coal and natural gas used as feed stocks
Iron and steel	Iron and steel manufacturing, including coke ovens
Non-ferrous metals	Primary aluminum and other nonferrous metals, such as copper, scene, and tin
Non-metallic minerals	Primary cement and other nonmetallic minerals, such as glass, lime, gypsum, and play product
Non-energy intensive manufacturing	
Other chemicals	Pharmaceutical (medicine and botanical), paint and coatings, adhesives, detergent and other miscellaneous chemical products, including chemical feedstocks
Other industrials	All other industrial manufacturing, including metal based durables (fabricated metal products, machinery, computer and electronic products, transportation equipment, and electrical equipment)
Non-manufacturing	
Agriculture, forestry, fishing	Agriculture, forestry, fishing
Mining	Coal mining, oil and natural gas extraction, and mining of metal and nonmetal minerals
Construction	Construction of buildings, (residential and commercial), heavy and civil engineering construction, industrial construction, and specialty trade contractors

In terms of the contribution of companies to the totality of air pollutant emissions, and the premature deaths that result from exposure to air pollution each year, the International Energy Agency (IEA) evaluated the contribution of different sectors. Industry (including both private sector and state-owned companies) were estimated to be responsible for approximately one quarter of nitrogen oxide (NO_x) and particulate matter ($PM_{2.5}$) emissions, and 46% of sulfur dioxide (SO_2) emissions (IEA 2018; IEA 2022a, b, c). Other key sources included the transport sector, which contributed over 50% of NO_x, and 5% of $PM_{2.5}$ emissions, and power generation, which contributed one third of global SO_2 emissions, and 10% of global NO_x emissions. The private sector makes a substantial contribution to the emissions from these sources due to air pollutant emissions from freight transport and customer travel, and through the electricity consumed in industrial and commercial activities.

The health impacts of air pollutant emissions from trade in goods and services can result in health impacts where the goods are produced, rather than where they are consumed. Zhang et al. 2017 analysed international trade patterns and calculated the air pollutant emissions emitted in one region in the production of goods and services that are consumed in another region. They concluded that over 700,000 premature deaths per year were attributable to air pollution exposure that resulted from air pollutant emissions in one region that were associated with goods and services consumed in another region. For example, over 10% of the $PM_{2.5}$-attributable deaths in China were associated with consumption of goods and services that were consumed in Europe and North America, and 30% of the $PM_{2.5}$-attributable deaths in eastern Europe are due to air pollution caused by the production of goods and services that are consumed in western Europe. This underlines that within a company's value chain, the location of the main sources of air pollutant emissions determines which population groups will have the highest levels of exposure to air pollutants. Commonly, lower-income countries and communities experience the largest impact from companies' air pollutant-emitting activities.

The IEA (2016) report on energy and air pollution outlines key actions that can achieve clean air globally. Many of these measures require actions by the private sector to achieve the reductions in air pollutant emissions, for example the implementation of industrial emission standards, emission standards for heavy duty vehicles, electromobility, efficiency standards for buildings and equipment. Hence the private sector has a critical role to play in taking actions that can alleviate the health burdens from air pollutants. This Guide aims to provide a framework for taking the first critical step, quantifying the contribution that a company makes through its value chain to air pollutant emissions.

Summary of private sector reporting on greenhouse gas and air pollutant emissions

Private sector companies and businesses have been engaging with the greenhouse gas quantification and reporting space since the 1990s (Levy and Kolk 2022), a practice that became more widespread in early 2000s. Several frameworks and standards have been developed over the years, to allow companies to quantify greenhouse gas emissions in order to comply with regulations and meet stakeholder expectations such as the Greenhouse Gas Protocol (WRI & WBCSD 2004), the (formerly Carbon Disclosure Project) CDP, and ISO 15064-1. In the U.S., the EPA mandates GHG reporting from major emitters (EPA 2024), while the EU's CSRD requires extensive emissions disclosure (European Commission 2023). The CSRD reporting is divided in environment, social and governance. Within the environmental standards, European Sustainability Reporting Standard Environmental Standard 1 (ESRS E1) is dedicated to greenhouse gas emissions and climate related disclosures while ESRS E2 focuses on Pollution, which includes pollution in air, water and soil (EFRAG 2023). The inclusion of air pollutant emissions (and other types of pollution) as part of the CSRD reporting requirements and the cross-cutting themes of these standards, opened the discussion for the need of integrated ways to report on, not just greenhouse gas emissions but other types of pollutants (e.g., air pollutants) as well. Regarding air pollutant emissions quantification and reporting, prior to 2021, few companies were engaging with air pollution as a material topic. The CSRD defines a material topic as, any topic (environmental, social or governance) that could substantively affect the organization's ability to create value in the short, medium and long term (EFRAG 2023) and had quantified the air pollutant emissions resulting by various activities and processes within their value chains. However, emissions to the atmosphere of GHGs contributing to climate change are often quantified as part of company's sustainability commitments and targets. There are also many tools and resources available to assess the GHG emissions within their value chains, which can promote consistency and comparability between companies and their GHG emission estimates.

As a result of the large overlap in GHG and air pollutant emission sources, there is substantial overlap between the methods and data needed to quantify GHG and air pollutant emissions. Therefore, there is a substantial opportunity for companies to enhance their existing systems (or new systems if these are not in place) to assess all emissions to the atmosphere from their value chains, by including air pollutant emissions. In many cases the data required to estimate emissions of greenhouse gases and air pollutants are the same, and international guidance to quantify GHG and air pollutant emissions are complementary and harmonised (EEA 2023; IPCC 2006, 2019). In 2021, the World Economic Forum (WEF) launched the Alliance for Clean Air (ACA), the first-of-its-kind coalition of private sector companies looking to quantify and reduce air pollutant emissions across their value chains. The first iteration of this Guide was consecutively endorsed by the members of the Alliance for Clean Air, and the companies started using the Guide to quantify air pollutant emissions, leading to the inclusion and publication of these emissions as part of their sustainability, climate (or other) reports. So far, more than 10 Alliance members have published their air pollutant emissions inventories, including IKEA, Maersk, Norsk Hydro, Oracle, Bloomberg, Accenture, Haleon, GoTo.

The combined reporting of greenhouse gas and air pollutant from different emissions sources within the value chains of businesses is gaining traction as a starting point to assess the opportunities to reduce these emissions. Some countries are developing directives asking businesses to report greenhouse gas and air pollutant emissions from different sources of the corporate value chain.

At the time of the compilation of the Guide 2.0 (2025), 467 companies have reported under the CSRD ESRS E2 with approximately 120 companies having found air pollution to be a material topic for their operations and several using the first version of the Guide (the Practical Guide for Business Air Pollutant Emission Assessment) to report on the magnitude of air pollutant emissions. The European Financial and Reporting Advisory Group has also included the Guide in their newly published guidance for Small and Medium Enterprises (SMEs) reporting.

Further to the above, all three Chinese stock exchanges issued their respective Corporate Sustainability Reporting Guidelines, which came into effect on March 2024 (Transition Asia 2024). The companies are required to disclose sustainability information in reports covering climate change, pollution control and ecosystem protection and other social and environmental aspects (Clifford Chance 2024). Starting from the financial year 2025, The Accounting and Corporate Regulatory Authority and Singapore Exchange Regulation in Singapore has issued details on mandatory climate reporting from listed as well as large non-listed companies (Latham & Watkins 2024).

1.6 Methods, approaches, data, sources and limitations

The aim of this Guide is to provide a comprehensive framework for private sector companies to enable them to quantify greenhouse gas and air pollutant emissions along their value chains through an integrated framework. To achieve this, this Guide has been using methods and approaches that are also used by the IPCC Guidelines (2006; 2019), developed for national greenhouse gas emission inventory development and reporting, and the EMEP/EEA (2023) guidelines which is used for the reporting of air pollutant emissions on the national level. The emission factors that are used throughout this document come from the EMEP/EEA (2023) guidelines for air pollution and IPCC guidelines (2006; 2019) for greenhouse gases as this is a widely used, peer reviewed, and scientifically robust document used for reporting air pollutant emissions. At the time of the publication of the Guide, the document includes all the categories that are included in the EMEP/EEA guidance, apart from fugitive emissions, secondary air pollutants, natural sources of greenhouse gases and air pollutants. However, there are a few cases where the EMEP/ EEA guidance (2023) currently does not provide a method, or an emission factor, or both, for a specific sector or sub-sector. For example, under Industrial processes, for the category of wood processing, the EMEP/EEA guidance does not currently include emission factors that are relevant to this work (EEA 2023). However, the purpose of this work has always been to expand to include more categories as part of this Guide but also to update and enhance the currently included emission factors. The updates are presented in the Guide 2.0 are part of our continuous effort to expand the categories and include more emission factors (e.g., emission factors for transport from COPERT). Finally, it should be highlighted that this Guide does not consider any of the natural sources of emissions (e.g., forest fire, volcanic eruption, dust storm) that are described under the EMEP/EEA (2023) guidance. The guide do not include land use and land use change (LULUC), a significant contributor to methane emissions from the agricultural activities under the IPCC (2019).

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02 Framework for quantifying the GHG and air pollutant emissions of a company

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This section of the Guide 2.0 gives introductory information regarding the sources and impacts 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) emissions.

2.1 Overview of key information

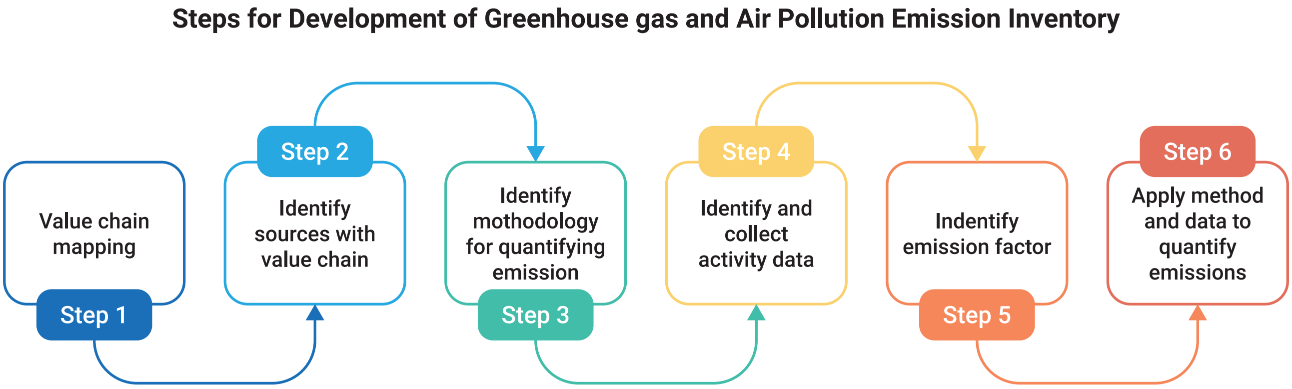
This chapter presents the methodological approaches presented in the Guide 2.0 on how to estimate greenhouse gas and air pollution emissions. It will further present steps that the user can take to map the value chain and identify significant sources of emissions. This chapter also provides a brief overview of the ways of collecting activity data, identifying emission factors (EFs) and application of the methods. Section 2.3 of this chapter provides detailed information of the emissions of greenhouse gas and air pollutants from the key steps of the value chain outlined in the Guide (such as raw material extraction, manufacturing, distribution etc.) of the value chain will be discussed in detail – data collection, methodology and basic principles.

Methodologies and approaches to estimate greenhouse gas and air pollutant emissions from different sources are adapted from the Intergovernmental Panel on Climate Change (IPCC) (2006; 2019), and the European Monitoring and Evaluation Programme/European Environment Agency (EMEP/EEA) guidelines (2023). These are the main guidelines used internationally to quantify greenhouse gas and air pollutant emissions respectively. In each of these documents, key terms are used and applied that relate to the quantification of GHG and/or air pollutant emissions.

2.2 Methodological approach

The overall approach suggested in this Guide to estimate the magnitude of a company's greenhouse gas and air pollutant emissions involves a six-step process shown below in Figure 2.1. To develop an integrated GHG and air pollutant emission inventory, the steps outline a process by which a company can identify the sources that emit GHG and air pollutants across the value chain and identify the methodologies and that will be used and applied to quantify the emissions from a particular source. These steps are consistent with those commonly undertaken to quantify GHG emissions in other guidance documents (e.g., GHG protocol). Therefore, if the company is simply adding air pollutant emissions to an existing GHG inventory, these can be amended or skipped as needed.

Figure 2.1: Steps to develop a GHG and air pollutant emission inventory.

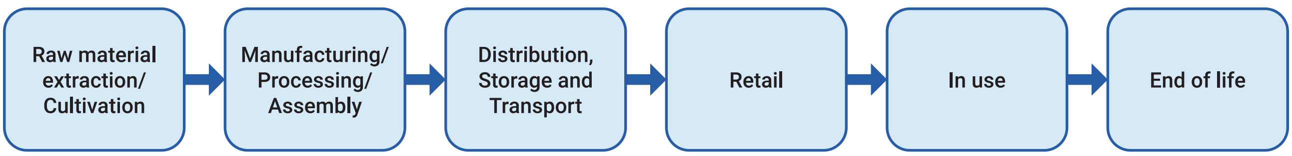


1

Step 1: Mapping the Value Chain

The first key step in quantifying greenhouse gas and air pollutant emissions, is for a company to develop a comprehensive map of their value chain. The aim in mapping a company's value chain is to identify specific emission sources within the different stages of a company's value chain. Figure 2.2 gives an example of a simplified value chain, with six key broad stages within a value chain. Methodologies to quantify greenhouse gas and air pollutant emissions are defined for specific sources and examples of sources include fuel combustion, or processes emissions in particular industries. Mapping the value chain therefore allows the company to comprehensively understand the activities related to the company that may be drivers of GHG and/or air pollutant emissions, and for which the methods described in Chapter 3 can then be applied to quantify them. Mapping the value chain is a key first step because this allows the user to identify the specific emission sources within the different operations and activities of a company's value chain.

Figure 2.2: A simplified diagram of a company's value chain.



Most companies will likely have a detailed analysis and/or description of their value chain, particularly if they have already engaged in a similar activity of quantifying their GHG emissions. It is recommended that an existing detailed mapping of the value chain is used if available. If not, then the structure of the value chain presented in Figure 2.2 could be adjusted and further developed in order to adequately map the different stages of the value chain for a specific company. Not all the steps of the diagram above will be relevant to every company and other stages within the value chain may need to be added or described in more detail depending on the activities that the company undertakes, the company size and supplier network.

