



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



# **A PRACTICAL GUIDE FOR BUSINESS AIR POLLUTANT EMISSION ASSESSMENT**



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#### CITATION

This document may be cited as: Stockholm Environment Institute and Climate and Clean Air Coalition (2022) A Practical Guide for Business Air Pollutant Emission Assessment. Available at: <https://www.ccacoalition.org/en/resources/practical-guide-business-air-pollutant-emission-assessment>

#### PHOTO CREDITS

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## ACKNOWLEDGEMENTS

This guide was prepared by Eleni Michalopoulou, Christopher S. Malley, and Johan C.I. Kuylenstierna, Stockholm Environment Institute, York Centre, Department of Environment and Geography.

### Thanks also to:

The authors of this document are grateful to Nathan Borgford-Parnell, of the Climate and Clean Air Coalition Secretariat, for his guidance and advice on the development of the document. The authors would deeply like to thank Alexandra Galef, Andreas Rangel Ahrens, Patrik Sander, Johann Spriet, Misha Fatima, Ana Velloso (Inter IKEA group), and the greater team of the Inter IKEA group, Rajvanshi Noorie (Siemens), Daniel Andrew (GoTo Group), Schroer Maximilian, Linda Hes, and Skovly Peter (A.P. Moller – Maersk), Banks Alison and Wilson N. Scott (Accenture), ʘb ʘMurty and 9a ʘmiStone, as well as all the members of the **Alliance for Clean Air** for contributing to the development and review of this document. We would also like to thank Roderick Weller, Shannon Engstrom, Denise Rotondo, and all the members of the World Economic Forum team and the Clean Air Fund team for their advice and contribution throughout the development of this document. Finally, we would like to thank Jessica Slater, Eve Palmer and Connie O'Neil for their advice and support.

The development of this guide was supported with funding from the Climate and Clean Air Coalition (CCAC) and Inter IKEA Group.



## EXECUTIVE SUMMARY

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 (WHO,2014), 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 air pollutant emissions 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 air pollutant emissions. 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, this Practical Guide for Business Air Pollutant Emission Assessment is intended to be used for quantification of air pollutant emissions of companies and businesses regardless of their size, product or service offered, and which industry they belong to.

This Guide 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 particulate matter ( $PM_{2.5}$ ,  $PM_{10}$ ), Black Carbon (BC), Organic Carbon (OC), Sulphur Dioxide ( $SO_2$ ), Nitrogen Oxides ( $NO_x$ ), Ammonia ( $NH_3$ ), Non- Methane Volatile Organic Compounds (NMVOCs) and Carbon Monoxide (CO). 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,2021).

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

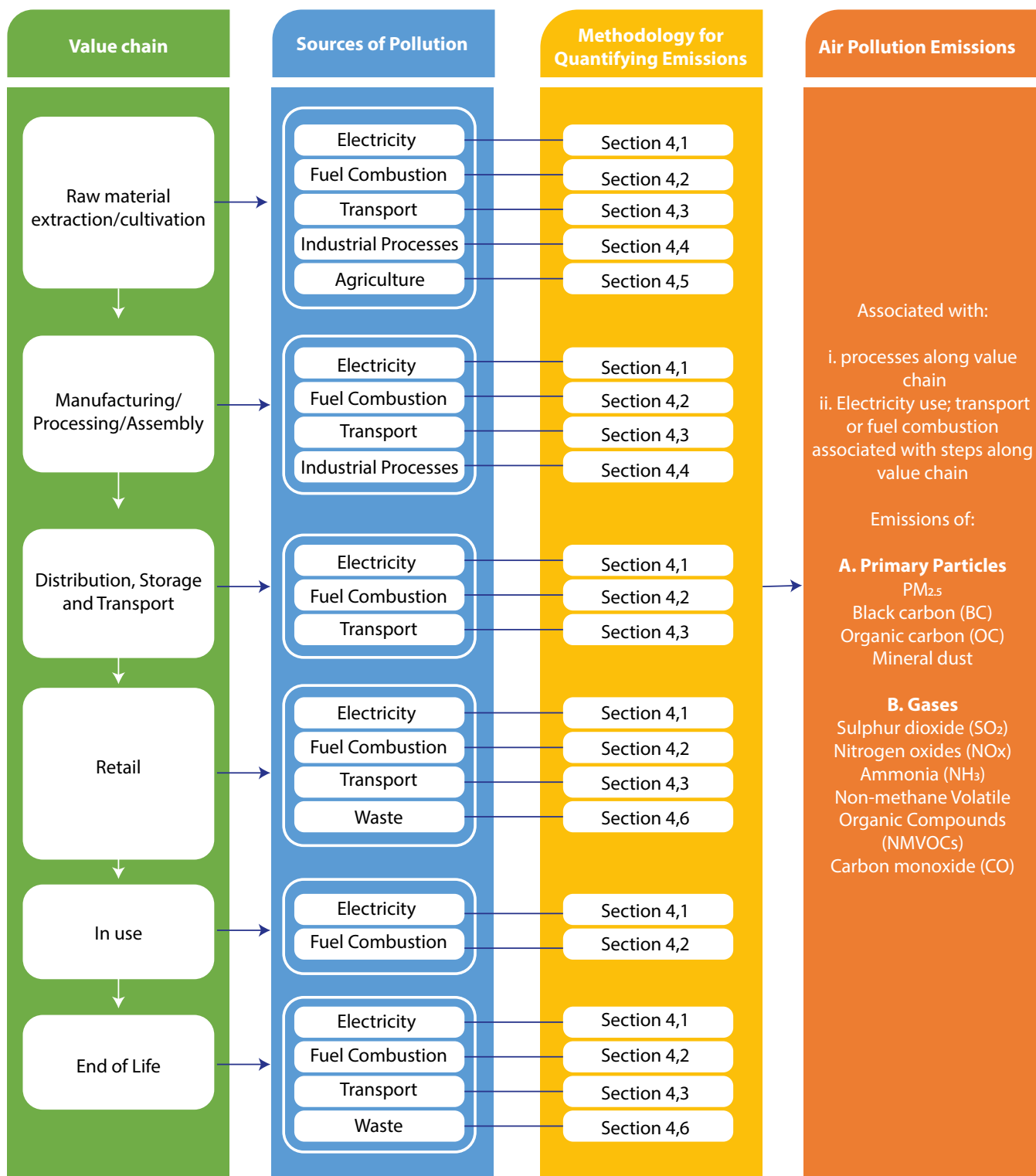


Figure i: Schematic overview of the Guide. The sources of pollution at each step of the value chain are shown and then the user is directed to the appropriate section in the Guide where the detailed methods to quantify emissions of the different pollutants are outlined.

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# 1. INTRODUCTION

The aim of this document is to provide businesses with practical guidance that will enable them to quantify air pollutant emissions down their value chains. Quantifying air pollutant emissions allows appropriate actions to be implemented, therefore facilitating the private sector to reduce air pollutant emissions that lead to serious health and environmental impacts. This Guide is designed both to be used by companies that currently have an existing greenhouse gas (GHG) emission inventory system, to extend and integrate these systems to also quantify air pollutants, and to be used as a standalone Guide for quantification of air pollutant emissions along a company's value chain.