2

Step 2: Identify Sources within Value Chain

As defined in Chapter 1, an emission source is the particular process that results in an emission of GHGs and/or air pollutant(s) to the atmosphere. Different sources are generally associated with different parts along a value chain. Multiple sources can exist at the same part of the value chain, and the same type of source can emit air pollutants in different parts of a company's value chain. There have been multiple attempts to standardise the categorisation of different sources. These are explained below.

Nomenclature for Reporting (NFR)

The IPCC (2006; 2019) and EMEP/EEA (2023) guidelines provide comprehensive methodologies for quantifying emissions of GHGs and air pollutants, respectively, for source sectors that are categorised according to a common reporting framework, called Nomenclature for Reporting (NFR). The NFR categorisation of emission sources used by IPCC and EMEP/EEA assigns emission sources a letter and number. Emission sources are categorised in a hierarchical structure, with 4 overarching sources (1 Energy, 2 Industrial Processes and Product Use, 3 Agriculture, Forestry and Other Land Use, 4 Waste), broken down in more detailed and specific sources, which are denoted by a unique set of letters and numbers.

The emission source used in the NFR framework and shown in Table 2.1 is used in this Guide to define the methods for quantifying emissions from different sources along a company's value chain. The reason for using the NFR categorisation of emission sources is that: i) internationally recognised methodologies are available for the quantification of air pollutant emissions from all NFR source categories, and ii) the sources included in the NFR categories represent the most disaggregated definition of emission sources. This allows the NFR emission source categories to be assigned across different parts of a company's value chain, to build up an overall accounting of a company's emissions. For example, if there is stationary fuel combustion within two parts of the value chain, such as in product manufacture, or in retail, then the source would be categorised as 1.A.2 Manufacturing industries and construction, or possible 1.A.4 depending on the specific activity, in the NFR categorisation. The methodologies to quantify emissions from these NFR source categories can then be applied to fuel combustion in both the product manufacture and retail parts of the value chain, to estimate the emissions from this source, occurring at different parts of the value chain.

Table 2.1: **Categorisation of emissions sources within the Nomenclature for Reporting (NFR) framework (note that this follows the EMEP/EEA guidelines and the category labels are the same as EMEP/EEA).**

1	**Energy**	2	**Industrial Processes and Product Use (IPPU)**
		2.A	Mineral products
		2.A.5.B	Construction and Demolition
1.A	Combustion	2.B	Chemical Industry
1.A.1	Energy Industries	2.C	Metal Production
1.A.2	Manufacturing industries and construction	2.D	Solvent and product use
1.A.3.a	Aviation	2.H	Other industry production
1.A.3.b	Road Transport	2.H.1	Pulp and paper industry
1.A.3.c	Railways	2.H.2	Food and beverages industry
1.A.3.d	Navigation (shipping)	2.H.3	Other industrial processes
1.A.3.e	Pipeline transport	2.I	Wood processing
1.A.4	Small combustion	2.J	Production of persistent organic pollutants
		2.K	Consumption of persistent organic pollutants and heavy metals
1.B	**Fugitive emissions from fuels**	2.L	Other production, consumption, storage, transportation or handling of bulk products
1.B.1	Fugitive emissions: solid fuels		
1.B.2	Fugitive emissions: oil and natural gas	5	**Waste**
		5.A	Solid waste disposal on land
3	**Agriculture**	5.B.1	Composting
3.B	Manure management	5.B.2	Anaerobic digestion
3.D	Crop production/ agricultural soils	5.C.1	Waste incineration
3.D.f, 3.I	Agriculture other including pesticides	5.C.2	Open burning of waste
3.F	Field burning of agricultural wastes	5.D	Wastewater handling
		5.E	Other waste

Table 2.2: Categorisation of emissions sources within the Nomenclature for Reporting (NFR) framework (note that this follows IPCC guidelines and the category labels are the same as IPCC 1996 and 2006).

Sector	Revised 1996 IPCC Guidelines	2006 IPCC Guidelines	Sector	Revised 1996 IPCC Guidelines	2006 IPCC Guidelines
1. Energy	1A. Fuel Combustion Activities	1A. Fuel Combustion Activities	**4. Agriculture, Forestry, and Other Land Use**	4A. Enteric Fermentation	3A. Enteric Fermentation
	1A1. Energy Industries	1A1. Energy Industries		4B. Manure Management	3B. Manure Management
	1A2. Manufacturing Industries and Construction	1A2. Manufacturing Industries and Construction		4C. Rice Cultivation	3C. Rice Cultivation
	1A3. Transport	1A3. Transport		4D. Agricultural Soils	3D. Agricultural Soils
	1A4. Other Sectors	1A4. Other Sectors		4E. Prescribed Burning of Savannas	3E. Prescribed Burning of Savannas
	1A5. Other (Not elsewhere specified)	1A5. Other		4F. Field Burning of Agricultural Residues	3F. Field Burning of Agricultural Residues
	1B. Fugitive Emissions from Fuels	1B. Fugitive Emissions from Fuels		4G. Other	3G. Other
	1B1. Solid Fuels	1B1. Solid Fuels	**5. Land Use, Land-Use Change, and Forestry (LULUCF)**	5A. Changes in Forest and Other Woody Biomass Stocks	4A. Forest Land
	1B2. Oil and Natural Gas	1B2. Oil and Natural Gas		5B. Forest and Grassland Conversion	4B. Cropland

Sector	Revised 1996 IPCC Guidelines	2006 IPCC Guidelines	Sector	Revised 1996 IPCC Guidelines	2006 IPCC Guidelines
2. Industrial Processes and Product Use	2A. Mineral Products	2A. Mineral Industry		5C. Abandonment of Managed Lands	4C. Grassland
	2B. Chemical Industry	2B. Chemical Industry		5D. CO_2 Emissions and Removals from Soil	4D. Wetlands
	2C. Metal Production	2C. Metal Industry		5E. Other	4E. Settlements
	2D. Other Production	2D. Non-Energy Products from Fuels and Solvent Use			4F. Other Land
	2E. Production of Halocarbons and Sulphur Hexafluoride	2E. Electronics Industry	**6. Waste**	6A. Solid Waste Disposal on Land	5A. Solid Waste Disposal
	2F. Consumption of Halocarbons and Sulphur Hexafluoride	2F. Product Uses as Substitutes for Ozone Depleting Substances		6B. Wastewater Handling	5B. Biological Treatment of Solid Waste
	2G. Other	2G. Other Product Manufacture and Use		6C. Waste Incineration	5C. Incineration and Open Burning of Waste
3. Solvent and Other Product Use				6D. Other	5D. Wastewater Treatment and Discharge

In this Guide, the Nomenclature for Reporting (NFR) categorisation of sources is simplified to highlight those sources that are most relevant to a company's value chain. In total, six categories of sources are included in this Guide, and methodologies for quantifying emissions from those sources are described in Chapter 4. The six sources included are:

- **Electricity Generation:** This source corresponds to the NFR sector 1.A.1 Energy Industries for both EMEP/EEA (2023) and IPCC (2006) guidelines. It includes the emissions associated with the production of electricity from the combustion of fossil fuels and/or biomass. In the context of a company's value chain, the air pollutant emissions result from the generation of electricity that is then consumed in the company's activities along its value chain.

- **Stationary Fuel Combustion:** This source corresponds to the NFR sectors 1.A.2 and 1.A.4 for both EMEP/EEA (2023) and IPCC (2006) guidelines. It includes the direct combustion of fossil fuels and biomass within a company's activities (in contrast to the electricity generation source where the generation of electricity may be done outside of the company and distributed through a national grid). This may include fuel combustion within industrial processes, or the operation of stationary machinery or other activities that require fuel combustion.

- **Transport:** This corresponds to 1.A.3 in the NFR categorisation for both EMEP/EEA (2023) and IPCC (2006) guidelines. The transport sector air pollutant source in this Guide covers both freight and passenger transport, and road, rail, shipping and aviation transport modes. Off-road vehicles, e.g., those used in agriculture or construction are also included within the transport source.

- **Industrial Processes:** This source corresponds to the NFR sector 2 for both EMEP/EEA (2023) and IPCC (2006) guidelines as in the table above. It covers all non-fuel combustion emissions that occur during industrial processes.

- **Agriculture:** This corresponds to the NFR sector 3 in for EMEP/EEA (2023) and NFR sector 4 in IPCC (2006) guidelines as detailed in the table above. This source covers all air pollutant emission sources related to livestock (e.g., manure management) and crop production (e.g., crop residue burning, manure and fertiliser application). Note that the processes of agricultural products in the food and beverage industry are covered under the Industrial Processes source

- **Waste:** This source corresponds to the NFR sector 5 for EMEP/EEA (2023) and NFR 6 for IPCC (2006) guidelines in the table above. It covers all sources of air pollutant emissions that occur as products and other goods reach the end of their life, based on how they are disposed of, e.g., through being placed in landfill sites, composted or incinerated or openly burned.

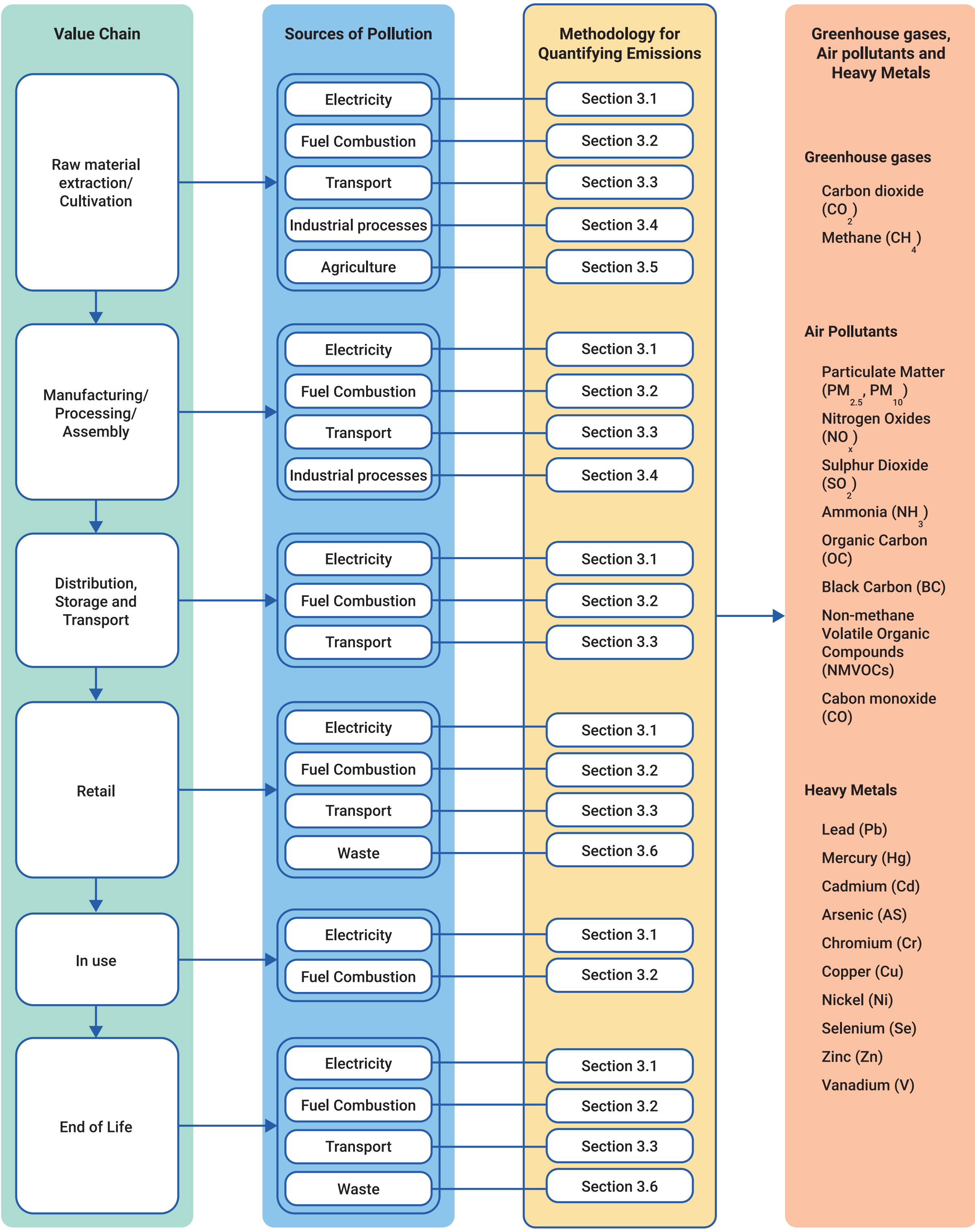
Sources within generic value chain

In this Guide, the value chain and the sources are the two key organising elements that are used to develop a comprehensive assessment of greenhouse gas and air pollutant emissions. The value chain, as described in Section 2.2, maps all the activities that relate to a company's operations, and within which different sources greenhouse gas and air pollutant emissions can occur.

The emitting sources within a company's value chain (noting that along a value chain multiple pollutants may be emitted at a particular stage, and the same type of source may be emitted at multiple stages) are categorised according to the NFR codes described above and used by IPCC and EMEP/EEA for disaggregated source sectors in national emission inventory development.

Figure 2.3 provides an overview of the sources that may be emitted at different stages along a generic value chain, and for which methodologies to quantify the magnitude of emissions from those sources are included in this Guide. It also highlights the different pollutants that could be emitted from each source that contribute to fine particulate matter and surface ozone concentrations, and which are covered in this Guide. The following sub-Chapters describe each of the six parts of the generic value chain that is shown in Figure 2.3 and highlights the possible greenhouse gas and air pollutant emission sources (out of the six overarching sources described above, that may be emitted at that part of the value chain). These sub-Chapters aim to aid the reader in identifying what parts of the value chain may be relevant for their own company, and to map the air pollutant emission sources that occur in each part of the value chain. Once this mapping has been completed, and the components of the values chain and the sources within each of them have been identified, as shown in Figure 2.3 for the generic value chain, then Chapter 4 can be used to identify the methods and data needed to quantify air pollutant emissions. The relevant sub-Chapter of Chapter 4 is shown in Figure 2.3.

Figure 2.3: Generic value chain (from raw material extraction, through manufacturing, retail, use and disposal) and possible sources of greenhouse gas and air pollutant emissions (electricity generation associated with use, transport and process emissions) at different points in the value chain.