## 1.1 Background

Exposure to indoor and outdoor fine particulate matter is associated with an estimated 7 million premature deaths each year (WHO, 2014), as well as substantial non-fatal impacts through adverse pregnancy outcomes, asthma exacerbations, and respiratory and cardiovascular emergency room visits. In addition to substantial impacts on human health, air pollution also reduces crop yields, impacting food security, and other vegetation and ecosystems. Air pollution refers to a broad range of gases and solid/liquid particles that are emitted to the atmosphere from anthropogenic activities and natural processes. The key anthropogenic sources of air pollutant emissions include energy (which includes sub-sectors such as electricity generation, transport, industry, commercial and public services, households, and oil and gas), industrial processes and product use, agriculture and waste. These sources are also major sources of greenhouse gases, meaning there is a substantial overlap in the sources of air pollution and climate change, and therefore a substantial opportunity to simultaneously mitigate both impacts. Over the past few decades, the air quality in many regions, particularly in Europe and North America has improved substantially, as a result of regulatory, technological and behavioural changes that have reduced air pollutant emissions. In contrast, rapid economic growth, and a reliance on the most polluting fuels and practices in other regions, such as Asia and Africa have resulted in air pollution concentrations, and associated health impacts rising rapidly. 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.

Activities within the value chains of companies contribute to the emissions of air pollutants. However, the magnitude of these emissions and the contribution of different stages of the value chain are typically not quantified or tracked and have not been the focus for Corporate Social Responsibility (CSR) or Corporate Sustainability Reporting. Due to the air pollutants emitted along a company's value chain, the private sector has huge potential to reduce air pollution and thus achieve major health benefits. Understanding the magnitude of air pollutant emissions within a company's value chain is an important and necessary first step to identify those activities, and interventions that could result in tangible reductions in air pollution. The aim of this Guide is to provide a practical framework and methods that can be applied by a diverse range of businesses to achieve this.

Companies that operate and participate in value chains with substantial air pollutant emissions are often the best positioned organizations in the world 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).

Few companies have quantified the air pollutant emissions that are emitted by various activities and processes within their value chains, making identifying the most effective actions to control emissions difficult. However, emissions to the atmosphere of GHGs contributing to climate change are often quantified as part of company's sustainability trackers. There are also a large number of 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 also substantial overlap between the methods and data needed to quantify emissions from GHGs and air pollutants. Therefore, there is a substantial opportunity for companies to enhance their existing systems (or new systems if these are not in place) for assessing all the 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 (EMEP/EEA, 2019; IPCC, 2006, 2019).

## 1.2 Aim of this Guide

The overall aim of this document is to provide a practical framework and detailed methodologies for how companies develop an air pollutant emissions inventory which they can include within their sustainability tracking systems. The objectives of this Guide are to:

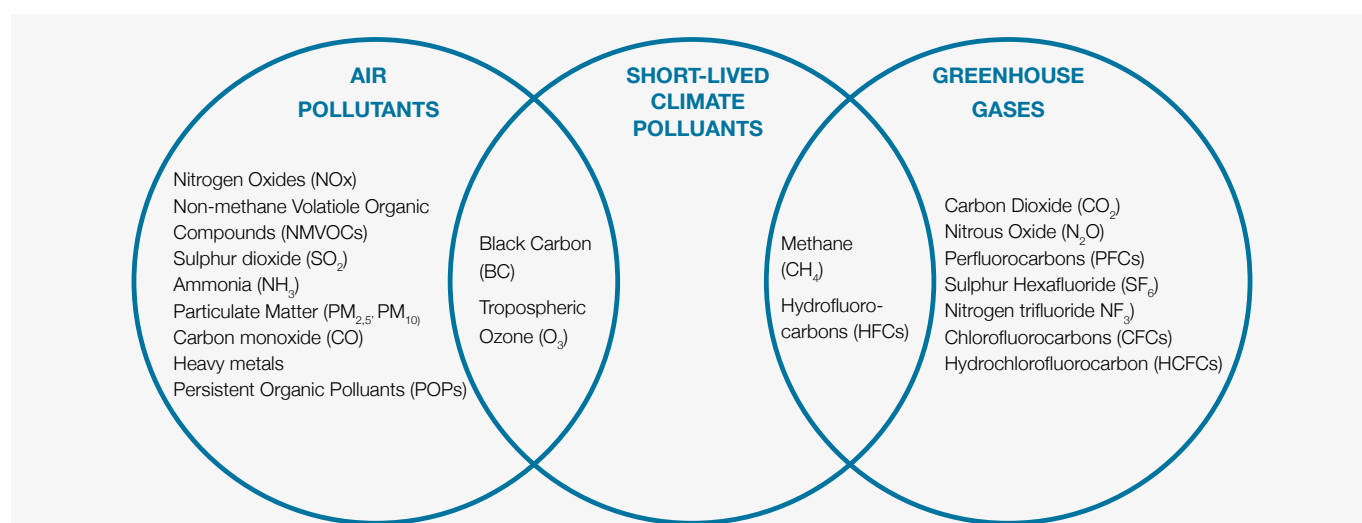
- Provide a consistent basis for quantification of air pollutant emissions to facilitate consistency, transparency and comparability in air pollutant emission estimates between companies and link to existing systems that companies may have in place already to estimate GHG emissions, to capitalize on 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 largest air pollutant emission sources, electricity generation, fuel combustion, transport, industrial processes, agriculture and waste. The Guide describes the data required and, where possible, provides default data that can be used in the absence of company-specific information. As much as possible, methods are aligned with those for estimating GHG emissions from

a company's value chain in international guidance such as the 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 guidance highlights how the air pollutant emission estimates can be extended to evaluate different mitigation options associated with a particular emission source.

## 1.3 Air Pollutants Covered

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. A common list of air pollutants is shown in Figure 1. 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<sub>10</sub> and PM<sub>2.5</sub>, 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) and formed in the atmosphere through chemical reactions from directly emitted precursor pollutants (secondary pollution). In terms of impacts on human health, primary and secondary pollution are both important in determining the impact of air pollution on human health. This Guide focuses on quantifying the emissions of those air pollutants that the WHO has set air quality guideline values for the protection of human health, and the precursors to these pollutants.



**Figure 1.1: A summary of common air pollutants, and their links to greenhouse gases and short-lived climate pollutants contributing to climate change (Source: Climate and Clean Air Coalition, <https://www.ccacoalition.org/en>)**

In particular, the pollutants covered in these guidelines are those that contribute to the formation of particulate matter (PM), and tropospheric ozone ( $O_3$ ), the two pollutants that have the largest effect on human health. Exposure to PM results from PM that is directly emitted to the atmosphere as solid/liquid particles (termed primary/direct PM), and from the chemical reaction of gases, including nitrogen oxides, ammonia, sulphur dioxide and volatile organic compounds that react in the atmosphere to form PM (secondary PM). All pollutants that contribute to form PM are included in the scope of this Guide. Ozone is not directly emitted and is formed in the atmosphere from the chemical reaction of nitrogen oxides ( $NO_x$ ), volatile organic compounds (VOCs), carbon monoxide (CO) and methane ( $CH_4$ ), which are termed 'ozone precursors'. The full list of pollutants covered in this Guide are:

- **Particulate Matter ( $PM_{2.5}$  and  $PM_{10}$ ):** Particulate matter (with aerodynamic diameter less than 2.5  $\mu m$  ( $PM_{2.5}$ ) and 10  $\mu m$  ( $PM_{10}$ )) 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 emissions of  $PM_{2.5}$  and  $PM_{10}$  calculated 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 the  $PM_{2.5}$  emissions – and their contribution to impacts needs to be assessed using chemical transformation and transport models.
- **Black carbon (BC):** A component of direct 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.
- **Nitrogen Oxides (NO<sub>x</sub>):** 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) and nitrogen

dioxide ( $NO_2$ ).  $NO_x$  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<sub>2</sub>):** 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.  $SO_2$  gas is also a pollutant affecting health, but only close to large point sources of emission. When  $SO_2$  is oxidized to sulphate it forms an aerosol that is part of  $PM_{2.5}$ .
- **Ammonia (NH<sub>3</sub>):** 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.
- **Non-methane volatile organic compounds (NMVOCs):** A collection of a range of different organic molecules emitted from a range of emission sources. 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.
- **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.

## 1.4 How to Use this Guide

This document provides a comprehensive set of methods and approaches for quantifying air pollutant emissions along a company's value chain. The intended users of this Guide are technical officers, sustainability teams, or inventory compilers within companies that are directly involved in the development of air pollutant emission estimates.

The Guide provides a framework for the quantification and categorization of air pollutant emissions associated with a company's activities that is organized around two key concepts:

**1. Value Chain:** The value 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. These sources cover over 98% of global total emissions of key air pollutants, as shown in Table 1.1.

**Table 1.1: Proportion of global emissions of selected air pollutants that are covered by the six source categories that are included within this Guide (Source: Janssens-Maenhout et al., 2012)**

Source sector	Black Carbon	Particulate Matter (PM <sub>2.5</sub> )	Nitrogen Oxides (NO <sub>x</sub> )
Electricity Generation	2.25%	7.23%	24.67%
Fuel Combustion	68.4%	63.4%	23.48%
Transport	19.3%	10.10%	46.64%
Industrial Processes	0.87%	5.37%	0.19%
Agriculture	7.12%	11.12%	4.36%
Waste	0.24%	0.55%	0.09%
<b>Total (%)</b>	<b>98.2%</b>	<b>97.82%</b>	<b>99.4%</b>
Global total emissions 2015 (kilotonnes)	5,104	38,222	124,718

The Guide has been developed with close attention to the methodologies for each emission source that are already used by companies to quantify their GHG emissions. Therefore, there are substantial overlaps and consistency with overarching guidance on GHG emission quantification methodologies and tools, such as the GHG protocol. For example, the Guide could be used to quantify Scope 1, 2 and 3 emissions if these approaches are already used to categorise GHG emissions within a company's activities. The Guide is divided into the following Sections:

**Sections 1 and 2** of this document provide a short introduction to air pollution, its impacts on human health and vegetation, and how quantification of air pollutant emissions can be a useful tool to identify major sources and opportunities to improve air quality and human health.

**Section 3** then provides a framework and process for the development of an 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 air pollutant emissions from those sources.

**Section 4** then 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.

**Section 5** 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.

**Section 6** provides 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 understanding of air pollutant emissions from a company's value chain and their impacts on human health and the environment, such as understanding their spatial

distribution, and linkage to exposure to air pollution and associated health impacts.

Finally, **Section 7** provides information on the limitations and further work related to the development of this Guide.

## 2. OVERVIEW OF AIR POLLUTION

### 2.1 Major air pollution sources

Air pollution comes from a wide array of sources, both natural and anthropogenic. Natural sources include volcanic eruptions, sea spray, soil dust, natural vegetation fires and lightning. Anthropogenic sources can broadly be divided into stationary (e.g., such as power plants, oil refineries, industrial facilities) and mobile (e.g., road transport, freight). Some of the most common human-driven sources include power generation, transportation, industrial activities, residential heating and cooking, agriculture, solvent use, oil and gas production, waste burning and construction. For the majority 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. Major urban sources include vehicles, burning of gas, coal and charcoal, wood for cooking and heating, and industrial sources still located in cities. Many large industrial 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 long distances in the air. Emissions from the oil and gas industry and the maritime sector can also travel over very long distances.

Agricultural sources, including burning to clear land for crops, and forest fires, contribute a lot to urban and rural air pollution levels. In very dry areas, close to deserts and eroded land, wind-blown dust can make up a large fraction of the  $PM_{2.5}$ . Most ammonia is emitted from agriculture and human waste treatment.

### 2.2 Impacts of air pollution on health and ecosystems

The World Health Organisation (WHO) categorises over 30 different chemicals as 'air pollutants' based on their

negative impacts on human health when emitted and exposed. 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, 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. Over the past decades, air pollutant levels have decreased in some regions, such as Europe, North America, and recently in China, and 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 guideline for ambient  $PM_{2.5}$  is  $5 \mu g m^{-3}$ , which is half of the previous value of 10. This means that more people are exposed to harmful levels of exposure to this pollutant than was previously estimated, including levels commonly found in Europe and North America.

Air pollution has been identified as the largest environmental risk to public health globally. Exposure to air pollution from indoor and outdoor sources was associated with approximately 6.6 million premature deaths in 2019 due predominantly to respiratory and cardiovascular diseases (Murray et al., 2020) and is responsible for a substantial amount of non-fatal health outcomes such as emergency-room visits, asthma exacerbations and adverse pregnancy outcomes (Anenberg et al., 2018; Malley et al., 2017).

Exposure to both short-term elevated concentrations of air pollutants like  $PM_{2.5}$  and  $O_3$ , and long-term, chronic exposure to air pollutants are associated with negative health effects. Short- and long-term air pollutant exposure is linked to increased risk of ischemic heart disease, stroke, chronic obstructive pulmonary disease (COPD), lung and upper aerodigestive cancers, adverse pregnancy outcomes (i.e., low-birth rate, pre-term births and reduced birth weight (babies born weighing less than five pounds), diabetes and cataracts (Health Effects Institute, 2019). 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.

Other air pollutants are also associated with significant negative impacts on human health, in addition to their roles in the formation of PM<sub>2.5</sub> and O<sub>3</sub>. For example, carbon monoxide (CO) restricts the transfer of oxygen to tissues and can be fatal in very high concentrations. Sulphur dioxide (SO<sub>2</sub>) is a potent lung irritant affecting the health of those with pre-existing respiratory disease (asthma and COPD), especially those living and working close to SO<sub>2</sub> sources. Nitrogen oxides (NO<sub>x</sub>) are linked to a range of impacts, spanning from respiratory irritation to the development of asthma and increased mortality.