The Section 2.3 provides detailed information on all emission sources present at every step of the value chain described in Figure 2.3 and the user is encouraged to visit that supplement if more detailed information is required in order to identify the sources of emissions and the Chapters linking to the methodologies required to quantify them.

3

Step 3: Identify Methods for Quantifying Emissions

There are broadly two ways to estimate emissions from sources. Direct measurements which are not common, and emissions estimated based on applying documented emission factors, which quantify the quantity of pollutant emitted per unit of activity, with company-specific activity variables which quantify the size or extent of an activity. These emission factors are calculated ratios relating emissions to a proxy measure of activity at an emissions source. In many cases, particularly when direct monitoring is unavailable or prohibitively expensive, accurate emission data can be calculated from fuel use data. Even small users usually know both the amount of fuel consumed and have access to data on the carbon content of the fuel through default carbon content coefficients or through more accurate periodic fuel sampling. Companies and users are encouraged to use the most accurate calculation approach available to them and that is appropriate for their reporting context.

For most small to medium-sized companies and for many larger companies, direct, energy-related emissions will be calculated based on the quantities of commercial fuels used (such as natural gas and heating oil) and published emission factors (e.g., such as those provided in the Guide 2.0 from the IPCC (2006;2019) and/or EMEP/EEA (2023) guidelines). Emissions related to indirect energy consumption will primarily be calculated from metered electricity consumption and supplier-specific, local grid, or other published emission factors. All other emissions will primarily be calculated from activity data, such as fuel use or passenger-kilometres, and published emission factors. In most cases, if source or facility specific emission factors are available, they are preferable to more generic or general emission factors. This is because the use of facility specific and/or country specific data and/or emission factors can significantly reduce the uncertainty related to the estimates.

Choice of Tiers for emission estimation

The Tier represents the level of methodological complexity. Different Tiers are linked to different types of activity data and the granularity of data; therefore, it is the data availability that will ultimately determines the choice of the Tier.

The Guide 2.0 follows the Intergovernmental Panel on Climate Change (IPCC) 2006 emission inventory guidelines and where appropriate, the IPCC 2019 Refinement to the 2006 guidelines (IPCC 2006; 2019). The IPCC 2006 and 2019 guidelines provide the appropriate methods for the quantification of GHG emissions. For air pollutants, the EMEP/EEA (2023) guidelines are used. Both the IPCC and EMEP/EEA guidelines use three Tiers in order to estimate greenhouse gas and air pollution accordingly. These methods differ in that a **Tier 1** method is the simplest method relying on available activity data and default emission factors and usually comes with a significant level of uncertainty. **Tier 2 and Tier 3** methods are more complex, and more demanding in terms of activity data required and emission factors, but they are considered by the IPCC (2006; 2019) and EMEP/EEA (2023) to be more accurate with less uncertainty related to them.

The **Tier 1** method, broadly uses activity data and emission factors (EF) following Equation (2.1):

Eq. 2.1

$$Emissions = Activity \times Emission\ Factor$$

The activity variable quantifies how big a particular activity or process is (e.g., the number of Terajoules of fuel consumed in a particular sector, the number of tonnes of production of a particular mineral, chemical or other product). Emission factors quantify the mass of pollutant emitted per unit of activity (e.g., the kilograms of black carbon emitted per Terajoule of fuel consumed). Activity data for this equation 2.1 can be taken from readily available and/or publicly available statistical information (sector specific and industry specific statistics, for example annual primary aluminium production from the statistics of the International Aluminium Institute).

The default tier 1 emission factors represent the 'typical' or 'averaged' process conditions and in this document the default EFs are predominantly taken from the IPCC (2006, 2019) EMEP/EEA (2023). In addition, for some sources, emission factors were taken from the scientific literature and are included in the excel sheets that are provided for each pollutant and for each source.

The **Tier 2** method uses a similar approach to the Tier 1 method, with activity data used but it applies country-specific and/or process and/or technology specific emission factors that need are developed using specific information on process conditions, fuel quality, abatement technologies, year the technology was developed and other specificities of the processes it is attempting to quantify the emissions of. The general equation that will be followed for most Tier 2 estimates is Equation (2.2):

Eq. 2.2

$$E_{GHG/pollutant} = \sum_{technologies} AR_{production,\ technology} \times EF_{production,\ pollutant}$$

The variable '$E_{GHG/pollutant}$' refers to the greenhouse gases and/or air pollutants emitted from a particular source, '$AR_{production,technology}$' is the production rate of the specific activity within the source category, using a specific technology, and the variable '$EF_{technology,pollutant}$' is the emission factor for the specific technology and the specific pollutant. In some cases, this equation will be diversified to reflect the specificities of the sector and/or technology it is attempting to quantify.

The Tier 3 method uses information that is much more disaggregated information and provides the highest level of granularity out of the three. It usually uses facility-, process- and/or country-specific data, and more advanced calculations. It can account for facility- and/or process-specific abatement, different technologies or lines of production within the same facility etc.

The Guide 2.0 provides information on the Tier 1 and Tier 2 methods for each of the sources and sectors. However, it is up to the user to identify what level of data is available and whether they have access to the information needed to choose a higher level of Tier than the simpler Tier 1. Tier 3 requires a very granular level of information very often technology, or process specific for which emission factors are rarely publicly available and/or may need to be country-, company-, technology- and process-specific. If the user has data available, and appropriate to apply a Tier 3 method, they can further investigate IPCC (2006; 2019) and EMEP/EEA (2023) on data requirements, methodologies and emission factors available on how to apply the Tier 3 method.

4

Step 4: Identify and collect activity data

Identifying and collecting the appropriate activity data is a key step as this will then allow to decide on which method (which Tier) will be appropriate to apply to quantify the emissions from the different sources. A company/user may not have access to all the data required to put together a complete inventory. There are several reasons why a company and/or user may not have access to data with a higher level of detail that could be used to apply a Tier 2 (or Tier 3) method. These reasons include commercial sensitivity of the data, lack of direct measurements, high cost of the data that needs to be obtained.

This can be mitigated in the following ways:

a. Identifying partners that have or can obtain access to the data: As a value chain can consist of different corporate or industrial entities, it is possible that the data missing could be obtained through one of those partners.

b. Using publicly available activity data: There are activity data available from several sources, for example, in the case of global aluminium production, the International Aluminium Institute publishes annual numbers (tonnes) of primary aluminium produced aggregated into regions (Europe, Asia (excluding China), China, Rest of the World etc) [International Aluminium 2025]. Using publicly available data should be done carefully as it can introduce a significant level of uncertainty.

c. Compiling the inventory using only the available data: If the lack of data cannot be mitigated, then it is still possible to compile the inventory using only the existing, available data. However, the company/user/inventory compiler need to carefully identify the sectors/sources/activities for which the data is incomplete, and make sure that this is adequately reflected in the results and any interpretation of the results.

5

Step 5: Identify Emission Factors

A list of all the emission factors related to the key pollutants covered in this Guide is presented in Chapter 3 for every sector and sub-sector covered. The choice of the emission factors depends on the level of detail of the data that has been obtained and/or identified.

Using the Tier 1 emission factors there is one emission factor related to each air pollutant. This emission factor is then used as described in Equation (2.1). However, as the Tier 2 emission factors need to be chosen based on the technology, and abatement level they represent, particular care needs to be taken when choosing the appropriate emission factor, as there can be large discrepancies between technologies and/or abatement levels. Excel sheets have been added with emission factors (e.g., from the EMEP/EEA database) in order to provide a user-friendly way for the emission factors to be included.

It should be noted that the Guide 2.0 is using the available emission factors that are suggested by the IPCC (2006; 2019) and EMEP/EEA (2023) because these are widely used and scientifically robust documents. In some cases, other emission factors might exist, for example emission factors that are specific to a certain process and/or industry, however, for the moment these are not included in this Guide. It is up to the user to decide whether there is a more appropriate emission factor that should be used instead of the suggested IPPC and/or EMEP/EEA emission factors that are included in the excel dataset provided in the resources (https://www.ccacoalition.org/resources/integrated-guide-business-greenhouse-gas-and-air-pollutant-emission-assessment).

6

Step 6: Apply methods and data to quantify emissions

Once the activity data has been obtained and the appropriate emission factors chosen based on the level of detail that the activity data suggests, the appropriate method can then be chosen. These methods are, as described, the Tier 1 or Tier 2. Chapter 3 will provide a detailed description of the appropriate equations linked to the different Tier methods.

2.3 Detailed information about the inputs to calculations for each value chain stage

This chapter contains detailed information on the key emitting sources for each stage of the value chains and provides detailed tables that can point the user to the appropriate chapters where the methodologies can be found.

A

Value Chain Stage A: Raw Materials extraction/cultivation

Within a value chain, the 'raw materials' stage involves all processes associated with the exploration, extraction, and/or cultivation of substances that are then used in the production of products or delivery of services. Examples of raw materials include the extraction of crude oil and oil products (e.g., diesel, gasoline), wood, metals, and other materials used in the manufacture of physical products (e.g., cotton or food). In this Guide raw materials also encompasses ingredients used in the manufacture of food and drinks. The possible sources of greenhouse gas and air pollutant emissions within the raw materials part of the value chain are outlined in Table 2.3.

Table 2.3 shows seven broad categories of emission sources contained within the raw materials category of the value chain. Some of these sources relate to specific raw materials. For example, fugitive emissions result from the extraction, processing and distribution of crude oil, oil products and natural gas, and there are specific sources of agricultural emissions associated with the use of crop and livestock 'raw materials'. In addition, in the extraction and processing of a wide range of raw materials there may also be emissions associated with fuel or electricity consumption, as well as non-energy, 'process' emissions that occur when raw materials are prepared. Table 2.1 covers all these sources and provides the link to the specific NFR code within Chapter 3 that provides the relevant methodology to quantify the emissions from that particular source.

To quantify the emissions associated with raw materials requires, at the most basic level, an understanding of the quantity of each raw material that is used in the company's operation within a given year. Default values are provided in Chapter 3 for emission factors and energy consumption for different raw materials, but company-specific data is needed on the quantity of raw material that the company consumes for these methodologies to be applicable.

Figure 2.4: Overview of input within the raw materials stage of the generic value chain.

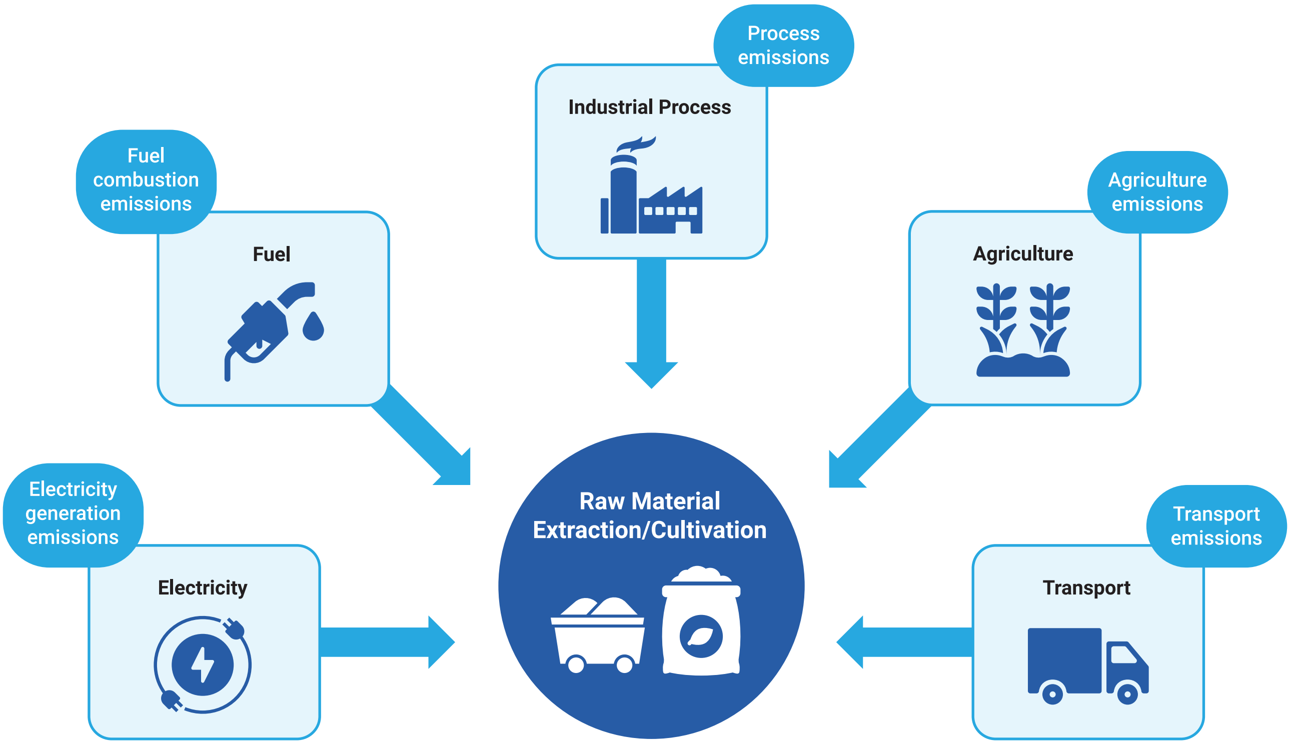


Table 2.3: Possible sources of greenhouse gas and air pollutant emissions within raw materials.

Source	Description	Methodology for quantifying emissions	Chapter with emission quantification methodology
Stationary fuel combustion	Stationary fuel combustion in the extraction of raw materials and/or production of agricultural products	Total fuel combusted multiplied by pollutant- and/or technology-specific emission factors	**3.2**
Electricity Generation	Electricity consumed in the extraction of raw materials and/or production of agricultural products	Fuel combusted to generate electricity consumed multiplied by pollutant- and/or technology-specific emission factors	**3.1**
Industrial Processes	Process (non-fuel consumption) emissions associated with extraction or processing of raw materials (e.g., mineral, chemical, metal production)	Quantity of raw material consumed multiplied by pollutant-specific emission factors	**3.4**

Source	Description	Methodology for quantifying emissions	Chapter with emission quantification methodology
Agriculture	Synthetic and fertiliser application in crop production		**3.5**
	Burning of agricultural residues	Quantify of residue generated in production of the quantity of crop used in food production multiplied by fraction of residue openly burned in fields and pollutant-specific emission factors	
	Management of manure from livestock	Quantity of manure managed in different systems that is generated from number of livestock needed to produce meat/dairy used in food production multiplied by system-specific emission factors for ammonia and nitrogen oxide.	
Transport	Emissions from freight transport during the production of extraction of raw materials Emissions from operation of mobile machinery during extraction processes (e.g., mining and quarrying)		**3.3**

B Value Chain Stage B: Manufacturing/Processing/Assembly

This section will discuss emissions related to the Manufacturing, Processing and Assembly which is the conversion of raw materials into a product, or service, that can then be retailed and used by consumers. A company may sell one, hundreds, or thousands of different products, and the process to manufacture, process and/or assemble each product may differ, and result in emissions of air pollutant from different sources.

In GHG emission inventory methodologies and databases, a common approach to quantifying the GHG emissions associated with the manufacture of a particular product is to multiply the amount of product produced by a pre-defined emission factors that accounts for the emissions from all sources associated with the production of that product. A key limitation of this approach is that the aggregate emission factor makes it difficult to determine the contribution of different emission sources to the emissions associated with the manufacture of a particular product, e.g., if the emissions are associated with the production of the raw material, the energy consumed in its production, or the transportation needed for its production. Therefore, in this Guide an alternative approach is outlined in which air pollutant emissions are calculated separately for individual emission sources associated with the manufacture, processing and/or assembly of a particular product.

In applying this guidance, the user is asked to consider each product for which the emissions associated with its production are to be estimated. The potential emission sources involved in the production of an example product, Product X, include the emissions associated with the raw materials used in its production, which have been covered in the previous Chapter. In addition, the production of Product X might require the combustion of fuel (e.g., biomass, gasoline, diesel, fuel oil, gas etc.), consumption of electricity, or some transportation. Finally, there may be non-energy 'process' emissions that result from the production of Product X.

Table 2.4 summarises these sources and includes the links to the relevant sections in Chapter 3 where the methodologies for quantifying the emissions from each source can be found.

Figure 2.5: **Overview of input within the raw materials stage of the generic value chain.**

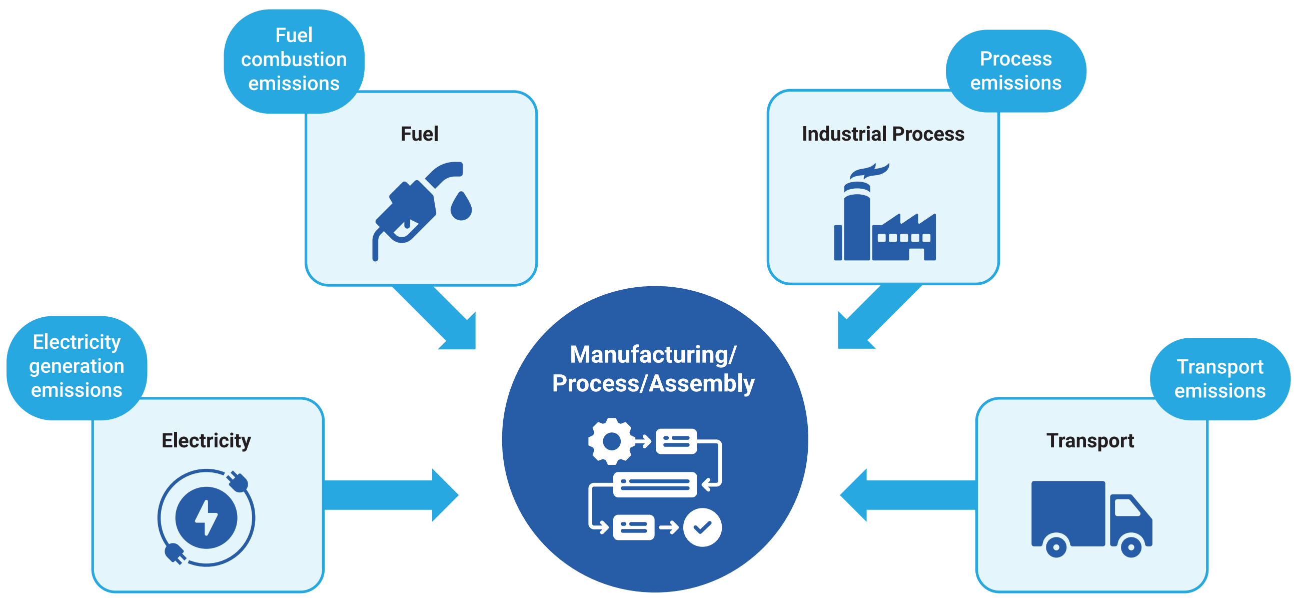


Table 2.4: Possible sources of greenhouse gas and air pollutant emissions within Manufacturing, Processing and Assembly.

Source	Description	Methodology for quantifying emissions	Chapter with emission quantification methodology
Stationary fuel combustion	Stationary fuel combustion of fossil fuels or biomass, e.g., in machinery, in the manufacturing, processing or assembly process	Total fuel combusted multiplied by pollutant- and/or technology-specific emission factors	**3.2**
Electricity Generation	Electricity consumed in the manufacturing, processing or assembly process that is generated from fossil fuels and/or biomass	Fuel combusted to generate electricity consumed multiplied by pollutant- and/or technology-specific emission factors	**3.1**
Industrial Processes	Process (non-fuel consumption) emissions associated with the manufacturing, processing, or assembly process (e.g., aluminium smelting, iron and steel production)	Quantity of material processed or manufactured multiplied by pollutant-specific emission factors	**3.4**
Transport	Emissions from freight transport during the manufacturing, processing, or assembly of materials and products. Emissions from operation of mobile machinery during manufacturing, processing or assembly of materials and products.	**See Chapter 3.3**	**3.3**

C

Value Chain Stage C: Distribution Storage and Transport

This section will discuss emissions from the distribution and storage of goods. A company can own their own distribution and storage centres, or these may be part of their extended supplier networks. Depending on the size of the value chain and the locations of the different manufacturers, assembly, distribution and storage points, distribution can include different types of transport like road, rail, air, or marine transport. It can also include a small or large number of storage and distribution points again, depending on the size of the value chain and the type and geographical area of operation of a company.

For distribution, emission sources are predominantly emissions from the transport of goods using different modes of travel and different type of vehicles, process emissions related to the production of vehicles, electricity generation related to storage and distribution centres as well as fuel combustion emissions.

In GHG emission inventory methodologies and databases, a common approach to quantifying the GHG emissions associated with the distribution of goods is to follow one of the following methods:

1. A fuel-based method, which involves determining the amount of fuel consumed and applying the appropriate emission factor for that fuel
2. A distance-based method, which involves determining the mass, distance, and mode of each shipment, then applying the appropriate mass-distance emission factor for the vehicle used
3. A spend-based method, which involves determining the amount of money spent on each mode of business travel transport and applying secondary environmentally extended input- output (EEIO) emission factors.

A key limitation of these approaches in relation to estimating air pollutant and SLCP emissions is that the emissions depend on the vehicle type, fuel type, fuel efficiency, fuel quality and emission standards (if applicable). As emissions are dependent on these factors, this Guide is using a 'distance travelled' and 'fuel consumed' approach to estimate emissions related to the distribution of goods.
The starting point of the methodology followed in this Guide is to estimate the tonnes-km by multiplying the tonnes of product that was transported using a particular mode of transport (e.g., freight) by the average distance travelled using the particular mode of transport.

Particularly for road transport where vehicle standards may apply, the tonnes-km estimated are then disaggregated by the vehicle standards based on the percentage of vehicles using the different kinds of standards.

The disaggregated tonne-km are then multiplied by an energy intensity that is fuel specific and technology specific to estimate the total fuel consumed by fuel and by technology. Finally, the total fuel consumed is multiplied by a fuel specific and technology specific emission factors.

In applying this guidance, the user is asked to consider the different types of vehicles used for the distribution of goods, the fuel consumed by those vehicles, including the technology and vehicle standards. This approach allows the user to estimate both inbound and outbound activities.

Table 2.5 summarises these sources and includes the links to the relevant sections in Chapter 4 where the methodologies for quantifying the emissions from each source can be found.

Figure 2.6: **Overview of inputs for the Distribution, Storage and Transport stage of the value chain.**

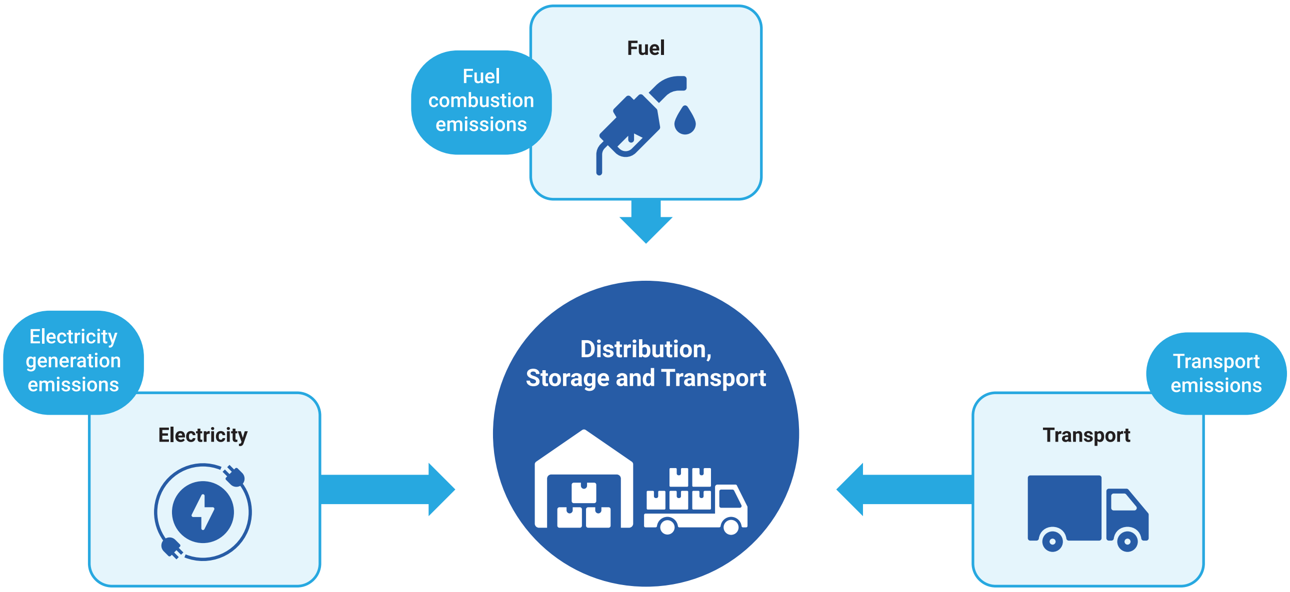


Table 2.5: **Possible sources of greenhouse gas and air pollutant emissions within Distribution, Storage and Transport.**

Source	Description	Methodology for quantifying emissions	Chapter with emission quantification methodology
Stationary fuel combustion	Stationary fuel combustion within distribution, storage and transport	Total fuel combusted multiplied by pollutant- and/or technology-specific emission factors	**3.2**
Electricity Generation	Electricity consumed during distribution, storage, and transport that is generated from the combustion of fossil fuels	Fuel combusted to generate electricity consumed multiplied by pollutant- and/or technology-specific emission factors	**3.1**
Transport	Emissions from freight transport during the distribution and storage of materials and products. Emissions from operation of mobile machinery during the distribution and storage of materials and products.	**See Chapter 3.3**	**3.3**

D

Value Chain Stage D: Retail

This section will discuss emissions from the retail stage of the value chain. There are of course, a wide variety of retailers with different types of products. The different kinds of retailers include grocery stores and supermarkets, general merchandise stores, specialty stores, non-store retailers, as well as restaurants and dining establishments. Most companies, depending on their size, will be selling more than one type of consumer goods however for most, it is more usual to be selling a large range of products. Emissions of air pollutants related to manufacturing and production of the products themselves are addressed above so this section will be focusing on the remaining sources, those related to the activities of the retailer.

Emissions of greenhouse gas and air pollutants related to the retail stage occur mainly from electricity consumption in the different retail facilities, fuel combustion, operations which can include but not restricted to, construction of new buildings and facilities, transport (both passenger and goods) and waste management, particularly waste burning. To estimate emissions from the electricity consumed in the different facilities, the user will need to identify all the activities that take place within the company which may include heating, cooling, lighting, air conditioning, ventilation of the facilities, cooking (e.g., bakery or restaurant), refrigeration and printing. All these activities relate particularly to the consumption of energy of a retail outlet.

Transport of goods, customers and staff is another key source of air pollutant emissions as is the construction of new buildings (e.g., selling points) and facilities (e.g., offices and administrative spaces) related to the retailer's activities. Air pollution occurring from customer travel relates to the preferred and chosen mode of transport that the customer uses to arrive at the retailer, manufacturer, storage facility, collection point, or other company premises.

For the user to estimate emissions related to the transport of their customers and staff, from and to their facilities they will need to have information on the number of customers (and/or staff) visiting their businesses and facilities. Because this Guide is using a distance travelled approach to estimate emissions related to customer travel, the user will also need to have an understanding and access to the average distance travelled for the customers and staff to get to their business by using different modes of transport (e.g., cars, buses, motorcycles, non-motorised).

These are the key variables that are required for the user to estimate the emissions. The user will then be able to estimate the number of passenger-km by multiplying the number of people visiting businesses by the average distance travelled to get to the business by mode. Then, the passenger-km for each mode of transport is disaggregated by vehicle standards based on the percent of vehicles meeting different Euro standards. Finally, the estimated passenger-km is multiplied by a fuel-specific (e.g., diesel, gasoline) and technology-specific (e.g., Euro standard) energy intensity (fuel consumption per passenger-km) to estimate the total fuel consumed by fuel and technology. Fuel and technology-specific emission factors are then multiplied by the fuel consumed to estimate the air pollutant emissions. Table 2.6 summarises these sources and includes the links to the relevant sections in Chapter 3 where the methodologies for quantifying the emissions from each source can be found.

Figure 2.7: Overview of inputs for the Retail stage of the generic value chain.