Air pollution also significantly impacts several different ecosystems, and it reduces crop and forest yields, negatively affects forest health, and causes acidification of sensitive lake ecosystems. It also reduces atmospheric visibility and increases corrosion of materials, buildings, monuments, and cultural heritage sites. 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).

### 2.3 Link between air pollution and climate change

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. They

also interact with each other in multiple ways. For example, GHGs, such as methane, contribute to the formation of ground-level-ozone, and levels of ground-level ozone increase with rising temperatures. Rising temperatures increase the frequency of wildfires, which in turn further elevate levels of particulate air pollution.

The group of pollutants, called 'Short-Lived Climate Pollutants' (SLCPs) which include black carbon, ozone, methane, and hydrofluorocarbons (HFCs), are highly potent climate forcers, are relatively short lived in the atmosphere and – in the case of ozone and black carbon – dangerous air pollutants. Many SLCP reduction measures also reduce other air pollutants, like nitrogen oxides. For example, black carbon reduction measures affect regional climate change and reduce the rate of near-term global warming. They also significantly reduce emissions that lead to PM<sub>2.5</sub> concentrations, thus benefiting human health. Integrated actions, such as those that target SLCPs can therefore provide triple-win scenarios, by achieving real-world multiple benefits for human health, agriculture and the climate.

The interlinkages between air pollution and climate change provide an opportunity to amplify the benefits of our actions and catalyse even greater mitigation ambition particularly for the private sector. Companies with existing plans and strategies to rapidly reduce warming, must therefore integrate actions to reduce all air pollutants and greenhouse gases that contribute to both near- and long-term climate impacts. As more companies are now setting out to develop GHG emission reduction plans, or net-zero pathways, it is critical that this is done with consideration of the effects of these strategies on air pollutant emissions and how policy impact can be maximized particularly in relation to the benefits of reducing air pollution on human health.

In addition to the physical linkages between the causes of climate change and air pollution, and the resultant opportunity to simultaneously mitigate both impacts through implementation of specific policies and measures, there are also technical linkages between quantification of greenhouse gas and air pollutant emissions. This is also reflected in the decision of the IPCC Task Force on National Greenhouse Gas Inventories to produce an IPCC Methodology Report on Short-lived Climate Forcers (49th Session of the IPCC). The development of a Greenhouse Gas emission inventory, for nations, is covered by the Intergovernmental Panel on Climate Change (IPCC) national GHG

emission inventory guidance document. The methods for quantifying emissions of GHGs have substantial overlap with methods for quantifying emissions of air pollutants. The European Monitoring and Evaluation Programme/European Environment Agency (EMEP/EEA) National air pollutant emission inventory guidebook provides the corresponding guidance to develop national air pollutant emission inventories. The methods overlap substantially with those in the IPCC GHG emission inventory guidance, to the extent that IPCC recommends that the EMEP/EEA guidance is used to quantify air pollutants in a consistent way to GHGs. For businesses, there are existing guides for the quantification of GHG emissions such as those presented in the GHG protocol which covers GHGs like CO<sub>2</sub>, hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs). However, there is no comparable and consistent guidance for air pollutant emission inventory development for businesses. The aim of this Guide is to fill this gap, so that businesses can develop integrated air pollutant and GHG emission inventories as the basis for identifying and evaluating strategies that can contribute to achieve simultaneous mitigation of air pollution and climate change along their value chains.

## 2.4 Private sector and their contribution to air pollution

The private sector includes businesses that encompass industry, manufacturing, hospitality, retail, etc. These businesses can be of different sizes with very 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 air pollutants. Examples of sources of emissions that may be present within a company's activities include:

- burning of fossil fuels and biomass in electricity generation, transport, industry, and buildings
- 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, steam and cogeneration, process heating and cooling, lighting, heating, and air conditioning for buildings. Some industries are more energy intensive than others. Table 2.1 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, nonmanufacturing'. 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 fuels and technologies that are consumed to provide the energy required for the business. In contrast to GHGs, where energy efficiency and switching to non-fossil fuels are generally the two primary options for reducing the GHG emission intensity of fuel consumption in industries, for air pollutants different technologies can be fitted to equipment that can substantially limit the magnitude of air pollutant 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. Where possible, the technology that is being used in fuel consumption should be taken into account when quantifying the magnitude of emissions.

**Table 2.1: Industrial sector: major groupings and representative industries (Source: IEA International Energy Outlook, 2016).**

Industry grouping	Representative industries
<b>Energy-intensive manufacturing</b>	
<b>Food</b>	Food, beverage, and tobacco product manufacturing
<b>Pulp and paper</b>	Paper manufacturing, printing and related support activities
<b>Basic chemicals</b>	Inorganic chemicals, organic chemicals (e.g., ethylene propylene), resins, and agricultural chemicals;
<b>Refining</b>	Petroleum refineries and coal products manufacturing, including coal and natural gas used as feedstocks
<b>Iron and steel</b>	Iron and steel manufacturing, including coke ovens
<b>Non-ferrous metals</b>	Primarily aluminum and other nonferrous metals, such as copper, zinc, and tin
<b>Non-metallic minerals</b>	Primarily cement and other nonmetallic minerals, such as glass, lime, gypsum, and clay products
<b>Nonenergy-intensive manufacturing</b>	
<b>Other chemicals</b>	Pharmaceuticals (medicinal and botanical), paint and coatings, adhesives, detergents, and other miscellaneous chemical products, including chemical feedstocks
<b>Other industrials</b>	All other industrial manufacturing, including metal-based durables (fabricated metal products, machinery, computer and electronic products, transportation equipment, and electrical equipment)
<b>Nonmanufacturing</b>	
<b>Agriculture, forestry, fishing</b>	Agriculture, forestry, fishing
<b>Mining</b>	Coal mining, oil and natural gas extraction, and mining of metallic and nonmetallic minerals
<b>Construction</b>	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 source sectors. Industry (including both private sector and state-owned companies) were estimated to be responsible for approximately one quarter of nitrogen oxide (NO<sub>x</sub>) and particulate matter (PM<sub>2.5</sub>) emissions, and 46% of sulfur dioxide (SO<sub>2</sub>) emissions (IEA, 2018; IEA, 2022a,b,c). Other key sources included the transport sector, which contributed over 50% of NO<sub>x</sub>, and 5% of PM<sub>2.5</sub> emissions, and power generation, which contributed one third of global SO<sub>2</sub> emissions, and 10% of global NO<sub>x</sub> emissions. The private sector makes a substantial contribution to both of these sources, e.g., 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 the trade in goods and services that private companies provide is

also not equally distributed between different countries and communities. 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<sub>2.5</sub>-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<sub>2.5</sub>-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 sources of air pollutant emissions determines the population groups that have the highest levels of exposure to air pollutants. Commonly, lower-income countries and communities experience the largest impact from company's 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 actually 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 the 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.