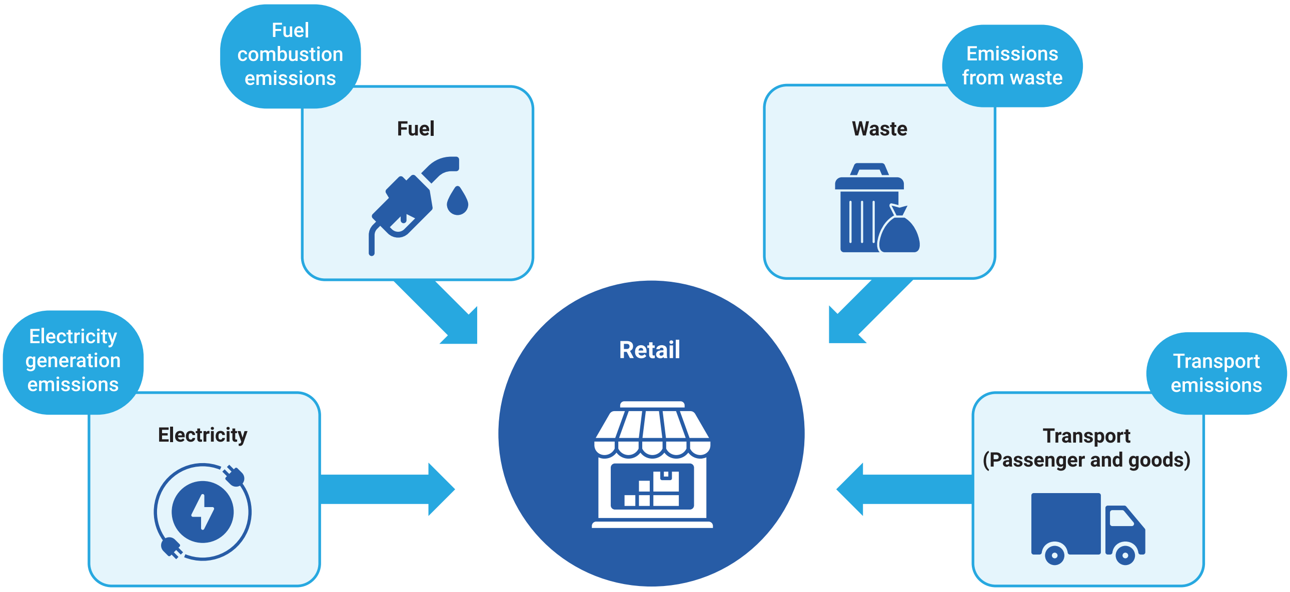


Table 2.6: Possible sources of greenhouse gas and air pollutant emissions within Retail.

Source	Description	Methodology for quantifying emissions	Chapter with emission quantification methodology
Stationary fuel combustion	Combustion of fossil fuels and/or biomass within retail component of value chain. Examples include diesel generators	Total fuel combusted multiplied by pollutant- and/or technology-specific emission factors	**3.2**
Electricity Generation	Electricity consumed during in retail operations (e.g. stores) that is generated from the combustion of fossil fuels and/or biomass	Fuel combusted to generate electricity consumed multiplied by pollutant- and/or technology-specific emission factors	**3.1**
Transport	Emissions from freight transport during the retail process (e.g. customer delivery) including road, rail, shipping and aviation travel Emissions from customer travel including road (public transport, private vehicles) and rail travel	**See Chapter 3**	
Waste	Emissions related to waste management and disposal	**See Chapter 3**	**3.3**

E

Value Chain Stage E: In Use

This section will discuss emissions from the 'In Use' stage of the value chain. Air pollutant emissions related to this stage of the value chain are related to electricity consumption of the products bought by the consumer but also, with emissions resulting from the use of appliances, for example, for cooking and heating.

For example, approximately 3 billion people still cook using solid fuels (such as wood, crop wastes, charcoal, coal, and dung) and kerosene in open fires and inefficient stoves. These cooking practices are inefficient and use fuels and technologies that produce high levels of household air pollution with a range of health-damaging pollutants. To estimate emissions from the In Use stage of the value chain the user needs to know how much energy is consumed.

Figure 2.8: Overview of inputs for In Use.

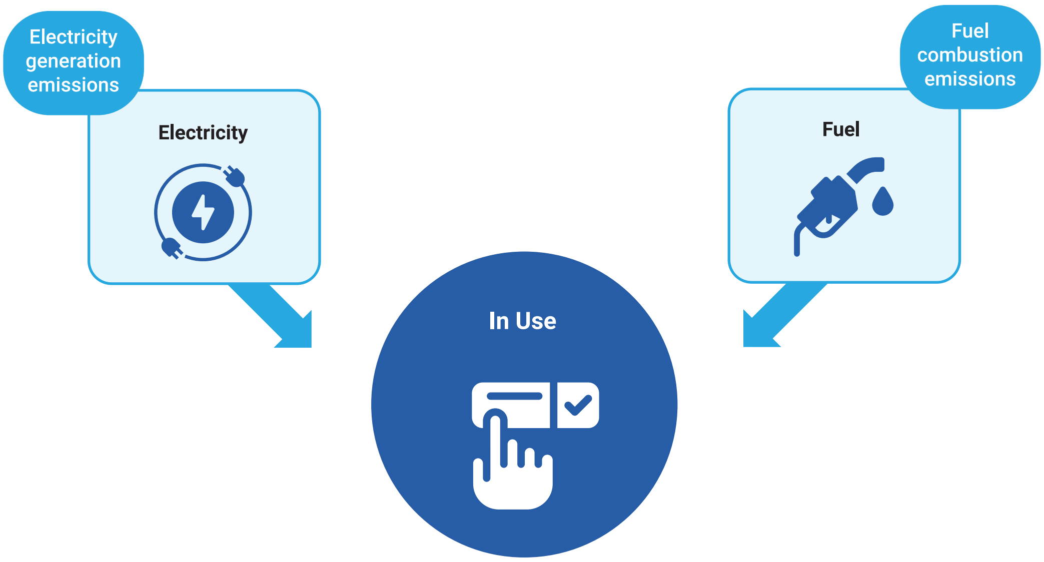


Table 2.7: Possible sources of greenhouse gas and air pollutant emissions within In Use.

Source	Description	Methodology for quantifying emissions	Chapter with emission quantification methodology
Stationary fuel combustion	Stationary fuel combustion from appliances that use fuel for heating, cooking or other purposes (e.g., from stoves, space heaters)	Total fuel combusted multiplied by pollutant- and/or technology-specific emission factors	**3.2**
Electricity Generation	Electricity consumed by different types of by appliances (e.g., fridges, kettles).	Fuel combusted to generate electricity consumed multiplied by pollutant- and/or technology-specific emission factors	**3.1**

F

Value Chain stage F: End of Life

This section will discuss emissions from the 'end of life' stage of the value chain. Emissions related to the 'end of life' stage can occur as a result of electricity generation, fuel combustion, transport to landfills, and waste management, which includes the burning of waste if and when this occurs. Additionally, air pollutant emissions can occur from the construction of buildings and/or facilities but these emissions can be addressed by following the steps in previous sections.

Figure 2.9: Overview of inputs for End of Life.

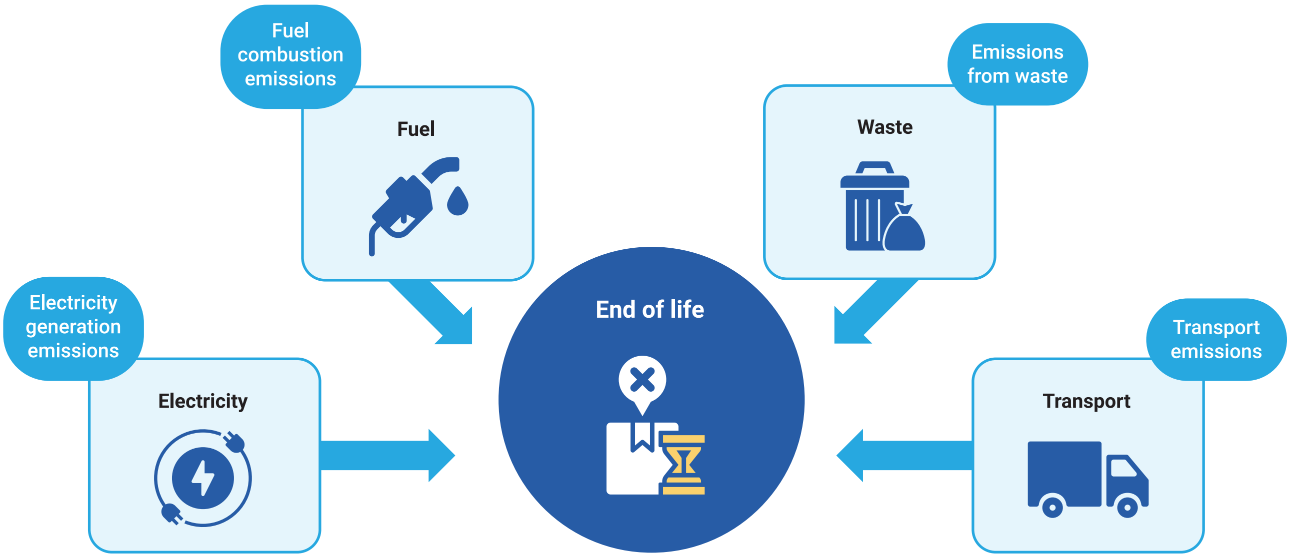


Table 2.8: Possible sources of greenhouse gas and air pollutant emissions within End of Life.

Source	Description	Methodology for quantifying emissions	Chapter with emission quantification methodology
Stationary fuel combustion	Stationary combustion of fossil fuels and biomass during disposal of waste generated from company activities	Total fuel combusted multiplied by pollutant- and/or technology-specific emission factors	**3.2**
Electricity Generation	Electricity consumed in the process of waste disposal	Fuel combusted to generate electricity consumed multiplied by pollutant- and/or technology-specific emission factors	**3.1**
Transport	Emissions produced from the transport of products at the end of their life to waste disposal facilities	**See Chapter 3**	**3.3**
Waste	Emissions related to waste management and disposal	**See Chapter 3**	**3.6**

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, Copenhagen. (Access at https://www.eea.europa.eu/publications/emep-eea- guidebook-2019)

EMEP/EEA (2023) EMEP/EEA air pollutant emission inventory guidebook 2023: Technical guidance to prepare national emission inventories. EEA Report No 13/2023, European Environment Agency, Copenhagen. (Access at https://www.eea.europa.eu/publications/emep-eea- guidebook-2023)

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

IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.

IPCC 2019, 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Calvo Buendia, E., Tanabe, K., Kranjc, A., Baasansuren, J., Fukuda, M., Ngarize, Osako S., Pyrozhenko A., Shermanau Y., P. and Federici, S. (eds). Published: IPCC, Switzerland.

03 Methods and Emission Factors for Key Emitting Sources

3.1 Estimating Greenhouse Gases and Air Pollutant Emissions from Electricity Consumption

Quote as: CCAC and SEI (2025). Section 3.1 Estimating Greenhouse Gas and Air Pollutant Emissions from Electricity Consumption. 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 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.

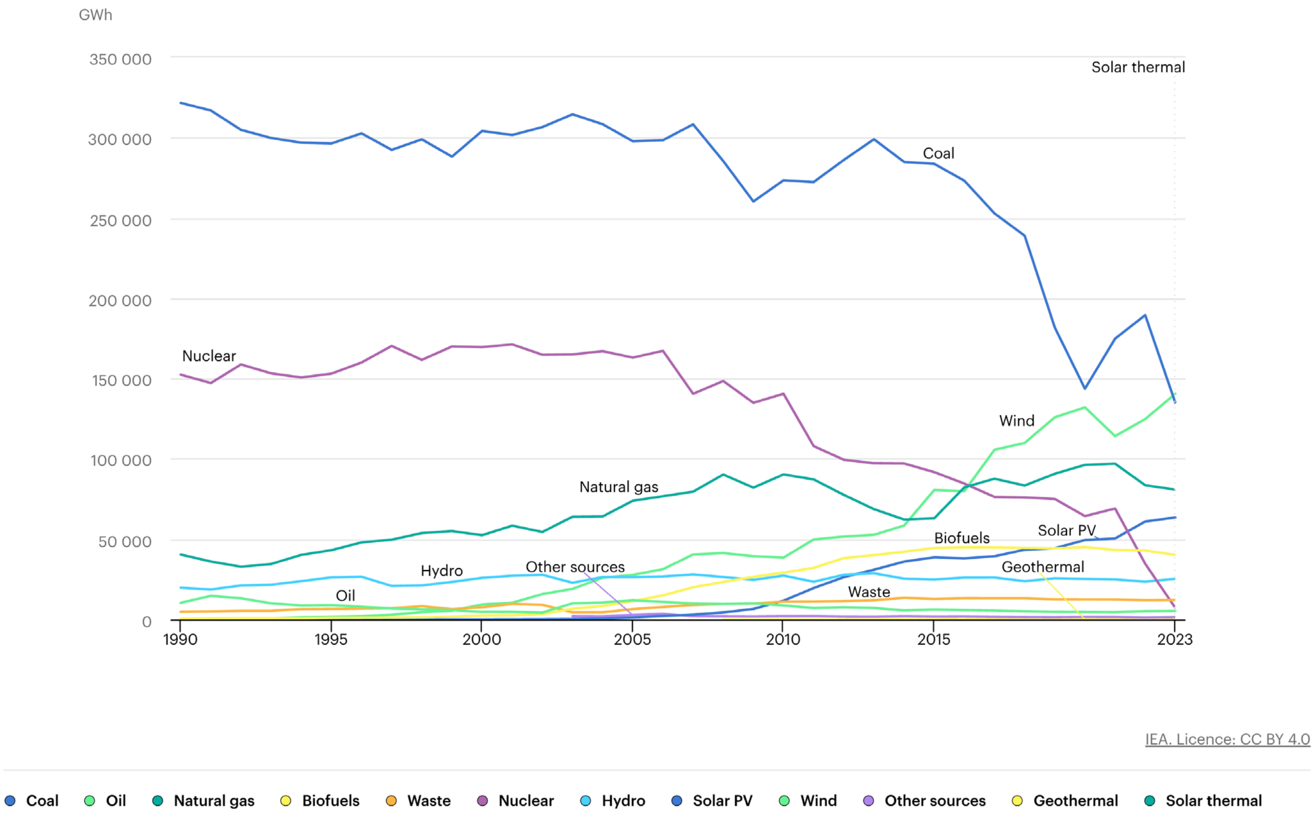
The proportion of electricity generated using different types of fuel and technology (Pn) can be substantially different across different countries. Therefore, to estimate (Pn), the user needs to identify the appropriate data for the electricity generated using different types of fuel and technologies (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: **Default efficiency values for power stations disaggregated by fuel**

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

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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

$$Em_k = FC_n \ x \ EF_k$$

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:

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

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

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

$Emission_{Biomass\ fuels}$ = 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

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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

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

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

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3.4 Estimating Greenhouse Gas and Air Pollutant Emissions from Industrial Processes

Quote as: CCAC and SEI (2025). Section 3.4 Estimating Greenhouse Gas and Air Pollutant Emissions from Industrial Processes. 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 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:

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**

EmissionsSO_x = 50,000 Mg x 3 g/Mg
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

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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

$$Fertiliser\ applied_{type\ of\ crop} = Land\ area_{type\ of\ crop} * Application\ rate_{type\ of\ crop}$$

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

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

where:

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

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

$AR(N_{applied})$ = 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

$$Mass\ of\ residue\ burned = Crop\ production_i * Residue\ to\ crop\ ratio_i * Dry\ matter\ fraction * Dry\ matter\ fraction * Fraction\ oxidised$$

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)

$EF_{k,t}$ = 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

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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.

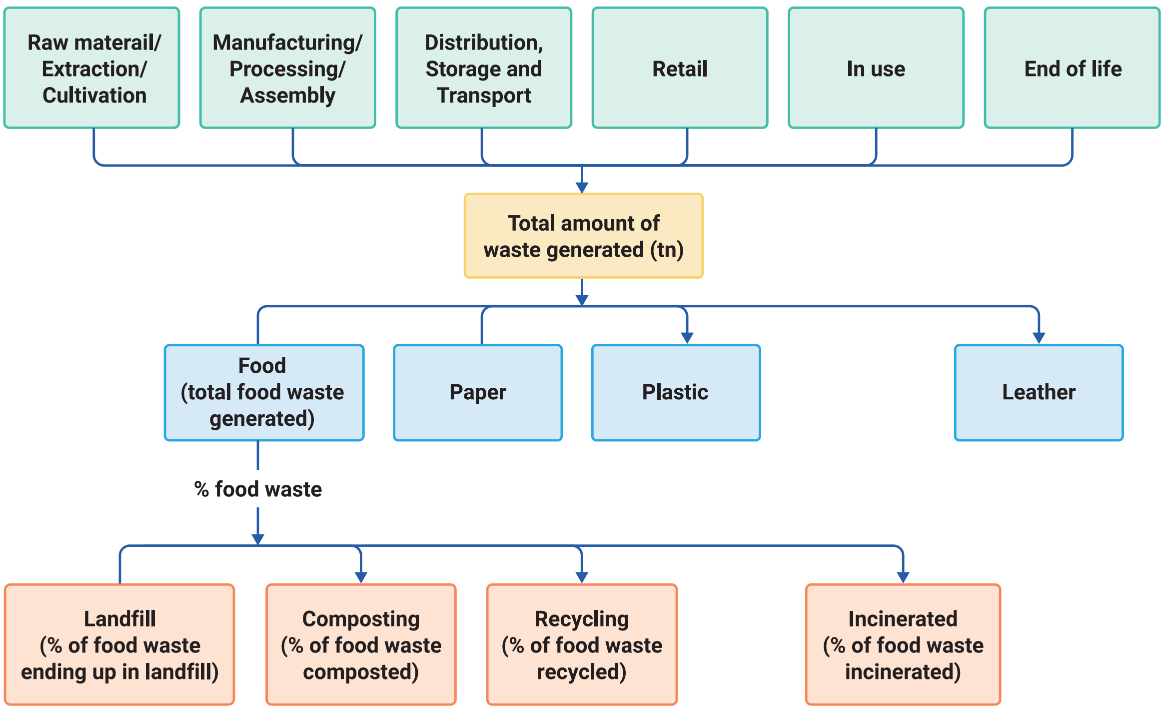
2 Step 2: Disaggregating the total amount of waste generated by different types of waste.

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:

ETP,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

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04 Uncertainties

Quote as: CCAC and SEI (2025). Section 4 Uncertainties, 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 and where uncertainties in the calculations 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) can occur and provides an overview of the methods the user can use to estimate these uncertainties.

Quantifying and estimating uncertainty is a key part of compiling an inventory and can be a challenging task. This chapter will give an overview of how uncertainty can be estimated for the categories described under Chapter 3. Overall, the user will need to follow three steps in order to estimates the uncertainties associated with the different sources of emissions: a) Identify sources of uncertainty, b) Quantify uncertainties for the different sources, c) Aggregating uncertainties. For clarity, a glossary is provided below with some key concepts that will be used throughout this Section.

Term	Definition
Probability density function (PDF)	The PDF describes the range and relative likelihood of possible values. The PDF can be used to describe uncertainty in the estimate of a quantity that is a fixed constant whose value is not exactly known, or it can be used to describe inherent variability. The purpose of the uncertainty analysis for the emission inventory is to quantify uncertainty in the unknown fixed value of total emissions as well as emissions and activity pertaining to specific categories.
Confidence Interval	The true value of the quantity for which the interval is to be estimated is a fixed but unknown constant. The confidence interval is a range that encloses the true value of this unknown fixed quantity with a specified confidence (probability). Typically, a 95 per cent confidence interval is used in inventories. From a traditional statistical perspective, the 95 per cent confidence interval has a 95 per cent probability of enclosing the true but unknown value of the quantity. An alternative interpretation is that the confidence interval is a range that may safely be declared to be consistent with observed data or information. The 95 percent confidence interval is enclosed by the 2.5th and 97.5th percentiles of the PDF.
Uncertainty	Lack of knowledge of the true value of a variable that can be described as a PDF characterising the range and likelihood of possible values. Uncertainty depends on the analyst's state of knowledge, which in turn depends on the quality and quantity of applicable data as well as knowledge of underlying processes and inference methods.

It is important that an inventory is precise in the sense that, as far as possible, it is neither over- or under- estimating emissions from the different categories and that the assumptions that have gone into the different methods and use of activity data have been as clearly mapped as possible. While it may not be possible to accurately identify, map, and quantify all sources of uncertainty, it is good practice to account and document, as far as possible, all causes of uncertainty including those that have not been considered.

4.1 Possible Sources of Uncertainty

Regardless of the methods used to estimate emissions for each sector and sub-sector, the uncertainty evaluation is based on the underlying data that has been used for every method. Overall, this Guide is using two key types of input data, the activity data that need to be identified by the user, and the emission factors used. These are the two key sources of uncertainty that need to be considered by the user.

4.1.1 Activity Data

The methods described in Chapter 3 of this Guide, require for company specific data to be used. Because the activity data needed will be company specific, this Guide cannot provide default uncertainty ranges for that data. The user will make their own assessment of the sources and magnitudes of uncertainty in that data. Common sources of uncertainty in the activity data could include:

Lack of data: In some cases, there may be a lack of the data needed to quantify air pollutant emissions from a key source, sector, or sub-sector, timeseries can be inconsistent and data can be 'patchy' (i.e., have discreet gaps). Sometimes this can be mitigated by using proxy or default data or by using interpolation/extrapolation.

Lack of representativeness of data: This is a source of uncertainty that is associated with the lack of correspondence between the conditions associated with the available data and the conditions associated with real world emissions or activity. For example, start-up and shut down processes of a plant many give different emission rates relative to the activity data, that means that while the activity data is representative for a plant that is running under 'normal conditions' the data will not be representative for the start-up and shut-down phases. Similarly, activity data used for one country and/or region, may not be representative for another country and/or region.

Measurement errors: These errors can be random and systematic and can result from errors in measuring, recording, and transmitting information, inexact values of measurements and reference materials including reporting methods, approximations and assumptions incorporated in the measurement method and estimation procedures, variations in observations, recording and assumptions. This should be particularly taken into consideration when relying on data provided by a 3rd party or by multiple external partners as different suppliers and companies could have different measuring and reporting systems and methods.

4.1.2 Emission Factors

Regarding the uncertainty of the emission factors there are two key issues that need to be highlighted: a) the sources of uncertainties related to the emission factors, and b) the uncertainty this leads to when applying the emission factors to specific processes.

The emission factors that have been used and presented throughout this Guide and the SI have been predominately taken from default emission factors of the EMEP/EEA Guidelines (2019). The EMEP/EEA Guidelines provide uncertainties for every emission factor presented in the Tier 1 and Tier 2 approaches under the different sectors and each has a 95% confidence interval associated with them. The uncertainties related to the emission factors are the result of the different estimation methods that have been used in each case.

For example, in some cases, emission factors where estimated based on a large number of measurements made at a large number or facilities across a comprehensive range of operating conditions that fully represent a sector. But in other cases, emission factors were estimated from a much smaller number of measurements, a less representative sample of facilities, or were based on expert knowledge and assumptions only.
What this means, is that these default emission factors may not be representative for a specific process, for a specific location, or for a specific company. Therefore, where available and when appropriate, the user is encouraged to use emission factors that are more representative of a process, or a location and have smaller uncertainties associated to them.

4.2 Aggregating Uncertainties

Once the uncertainties in activity data, emission factor or emissions for a category have been determined, they may be combined to provide uncertainty estimates for the entire inventory in any year and the uncertainty in the overall inventory trend over time. The IPCC Guidelines (2006, 2019) and the EMEP/EEA Guidelines suggest two approaches for the estimation of combined uncertainties: Approach 1 uses simple error propagation equations, while Approach 2 uses Monte Carlo or similar techniques. Either Approach may be used for emission sources, subject to the assumptions and limitations of each Approach and availability of resources.

4.2.1 Approach 1: Propagation of error

Key assumptions of Approach 1

Approach 1 is using error propagation to estimate uncertainty in individual categories, in the inventory as a whole, and in trends between a year of interest and a base year. In Approach 1, uncertainty in emissions can be propagated from uncertainties in the activity data, emission factor and other estimation parameters through the error propagation equation.

The Approach 1 method does not account for correlation and dependency between source categories that may occur because the same activity data or emission factors may be used for multiple estimates. Correlation and dependency may be significant for fossil fuels because a given fuel is used with the same emission factor across several sub-categories. In addition, in many cases total consumption of a fuel may be better known than consumption disaggregated by source category, which implies that hidden dependencies will exist within the statistics because of the constraint provided by overall consumption. Dependency and correlation can be addressed by aggregating the source categories to the level of overall consumption of individual fuels before the uncertainties are combined. This entails some loss of detail in reporting on uncertainties but will deal with the dependencies where they are thought to be significant (e.g., where the uncertainties in fossil fuel emissions when aggregated from the source category level are greater than expected).

Procedure of Approach 1

The error propagation equation yields two convenient rules for combining uncorrelated uncertainties under addition and multiplication:

Rule A: Where uncertain quantities are to be combined by multiplication, the standard deviation of the sum will be the square root of the sum of the squares of the standard deviations of the quantities that are added, with the standard deviations all expressed as coefficients of variation, which are the ratios of the standard deviations to the appropriate mean values. This rule is approximate for all random variables.

A simple equation (Equation 4.1) can then be derived for the uncertainty of the product, expressed in percentage terms:

Eq. 4.1

$$U_{total} = \sqrt{U_1^2 + U_2^2 + \cdots + U_n^2}$$

Where:

Utotal = the percentage uncertainty in the product of the quantities (half the 95 percent confidence interval divided by the total and expressed as a percentage);

Ui = the percentage uncertainties associated with each of the quantities.

Rule B: Where uncertain quantities are to be combined by addition or subtraction, the standard deviation of the sum will be the square root of the sum of the squares of the standard deviations of the quantities that are added with the standard deviations all expressed in absolute terms (this rule is exact for uncorrelated variables). Using this interpretation, a simple equation (Equation 4.2) can be derived for the uncertainty of the sums:

Eq. 4.2

$$U_{total} = \frac{\sqrt{(U_1 * X_1)^2 + (U_2 * X_2)^2 + \cdots + (U_n * X_n)^2}}{X_1 + X_2 + \cdots + X_n}$$

Where:

Utotal = the percentage uncertainty in the sum of the quantities (half the 95 percent confidence interval divided by the total (i.e., mean) and expressed as a percentage). This term 'uncertainty' is thus based upon the 95 percent confidence interval;

xi and Ui = the uncertain quantities and the percentage uncertainties associated with them, respectively.

Uncertainties in Trends

An emission factor that over- or underestimates emissions in the base year will probably do so in subsequent years. Therefore, uncertainties due to emission factors will tend to be correlated over time. The Approach 1 uncertainty aggregation method, as proposed by 2006 IPCC Guidelines, is in principle able to deal with this issue.

Trend uncertainties are estimated using two sensitivities:

i. Type A sensitivity: the change in the difference in overall emissions between the base year and the current year, expressed as a percentage, resulting from a 1 % increase in emissions of a given source category and pollutant in both the base year and the current year. Type A sensitivity arises from uncertainties that affect emissions in the base year and the current year equally

ii. Type B sensitivity: the change in the difference in overall emissions between the base year and the current year, expressed as a percentage, resulting from a 1 % increase in emissions of a given source category and pollutant in the current year only. Type B sensitivity arises from uncertainties that affect emissions in the current year only. Uncertainties that are fully correlated between years will be associated with Type A sensitivities, and uncertainties that are not correlated between years will be associated with Type B sensitivities. The 2006 IPCC Guidelines suggest that emission factor uncertainties will tend to have Type A sensitivities, and activity data uncertainties will tend to have Type B. However, this association will not always hold and it is possible to apply Type A sensitivities to activity data, and Type B sensitivities to emission factors to reflect particular national circumstances. Type A and Type B sensitivities are simplifications introduced for the analysis of correlation.

Once the uncertainties introduced into national emissions by Type A and Type B sensitivities have been calculated, they can be summed using the error propagation equation (Rule A) to give the overall uncertainty in the trend.

Worksheet for Approach 1 Uncertainty Calculation

The EMEP/EEA guidelines have adopted the worksheet for estimating uncertainty using the Approach 1 from the IPCC guidelines. This worksheet that can be used for uncertainty calculation when estimating air pollutant emissions can be found under Chapter 5, Uncertainties of the EMEP/EEA guidebook.

4.2.2 Approach 2: Monte-Carlo simulations

The Monte Carlo analysis is suitable for detailed category-by-category assessment of uncertainty, particularly where uncertainties are large, distribution is non-normal, the emission estimation algorithms are complex functions and/or there are correlations between some of the activity sets, emission factors, or both. In Monte Carlo simulation, pseudo-random samples of model inputs are generated according to the probability density functions (PDFs) specified for each input.