### 3. FRAMEWORK FOR QUANTIFYING THE AIR POLLUTANT EMISSIONS OF A COMPANY

Methodologies and guides to estimate emissions of different pollutants and GHGs from different sources include national emission inventory guidebooks produced by the Intergovernmental Panel on Climate Change (IPCC) for quantifying emissions of greenhouse gases (IPCC, 2006; 2019), primarily at the national scale. The European Monitoring and Evaluation Programme/European Environment Agency (EMEP/EEA) air pollutant emission inventory guidebook (EMEP/EEA, 2019), which focuses on methods for quantifying air pollutant emissions, primarily on emissions sources within the UN Economic Commission

for Europe region, is the main guide used internationally to quantify air pollutant emissions. For the private sector, the GHG Protocol provides guidance, templates and methods specifically designed to quantify greenhouse gas emissions from the private sector. In each of these documents, key terms are used and applied that relate to the quantification of GHG and/or air pollutant emissions. For clarity, Table 3.1 summarises and provides the definition used in this Guide for key terms used in this document related to air pollutant emission quantification.

**Table 3.1: Glossary of key terms related to quantification of air pollutant emissions and definition as to how they are used in this document.**

Term	Definition
<b>Air pollutant</b>	Suspended particles and gases in the atmosphere that have negative impacts on human health and the environment
<b>Emission</b>	The production and discharge of a substance into the atmosphere
<b>Source</b>	The type of activity/process which gives rise to the emission
<b>Sector</b>	The area of the economy which contains the emission source
<b>Value Chain</b>	The full range of activities undertaken by a company required to produce a product or service
<b>Value Chain</b>	The network and activities between the company and its suppliers to produce and distribute a product to a customer
<b>Activity Variable</b>	The quantitative measure of the size of a particular process, action or other activity that is a source of air pollutant emissions.
<b>Emission Factor</b>	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
<b>Scope 1 Emissions</b>	Direct emissions that occur from sources controlled and owned by the organisation
<b>Scope 2 Emissions</b>	Indirect emissions associated with the purchase of electricity, heat, steam or cooling
<b>Scope 3 Emissions</b>	The result of activities from assets not controlled or owned by the reporting organisation

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:

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



The value chain maps the full set of activities that are undertaken within a business. Sources refer to the specific emission sources that can be identified and assigned to the different activities undertaken within the value chain. Section 3.1 outlines the methodological approaches that can be used to map the value chain, identify emission sources within the value chain, and finally how the magnitude of emissions from each source identified in the value chain can be quantified and accounted for.

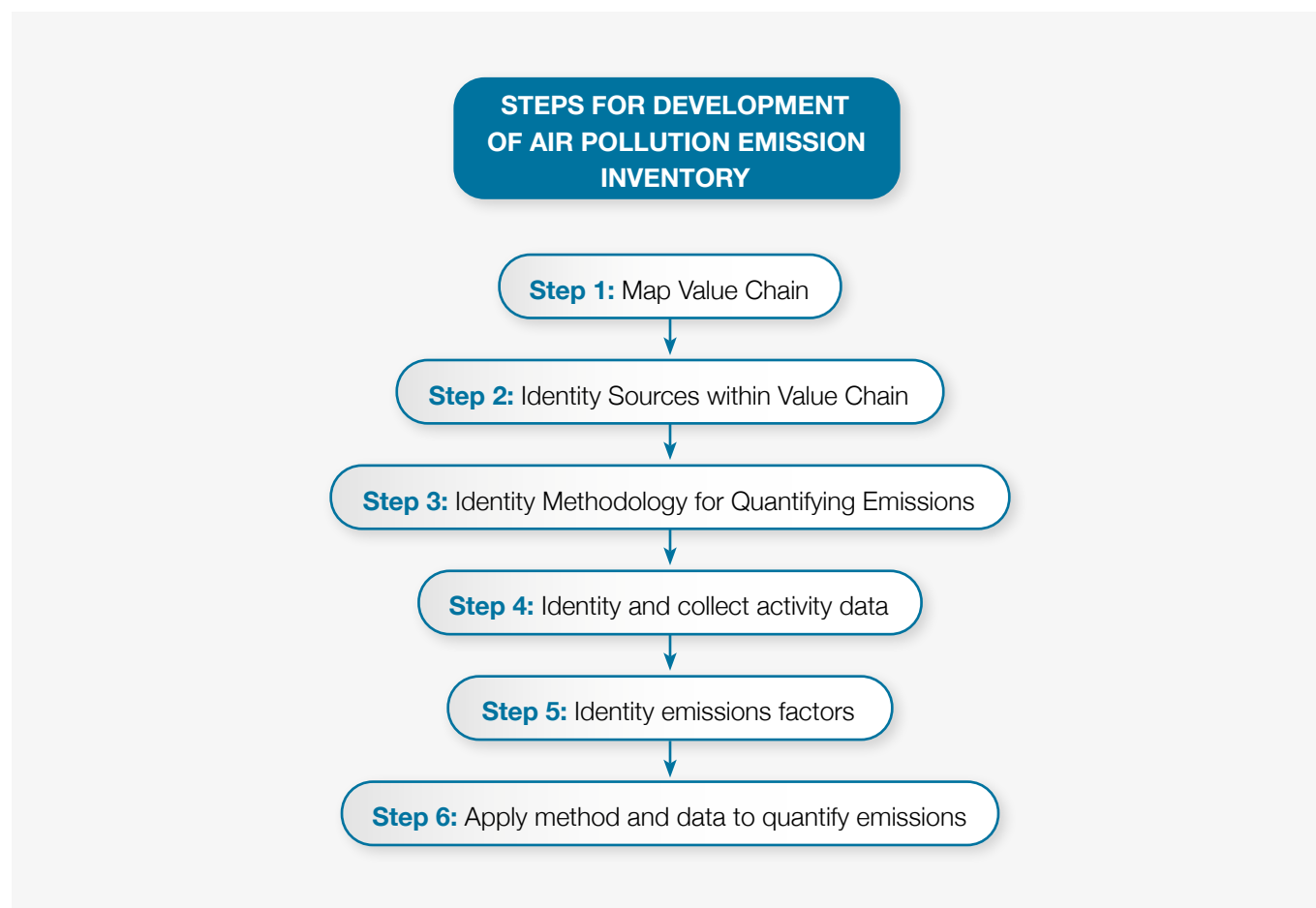
The user of this document, i.e., an inventory compiler for a company, will need to make some key decisions that will define how, and at what level of detail, air pollutant emissions are estimated for their value chain. These key decisions relate to the availability of data to estimate the emissions, but they also relate to which parts of the value chain the user wants to include in their reporting and calculations. For that purpose, the document outlines a six-step process for the development of the air pollutant emission inventory for a particular business (Section 3.2 – 3.7). It that guides the user on the methods, and also the appropriate boundary that will include the emissions specific to their value chain. In this Guide, the boundary is not

determined by whether the emissions are under Scopes 1, 2 or 3 but rather by whether specific source emissions are present within a company's value chain regardless of these activities being controlled and/or owned by the company.

### 3.1 Methodological approach

The overall method suggested in these guidelines to estimate the magnitude of a company's air pollutant emissions involves a six-step process shown below in Figure 3.1. To develop an air pollutant emission inventory, the steps outline a process by which a company can identify the sources that emit air pollutants across the value chain, and for which emission estimates will be quantified, to identifying the methodologies and that will be used and applied to quantify the emissions from a particular source.