If the model has two or more inputs, then random samples are generated from the PDFs for each of the inputs, and one random value for each input is entered into the model to arrive at one estimate of the model output. This process is repeated over a desired number of iterations to arrive at multiple estimates of the model output. The multiple estimates are sample values of the PDF of the model output. By analysing the samples of the PDF for the model output, the mean, standard deviation, 95 percent confidence interval, and other properties of the output PDF can be inferred. Monte Carlo simulation is a numerical method, and therefore the precision of the results typically improves as the number of iterations is increased. 6.1 Key assumptions Under the Monte Carlo approach, the simplifying assumptions required for the error propagation can be relaxed. Thus, numerical statistical techniques, particularly the Monte Carlo technique, as they can be generally applied, are more appropriate than Approach 1 for estimating uncertainty in emissions (from uncertainties in activity measures and emission factors/estimation parameters) when:

- uncertainties are large
- their distribution is non-Gaussian
- algorithms are complex functions
- correlations occur between some of the activity data sets, emission factors, or both
- uncertainties are different for different years of the inventory.

Key requirements

Monte Carlo simulation requires the analyst to specify PDFs that reasonably represent each model input for which the uncertainty is quantified. The PDFs may be obtained by a variety of methods, including statistical analysis of data or expert elicitation. A key consideration is to develop the distributions for the input variables to the emission/removal calculation model so that they are based upon consistent underlying assumptions regarding averaging time, location, and other conditioning factors relevant to the particular assessment (e.g., climatic conditions influencing agricultural emissions of ammonia (NH_3). Monte Carlo analysis can include probability density functions of any physically possible shape and width, as well as varying degrees of correlation (both in time and between source categories). Monte Carlo analysis can deal with simple models (e.g., emission inventories that are the sum of sources and sinks, each of which is estimated using multiplicative factors) as well as more complex models.

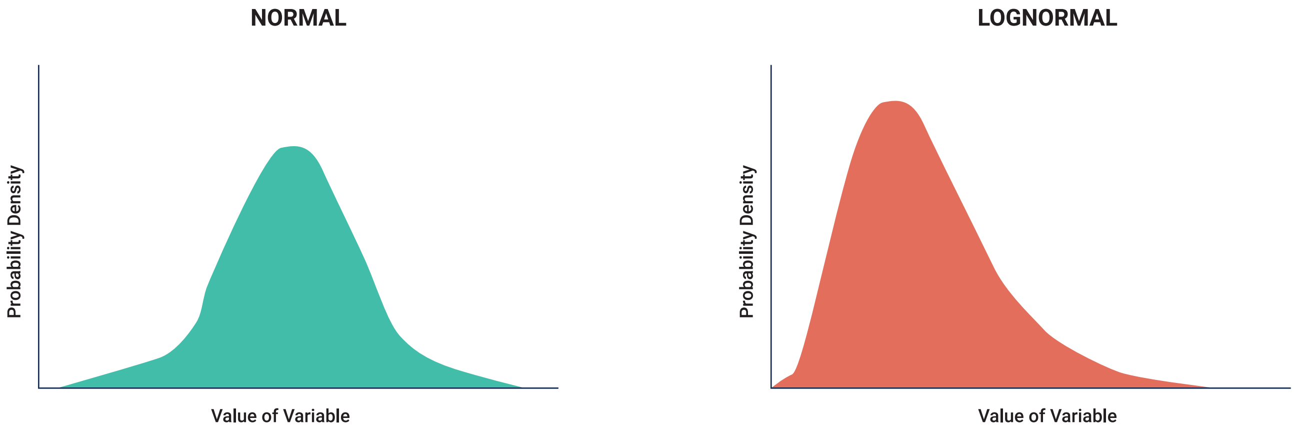
Monte Carlo procedures

The principle of Monte Carlo analysis is to select random values of emission factor, activity data and other estimation parameters from within their individual probability density functions, and to calculate the corresponding emission values. This procedure is repeated many times and the results of each calculation contribute to an overall emission probability density function. Monte Carlo analysis can be performed at the category level, for aggregations of categories or for the inventory as a whole. Statistical software packages are readily available – some of which include Monte Carlo algorithms that are very user-friendly. Like all methods, Monte Carlo analysis only provides satisfactory results if it is properly implemented. This requires the analyst to have scientific and technical understanding of the inventory. Of course, the results will only be valid to the extent that the input data, including any expert judgements, are sound. There are several types of software that are available online and can facilitate the user to perform a Monte Carlo analysis (e.g., Crystal Ball, AnyLogic).

Good practice guidance for selecting Probability Distribution Functions

There are several Probability Density Functions (PDFs) outlined in the statistical literature that often represent particular real situations. The choice of a particular type of PDF depends, at least in part, on the domain of the function (e.g., can it have both positive or negative values, or only non-negative values), the range of the function (e.g., is the range narrow or does it cover orders-of-magnitude), the shape (e.g., symmetry), and processes that generated the data (e.g., additive, multiplicative). The key issue to consider when trying to decide on the appropriate probability distribution function is the source of the data, for example If there is empirical data available, it is good practice to use a normal (Figure 5.1 (a)) distribution, but if expert judgement is used then it is good practice to use a normal or log-normal (Figure 4.1 (b)) distribution. These considerations and the different types of probability distribution functions are described under Chapter 4, Uncertainties of the EMEP/EEA Guidebook and the user is strongly encouraged to engage with that in order to consider the PDFs appropriate for the data they have available.

Figure 4.1: Normal (a) and log-normal (b) distributions



05 Interpreting and Using an Integrated Emissions Inventory

Quote as: CCAC and SEI (2025). Chapter 5: Interpreting and Using an Integrated Emissions Inventory. In: Integrated Guide for Business Greenhouse Gas and Air Pollutant Emission Assessment. Version 2.0. Climate and Clean Air Coalition and Stockholm Environment Institute. CCAC, 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 quantification of 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) can be used to compile an integrated emissions inventory, and how this inventory can be interpreted and understood.

5.1 What is an Emission Inventory?

Developing an emissions inventory is an essential part of greenhouse gas and air quality management as it is a fundamental step in understanding the key sources of emission of the different pollutants. Essentially, an emissions inventory is a database that lists, by key emitting source (e.g., electricity consumption, stationary fuel combustion), the amount of greenhouse gas and air pollutants discharged into the atmosphere during one (or more) years. Emission inventories are developed by national or local governments, as well as private sector companies and businesses, and are used as the starting point of assessment of mitigation strategies. The types of emission inventories that simultaneously quantify and include greenhouse gas and air pollutant emissions are referred to as **integrated greenhouse gas and air pollutant emissions inventories** and have the advantage of allowing the (public or private sector) stakeholders, to evaluate, at the same time the emissions of different types of pollutants, usually coming from the same source (e.g., emission of greenhouse gas and air pollutants from the combustion of fuel in mobile and stationary sources).

The Climate and Clean Air Coalition have developed several documents, and guidance on the benefits and opportunities for national (or local) governments to develop integrated greenhouse gas and air pollutant emissions inventories including 'Opportunities For Increasing Ambition Of Nationally Determined Contributions Through Integrated Air Pollution And Climate Change Planning: A Practical Guidance Document' (Malley et al. 2019), and 'Leveraging the Benefits of non-CO_2 Pollutants and Air Quality in NDC 3.0 (UNEP-Convened Climate and Clean Air Coalition Secretariat 2024).

Governments use national emission inventories to help determine significant sources of greenhouse gas and/or air pollutants and focus on policy and regulatory actions. National emission inventories include estimates of the emissions from various emitting sources in a defined geographical area.

For a company's value chain, this is different in the sense that a value chain and its different stages (as described in Section 3), will possibly be spread across different countries and/or regions.

But regardless of how wide the geographic spread of a company's operations may be across one or multiple countries and/or regions, the compilation of an integrated inventory remains the first key step that is required to understand the contribution of the different sources to greenhouse gas and air pollutant emissions from the different stages of the value chain.

5.2 Why companies develop emission inventories?

There are several reasons why a company would develop an emissions inventory, whether that inventory is focusing on one type of emissions to the atmosphere (e.g., a greenhouse gas emission inventory) or whether it is focusing on more than one type of emissions as it is the case in an integrated greenhouse gas and air pollutant emissions inventory. These reasons can range from the need to quantify, manage, and report specific types of emissions as an important part of their sustainability strategies, or the need to comply with regulatory requirements, various stakeholder needs, and manage risk. Broadly, companies will develop these inventories and report on the results because they are either required to do so by regulation and for compliance reasons (mandatory reporting) or because they choose to report on a topic that they have internally identified as important and/or they are encouraged to do so by various frameworks or standards (voluntary reporting).

1. **Policy and Regulation:** With the evolving global legislation, it is becoming increasingly important for corporations to report not only their GHG emissions but also their contributions to air pollution. Within the European Union (EU), the Corporate Sustainability Reporting Directive (CSRD) mandates that large companies and listed small and medium-sized enterprises (SMEs) disclose their environmental impacts under the European Sustainability Reporting Standards (ESRS). These requirements encompass the reporting of GHG emissions across Scopes 1, 2, and 3, as well as disclosure of air pollutants if the topic is deemed as material by the reporting company (European Commission 2023).

   This regulatory trend is not isolated to Europe. In Asia, China has demonstrated a similar commitment to sustainability reporting. In March 2024, all three major Chinese stock exchanges implemented their respective Corporate Sustainability Reporting guidelines, which include provisions for environmental impact disclosures (Transition Asia, 2024). Likewise, in the United States, California enacted the Climate Corporate Data Accountability Act (SB 253), which requires large corporations operating within the state to report their full emissions inventory, including Scope 3 emissions (California Legislative Information, 2023). These developments underscore – what currently seems to be - a broader global shift toward comprehensive environmental transparency, making emissions inventories—encompassing both GHG and air pollution—an essential tool for corporate accountability and compliance.

2. **Environmental / Mitigation Planning:** The inventory provides data for tracking greenhouse gas emissions and measuring progress toward climate goals (e.g., Paris Agreement targets). Air pollution inventories can similarly be used to understand the company's contribution to local, national and regional air pollution, depending on the breadth of operations in a company's value chain and where these are located.

3. **Public Transparency:** The impacts from greenhouse gas emissions as a result of anthropogenic activities have been very widely studied and understood. But other pollutants are also contributing either to climate change or climate change and are also impacting health (e.g., the short-lived climate pollutants black carbon, methane and hydrofluorocarbons). With significant health impacts related to air pollution and increased frequency of extreme weather events, including heat waves, companies

are increasingly aware of the need to quantify greenhouse gas and air pollutant emissions from their operations. Businesses increasingly promote transparency in environmental reporting in response to stricter legislation and stakeholder awareness, particularly recognising accountability for climate related risks as a cornerstone of sustainability performance.

Integrated greenhouse gas and air pollutant emission inventories, therefore, enable companies to quantify and (potentially) disclose the sources and magnitudes of emissions across their operations and value chains, fostering stakeholder trust and facilitating informed decision-making by investors, regulators, and the public (Carbon Disclosure Project [CDP] 2022). Furthermore, transparent emissions reporting aligns with global disclosure frameworks such as the Global Reporting Initiative (GRI) and the Task Force on Climate-related Financial Disclosures (TCFD), which emphasize the importance of accurate, consistent, and comparable data. By openly sharing their emissions data, organizations demonstrate their commitment to environmental stewardship and regulatory compliance, while also positioning themselves as leaders in sustainability and risk management.

5.3 Using the Guide 2.0

The methods and approaches within the Guide 2.0 (Chapter 3) allow the user to estimate greenhouse gas and air pollution emissions across six key emitting sources, namely electricity consumption, stationary fuel combustion, transport, industrial processes, agriculture and waste (Chapter 1 and 3). These methods and approaches are based on established international frameworks, notably those developed by Intergovernmental Panel on Climate Change (IPCC 2006; 2019) and the European Environmental Agency (EEA 2023).

All methodologies are underpinned by the same foundational equation that is commonly used in inventory development (Equation 5.1):

Eq. 5.1

$$\textit{Emissions} = \textit{Activity Data} * \textit{Emission Factor}$$

Emissions=Activity Data * Emission Factor (Equation 5.1)

Where:

Activity data = e.g., amount of fuel combusted, or vehicle kilometres travelled

Emission factor = emissions per unit of activity

The IPCC guidelines provide detailed methods for quantifying GHG emissions from various sectors (IPCC, 2006), whereas the EMEP/EEA guidelines focus on the estimation of air pollutant emissions (EEA 2023) for reporting at the national (or local) level. The Guide 2.0 builds on these methodologies to adapt them to be applicable for private sector needs and integrates both greenhouse gas and air pollution emissions into a unified, comprehensive framework, that allows companies to quantify greenhouse gas and air pollutant emissions simultaneously.

Compared to a national inventory that has been compiled for a country, there are added complexities for an inventory compiled for the value chain of a company because for different stages of a value chain and the fact that a company's activities and operations can be distributed across one or more countries in different regions of the world. However, regardless of where the emissions of greenhouse gases and/or air pollutant emissions are occurring (i.e., in different countries or regions or in different parts of the value chain) the methods to estimate these emissions remain the same which means that they can be applied regardless of the location of the source sector where emissions take place.

A very important aspect of the Guide 2.0 and of the compilation of the integrated greenhouse gas and air pollutant emissions inventory is that for the most part, as greenhouse gas and air pollutant emissions will be emitted from common sources (Chapter 1), the activity data required to estimate these emissions will be the same for greenhouse gas and air pollutant emissions. This gives companies the opportunity to quantify emissions for more than one (potentially) material topic, without the need to collect additional information or data.

As discussed in Chapter 1, the Guide 2.0 uses two organising principles:

Value Chain: The value chain describes the different activities that businesses undertake to produce and sell a product or service.

Emission Source: An emission source is a discrete activity, or process, that is located within a part of a company's value chain, that directly results in air pollutants being emitted to the atmosphere.

The reason for choosing the specific organising principles is because – as briefly described above – the same emission source (e.g., combustion of fuel) can be present in various parts of a company's value chain (e.g., manufacturing, assembly) and regardless of where the emission source is present, the methods to estimate emissions are only defined by the type of activity and not where the activity happens (within the value chain). What that means in simple terms, is that the method to estimate transport related emissions from a companies Scope 1 operations, are the same as the methods needed to estimate transport related emissions from their Scope 3 operations.

Even though the classification of emissions in Scopes is widely used in greenhouse gas reporting, the Guide 2.0 is focusing on a value chain and emission source approach.

Once the user has used the methods outlined in Chapter 3 in order to quantify greenhouse gas and air pollutant emissions from those parts of their value chain and key emitting sources that they are able to identify (and for which they have the appropriate information), they can still group the resulting emissions in way that the different Scopes can be reflected. An example of this is highlighted below.