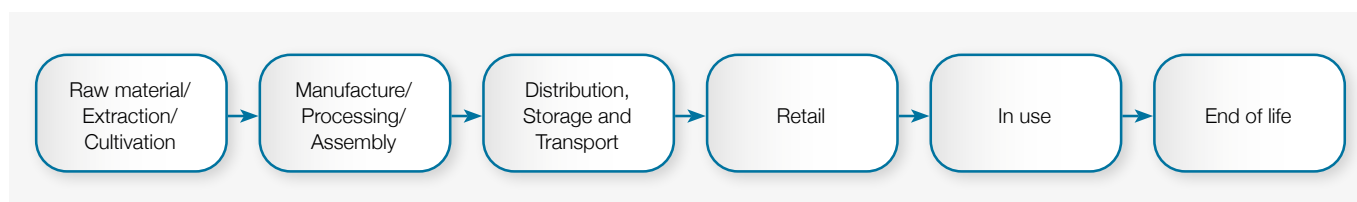
These steps are consistent with those commonly undertaken to quantify GHG emissions. Therefore, if the company is simply adding air pollutant emissions to an existing GHG inventory, these can be amended, or skipped as needed.



**Figure 3.1: Steps to develop air pollutant emission inventory.**

## Step 1: Mapping the Value Chain

The first key step in quantifying emissions of air pollutants and SLCPs, is for a company to develop a comprehensive map of their value chain. The aim in mapping a company's value chain is so that the specific emission sources within the different stages of a company's value chain can then be identified. Figure 3.2 gives an example of a simplified value chain, with six key, and broad, stages within a value chain. Methodologies to quantify air pollutant emissions are defined for specific sources and examples of sources



**Figure 3.2: 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 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 3.2 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, 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.

## Step 2: Identify Sources within Value Chain

As defined above in Section 3, an emission source is the particular process that results in an emission of an 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 and EMEP/EEA emission inventory guidebooks 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

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 include sources of air pollutant emissions, and for which the methods described in Section 4 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 elements of a company's value chain.

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 3.2 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 3.2: 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).**

<b>1</b>	<b>Energy</b>	<b>2</b>	<b>Industrial Processes and Product Use (IPPU)</b>
		2.A	Mineral products
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
<b>1.A.3.e</b>	Pipeline transport	2.I	Wood processing
<b>1.A.4</b>	Small combustion	2.J	Production of persistent organic pollutants
		2.K	Consumption of persistent organic pollutants and heavy metals
1.B	<b>Fugitive emissions from fuels</b>	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	<b>Waste</b>
		5.A	Solid waste disposal on land
3	<b>Agriculture</b>	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

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 Section 4. The six sources included are:

- **Electricity Generation:** This source corresponds to the NFR sector 1.A.1 Energy Industries above. 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.

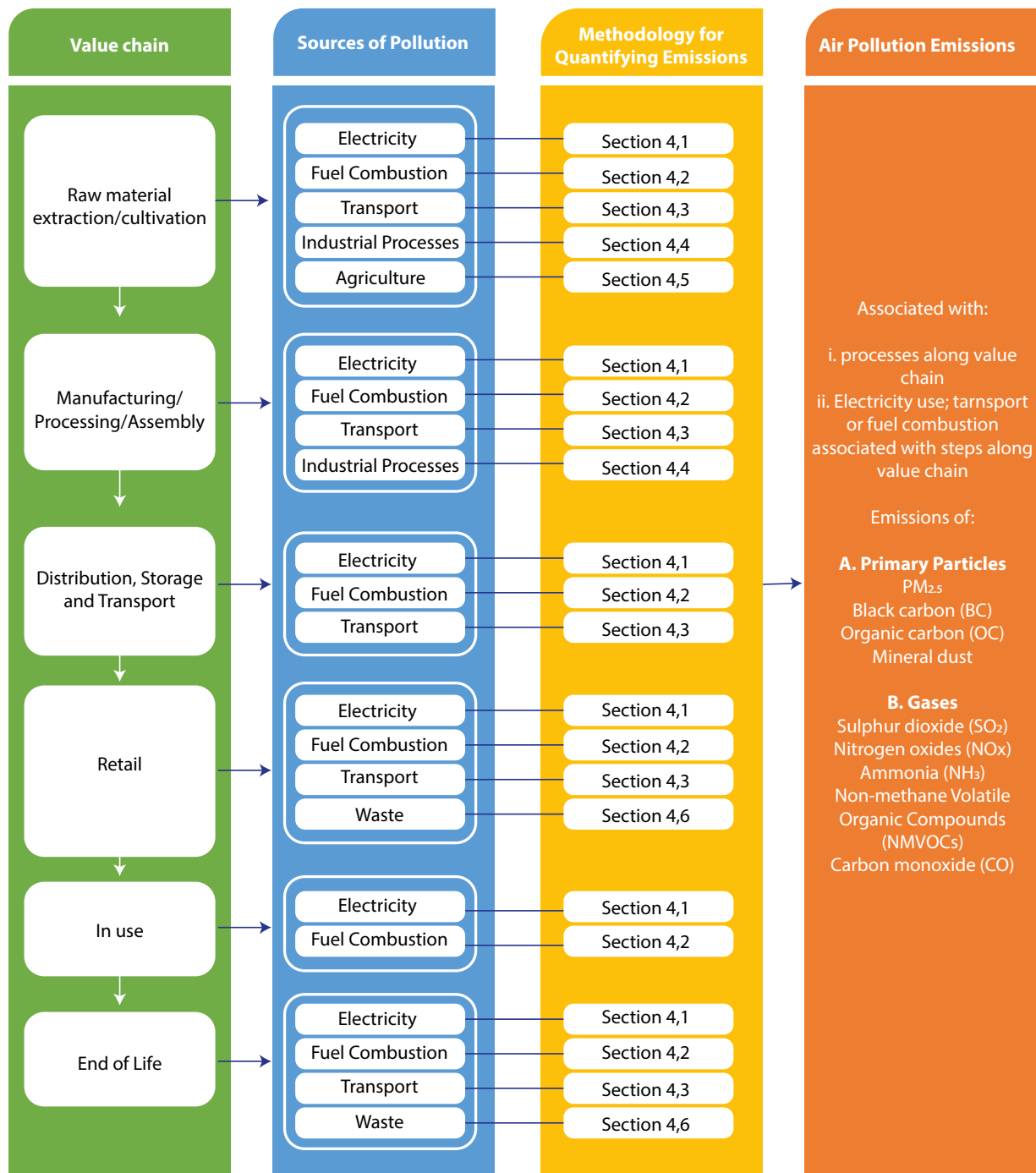
- **Stationary Fuel Combustion:** This source corresponds to the NFR sectors 1.A.2 and 1.A.4 outlined above. It includes the direct combustion of fossil fuels and biomass within a company's activities (in contrast to the electricity generation source where the generation of electricity may be done outside 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 above. 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 in the table above. It covers all non-fuel combustion emissions that occur during industrial processes.
- **Agriculture:** This corresponds to the NFR sector 3 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 is covered under the Industrial Processes source
- **Waste:** This source corresponds to the NFR sector 5 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 air pollutant emissions. The value chain, as described in Section 3.2, maps all the activities that relate to a company's operations, and within which different sources can air pollutant emissions occur.

The emitting sources within a company's value chain (noting that along a value chain multiple sources 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 3.3 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-sections describe each of the six parts of the generic value chain that is shown in Figure 3.3 and highlights the possible 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-sections 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 3.3 for the generic value chain, then Section 4 can be used to identify the methods and data needed to quantify air pollutant emissions. The relevant sub-section of Section 4 is shown in Figure 3.3.



**Figure 3.3: Generic value chain (from raw material extraction, through manufacturing, retail, use and disposal) and possible sources of emissions (electricity generation associated with use, transport and process emissions) at different points in the value chain.**



### Value Chain Stage A: Raw Materials extraction/cultivation

Within the 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 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 air pollutant emissions within the raw materials part of the value chain are outlined in Table 3.4.

Table 3.4 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 3.4 covers all these sources, and provides the link to the specific NFR code, and section within Section 4 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 Section 4 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.

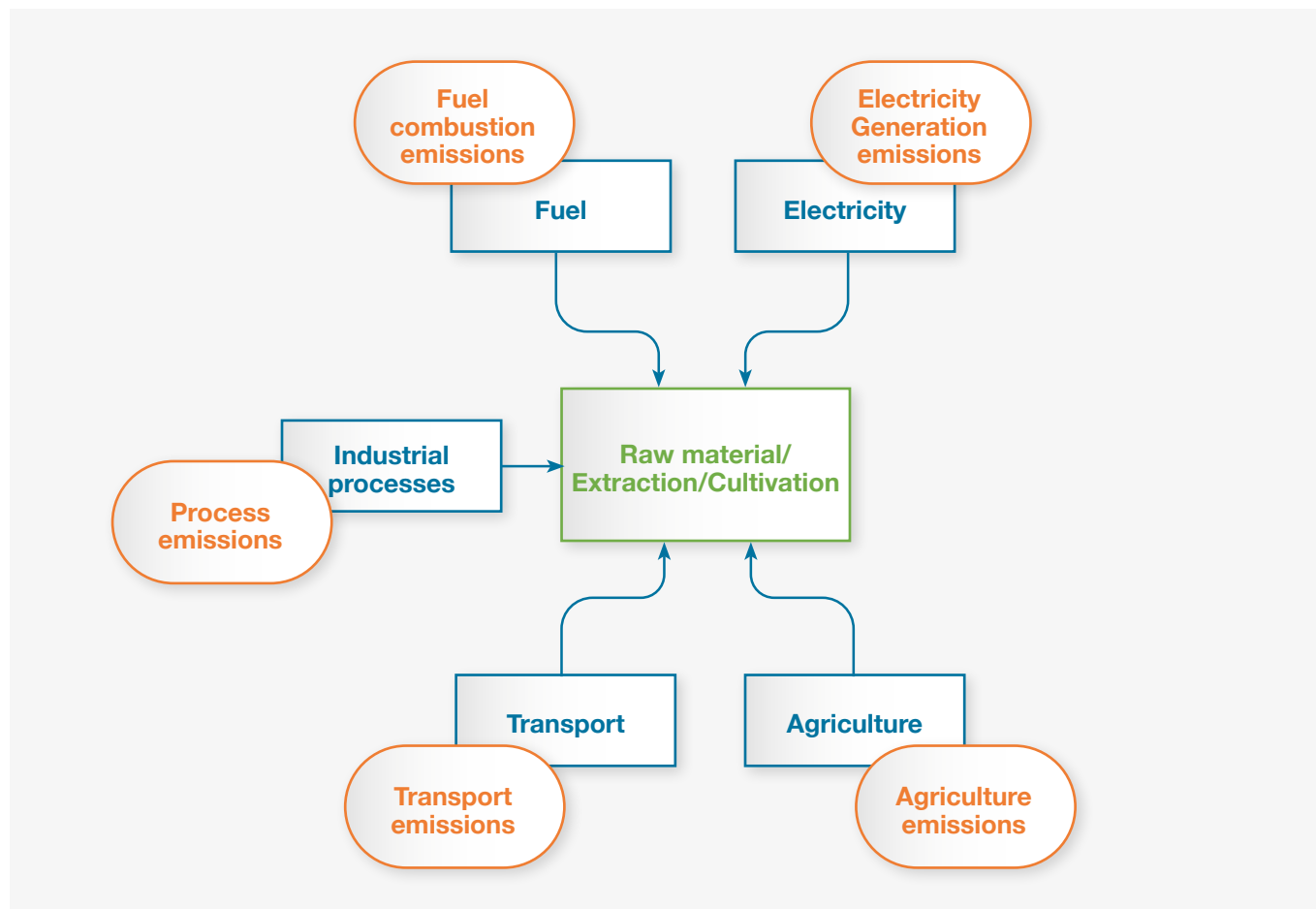


Figure 3.4: Overview of input within the raw materials stage of the generic value chain.

**Table 3.3: Possible sources of air pollutant emissions within raw materials.**

Source	Description	Methodology for quantifying emissions	Section with emission quantification methodology
<b>Stationary fuel combustion</b>	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	<b>4.2</b>
<b>Electricity Generation</b>	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	<b>4.1</b>
<b>Industrial Processes</b>	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	<b>4.4</b>
<b>Agriculture</b>	Synthetic and fertiliser application in crop production  Burning of agricultural residues  Management of manure from livestock	Quantity of fertiliser applied to produce quantity of crop used in food production multiplied by emission factors for ammonia and nitrogen oxide  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  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.	<b>4.5</b>
<b>Transport</b>	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)	See Table 4.1	<b>4.3</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.

raw materials used in its production, which have been covered in the previous section. 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.

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

Table 3.4 summarises these sources and includes the links to the relevant sections in Section 4 where the methodologies for quantifying the emissions from each source can be found.