Table 5.1 illustrates how various segments of a company's value chain can contribute to one or more scopes of emissions as defined by the GHG Protocol. Developing a greenhouse gas and air pollution emission inventory enables the systematic collection of emission data from diverse sources across the value chain. Methodological approaches such as the Tier 1 ('simple') and Tier 2 ('more detailed') frameworks facilitate the quantification of these emissions, allowing for varying levels of accuracy depending on data availability and quality (EEA 2023).

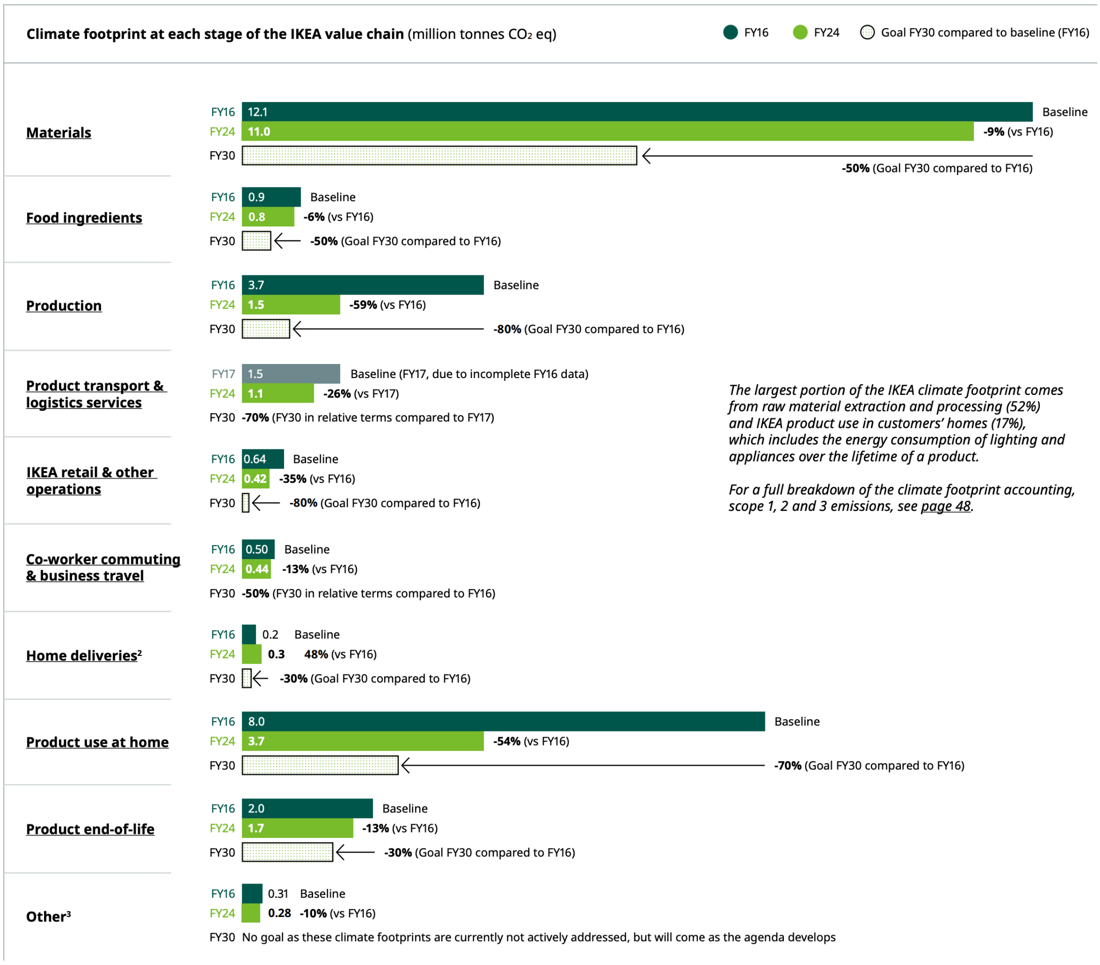
Table 5.1: Relationships between the organising principles and key emitting sources of the Guide 2.0 and the Scope of Emissions (Scope 1, 2, 3) in the corporate sector

Key emitting sources	Emission Sources in Corporate Value Chain	Scope 1	Scope 2	Scope 3
Electricity Consumption	Grid supplied energy to own business units and operations			
Stationary Fuel Combustion	Product manufacturing, retail etc: Own operations or 3rd party suppliers			
Transport	Company owned vehicles and hired freight forwarders			
Industrial Process	Company owned or hired manufacturing and construction activities			
Agriculture	Company owned or leased, hired agricultural activity, livestock and crop production			
Waste	Waste generated by company (own operations, business or manufacturing units) and supplier's waste.			

The data required to estimate greenhouse gas and air pollutant emissions, as well as the methodologies that need to be applied for each key emitting source, remain the same regardless of whether emissions originate from a company's own operations or from its upstream and downstream partners (e.g., direct or indirect). This consistency allows for a clear categorization of emissions into Scope 1 (direct), Scope 2 (indirect from purchased energy), and Scope 3 (other indirect emissions across the value chain). For example, if a company gathers data on fuel consumption, travel distance, and the quantity of goods transported by its own fleet, the resulting emissions are categorized under Scope 1. However, if the same data are collected from third-party logistics providers or suppliers performing similar transport activities, the corresponding emissions are classified under Scope 3 (WRI & WBCSD 2004). This demonstrates that while the calculation methodology remains unchanged, the classification of emissions into different scopes can still be determined by the ownership or control of the emission source.

For IKEA, pollution is not deemed as material topic, but IKEA reported it voluntarily under Pollution ESRS E2 (IKEA 2024).

Figure 5.1: IKEA Greenhouse gas (mandatory) and Air Pollution reporting (voluntary) (IKEA 2024)



Greenhouse gas inventory: scope emissions 1, 2 & 3

Sum of GHG emissions (tonnes CO_2 eq)	FY16	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24
Scope 1	**116,529**	**108,797**	**105,864**	**82,423**	**70,934**	**69,073**	**79,685**	**62,454**	**66,497**
On-site generation, fuel combustion and refrigerants									
Scope 2									
Purchased electricity & heating									
Location-based	430,628	378,856	411,465	405,000	376,680	368,117	368,520	283,118	246,855
Market-based	275,636	226,899	265,810	148,965	83,286	68,716	20,657	13,883	5,418
Scope 3									
1. Purchased goods and services	**16,161,879**	**16,469,068**	**17,489,238**	**17,133,958**	**15,385,333**	**16,615,125**	**16,472,069**	**13,917,369**	**13,296,377**
Food ingredients	864,085	899,309	974,772	891,476	721,033	700,534	867,276	861,316	809,900
Materials	12,117,088	12,313,394	13,256,017	13,086,366	11,825,379	13,624,222	13,450,536	11,209,918	11,019,165
Production	3,124,317	3,189,599	3,209,617	3,099,570	2,803,568	2,245,823	2,108,524	1,802,776	1,424,549
Retail equipment & co-worker clothing	56,389	66,766	48,832	56,547	35,354	44,546	45,733	43,358	42,764
2. Capital goods	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
3. Fuel- and energy related activities	**108,605**	**73,015**	**101,862**	**61,624**	**56,404**	**49,830**	**40,350**	**30,070**	**23,188**
4. Upstream transportation and distribution	**1,311,001**	**1,516,590**	**1,565,448**	**1,484,401**	**1,290,255**	**1,441,306**	**1,411,197**	**1,131,146**	**1,130,540**
5. Waste generated in operations	**53,190**	**79,700**	**103,207**	**87,552**	**51,432**	**46,654**	**36,179**	**34,069**	**21,393**
6. Business travel	**151,261**	**146,614**	**152,910**	**116,824**	**57,007**	**14,163**	**29,555**	**54,816**	**47,137**
7. Employee commuting	**353,421**	**377,550**	**394,153**	**398,111**	**389,220**	**428,153**	**424,375**	**398,058**	**390,514**
8. Upstream leased assets	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
9. Downstream transportation and distribution	**211,872**	**247,113**	**285,454**	**361,627**	**303,173**	**367,160**	**367,855**	**371,776**	**313,557**
10. Processing of sold products	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
11. Use of sold products	**7,990,126**	**7,467,481**	**7,230,826**	**6,384,018**	**5,743,429**	**5,534,870**	**4,390,868**	**3,819,585**	**3,671,144**
12. End-of-life treatment of sold products	**2,000,216**	**1,971,969**	**2,110,619**	**2,122,966**	**1,968,093**	**2,136,899**	**1,972,389**	**1,786,620**	**1,737,883**
13. Downstream leased assets	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
14. Franchises	**816,412**	**813,631**	**1,038,155**	**959,828**	**809,419**	**708,040**	**631,766**	**716,596**	**617,833**
15. Investments	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Grand total (For scope 2 emissions, the market-based value is used for purchased electricity and heating)	**29,550,148**	**29,498,427**	**30,843,545**	**29,342,295**	**26,207,986**	**27,479,988**	**25,876,944**	**22,336,442**	**21,321,480**
Outside the scopes	**2,349,199**	**2,307,777**	**2,429,459**	**2,428,053**	**2,152,532**	**2,088,690**	**2,150,899**	**1,933,590**	**1,933,534**
On-site generation, fuel combustion and refrigerants	420,488	355,503	417,474	477,429	445,418	436,400	487,516	364,684	341,104
Customer travel	1,940,054	1,952,274	2,011,985	1,950,624	1,707,115	1,652,290	1,663,384	1,568,906	1,592,430

In case of Norsk Hydro, is an **energy-intensive and extractive industries** such as aluminium production and mining. In their double materiality analysis, the reporting company deemed Pollution – ESRS E2 as material (Norsk Hydro 2024), Therefore, reporting Pollution under ESRS E2 is mandatory for the company (CSRD 2023).
Figure 5.2 Norsk Hydro Greenhouse gas and Air Pollution reporting (mandatory) (Norsk Hydro 2024)

Figure 5.2: Norsk Hydro Greenhouse gas and Air Pollution reporting (mandatory) (Norsk Hydro 2024)

Emissions to air

Metric tonnes	2024	2023	2022	2021	2020
Sulphur dioxides (SO_2)	15,167	25,370	24,794	31,110	25,108
Nitrogen oxide (NO_x)	5,533	13,125	14,564	14,959	14,466
Particulate matter (PM_{10})	2,929	3,974	3,730	4,037	3,009
Non-methane volatile organic compounds (NMVOC)	369	134	324	209	145
Carbon monoxide (CO)	1,111	NR	NR	NR	NR
Black Carbon	171	NR	NR	NR	NR
Polycyclic aromatic hydrocarbons (PAHs) - EPA 16 definition[1])	7.81	11.75	12.62	10.09	15.27
Polycyclic aromatic hydrocarbons (PAHs) - E-PRTR definition[1])	0.02	NR	NR	NR	NR
Anthracene	0.06	NR	NR	NR	NR
Naphthalene	1.97	NR	NR	NR	NR
Fluorine and inorganic compounds (HF)	443	NR	NR	NR	NR
Mercury and compounds (as Hg)	0.49	NR	NR	NR	NR

1) PAH emissions excludes emissions from Albras. NR = Not reported.

Greenhouse gas emissions per segment - ownership

Million tonnes CO_2e	2024	2023	2022	2021	2020
Direct GHG emissions	**5.67**	**5.92**	**6.19**	**6.65**	**6.10**
Bauxite & Alumina	1.85	2.16	2.20	2.31	2.09
Primary aluminium production	3.25	3.20	3.41	3.72	3.42
Remelters (mostly Metal Markets)	0.13	0.11	0.12	0.12	0.11
Extruded solutions[1])	0.43	0.44	0.47	0.50	0.47
Indirect GHG emissions	**3.31**	**3.37**	**3.56**	**3.97**	**3.74**
Electricity consumption (mainly primary aluminium production	3.31	3.37	3.56	3.97	3.74
Total GHG emissions	**8.98**	**9.29**	**9.75**	**10.63**	**9.83**

1) Includes GHG emissions from remelt activities in

5.4 Mitigation Actions

Once the inventory has been compiled the user will have an understanding of the magnitude of emissions of the different greenhouse gases and air pollutants, by source sector and sub-sector for one or several years.

This is a key step that will allow for specific mitigation and implementation strategies to be developed. There are broadly 2 different categories of mitigation measures, mitigation measures that are focusing on technology and those focusing on behaviour.

For example, depending on the key source responsible for emitting the different greenhouse gases and air pollutants, technological solutions will include improved energy efficiency, or the use of cleaner fuels and/or best available technologies. For behaviour, mitigation actions can include a shift in the transport mode (e.g., employee commute or transportation of goods) or changes in consumption (e.g., reduced waste generation). The methodologies under Chapter 3 have been broadly compiled using two key variables, activity data and emission factors. And these key variables will point to where mitigation is required but also the type of mitigation that is needed. For example, having estimated the greenhouse gas and/or air pollutant emissions, for example, from the open burning of waste the user will be able to identify if this is a key source and whether appropriate mitigation measures need to be taken, in this case, reduction or banning of the open burning of waste

5.5 Approaches to Implementation

In addition, when mitigation actions are considered to reduce the estimated level of emissions, there are only a limited number of policy options and measures that can be applied which are, in the main, common across different countries and regions. These different policy approaches were reviewed in the UNEP and WMO (2011) assessment and are:

Regulatory approaches, which include rules or standards that define allowable levels of emissions, types of pollution control technologies, quality of fuel or resource inputs, and amount of emission activity. A typical example is an emissions standard for vehicles. This type of command-and-control approach requires effective implementation and oversight.

In contrast, economic, or market-driven approaches use financial incentives or disincentives in the form of taxes, fees, subsidies and markets to encourage emissions reductions. By giving sources more discretion over abatement options, this approach may bring down the costs of abatement. A typical example is an emissions trading scheme.

Planning approaches can be effective in reducing pollution. These often focus on infrastructure investments and land-use changes that can limit the amount of pollution activity, especially in the transportation sector. A typical example is transport-oriented urban planning that reduces travel activity and distances travelled.

Informational approaches increase awareness of unsustainable consumption patterns and alternative production techniques. Disseminating that information to the public in easily accessible formats can change behaviour or generate pressure on pollution sources to reduce emissions.

Finally, voluntary approaches typically involve setting agreements between private companies, industry associations and government agencies to reduce emissions to mutually agreed levels.

5.6 References

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CLIMATE & CLEAN AIR COALITION
TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

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