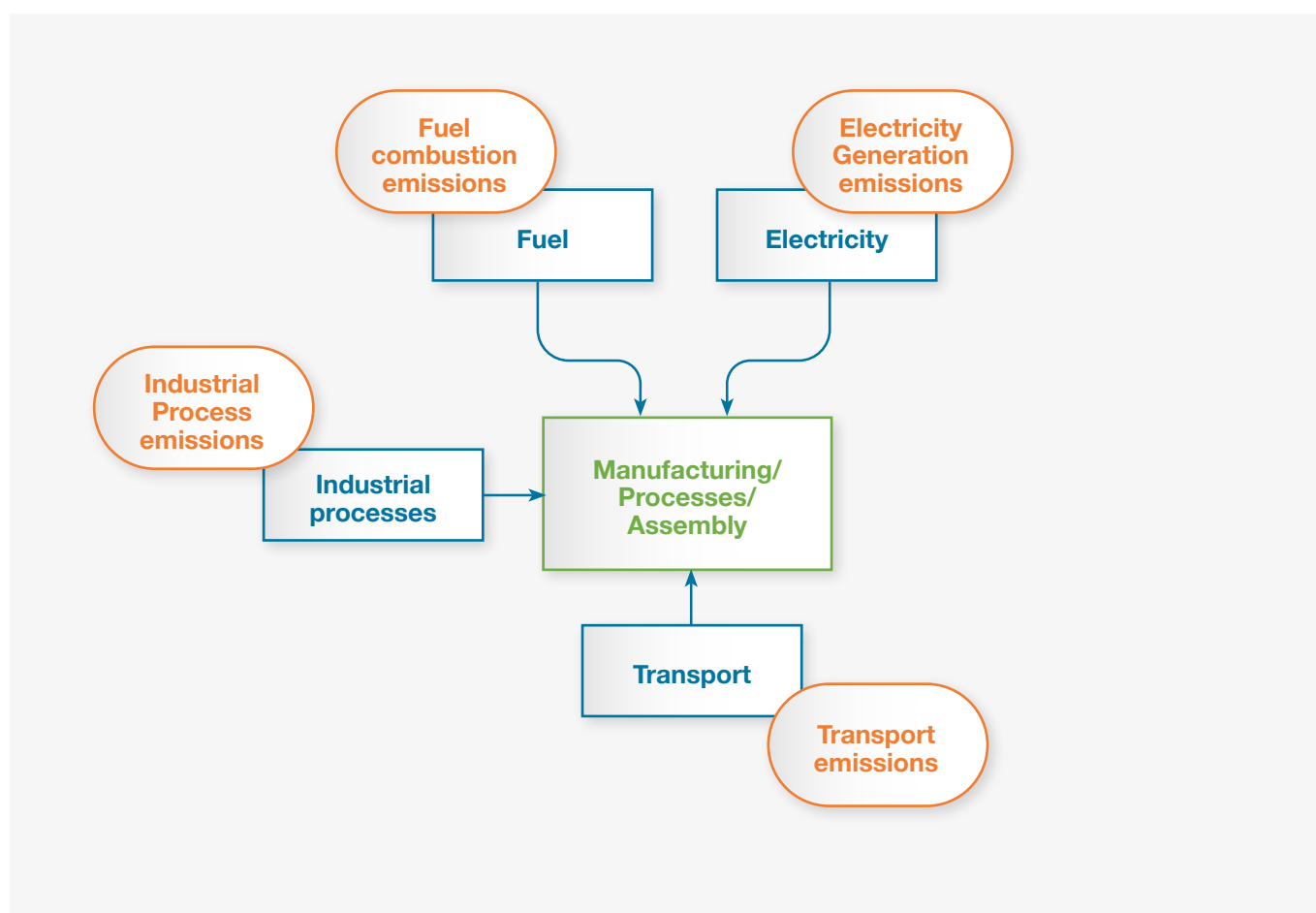


Figure 3.5: Overview of inputs for the Manufacturing, Processing and Transport stage of the value chain.

**Table 3.4: Possible sources of air pollutant emissions within Manufacturing, Processing and Assembly.**

Source	Description	Methodology for quantifying emissions	Section with emission quantification methodology
<b>Stationary fuel combustion</b>	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	<b>4.2</b>
<b>Electricity Generation</b>	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	<b>4.1</b>
<b>Industrial Processes</b>	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	<b>4.4</b>
<b>Transport</b>	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 Table 4.1	<b>4.3</b>

### 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.

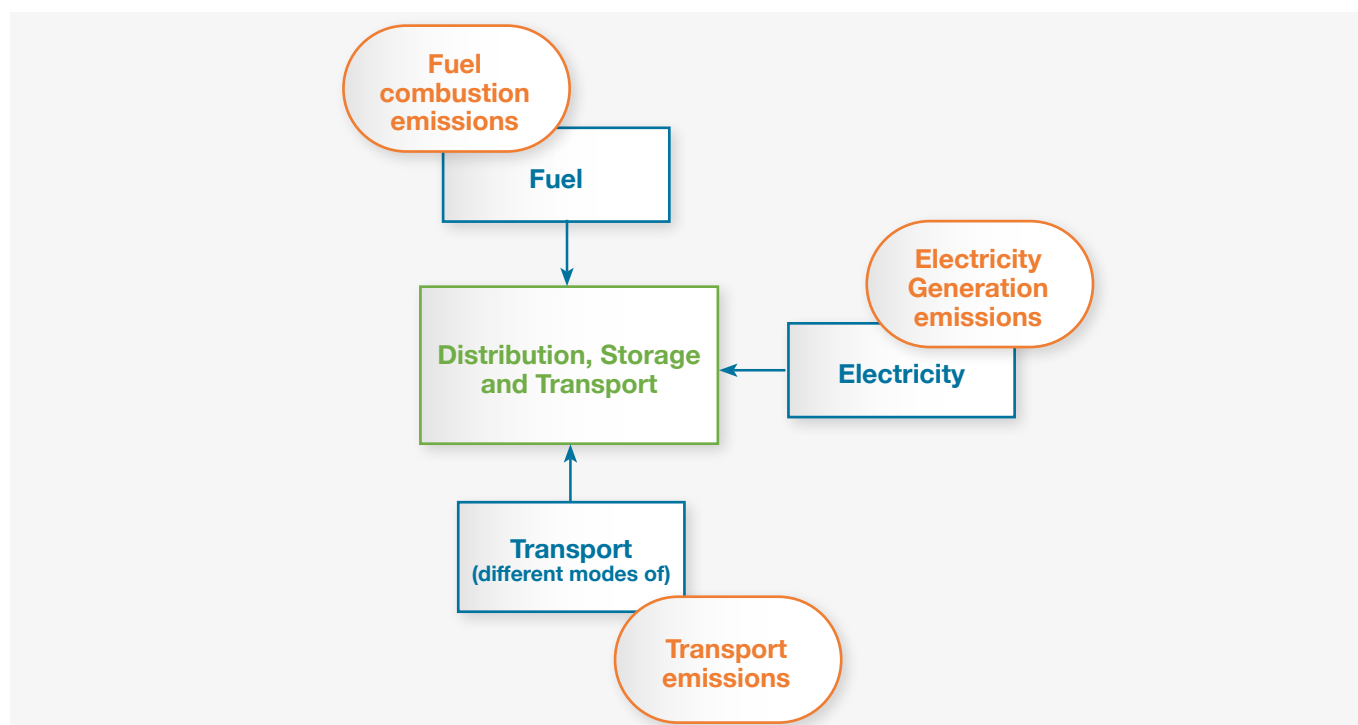
The starting point of the methodology followed in this Guide is to estimate the tonnes-km by multiplying the tonnes of product that was transported using a particular mode of transport (e.g., freight) by the average distance travelled using the particular mode of transport.

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



**Figure 3.6: Overview of inputs for the Distribution, Storage and Transport stage of the value chain.**

**Table 3.5: Possible sources of air pollutant emissions within Distribution, Storage and Transport.**

Source	Description	Methodology for quantifying emissions	Section 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	<b>4.2</b>
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	<b>4.1</b>
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 Table 4.1	<b>4.3</b>

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



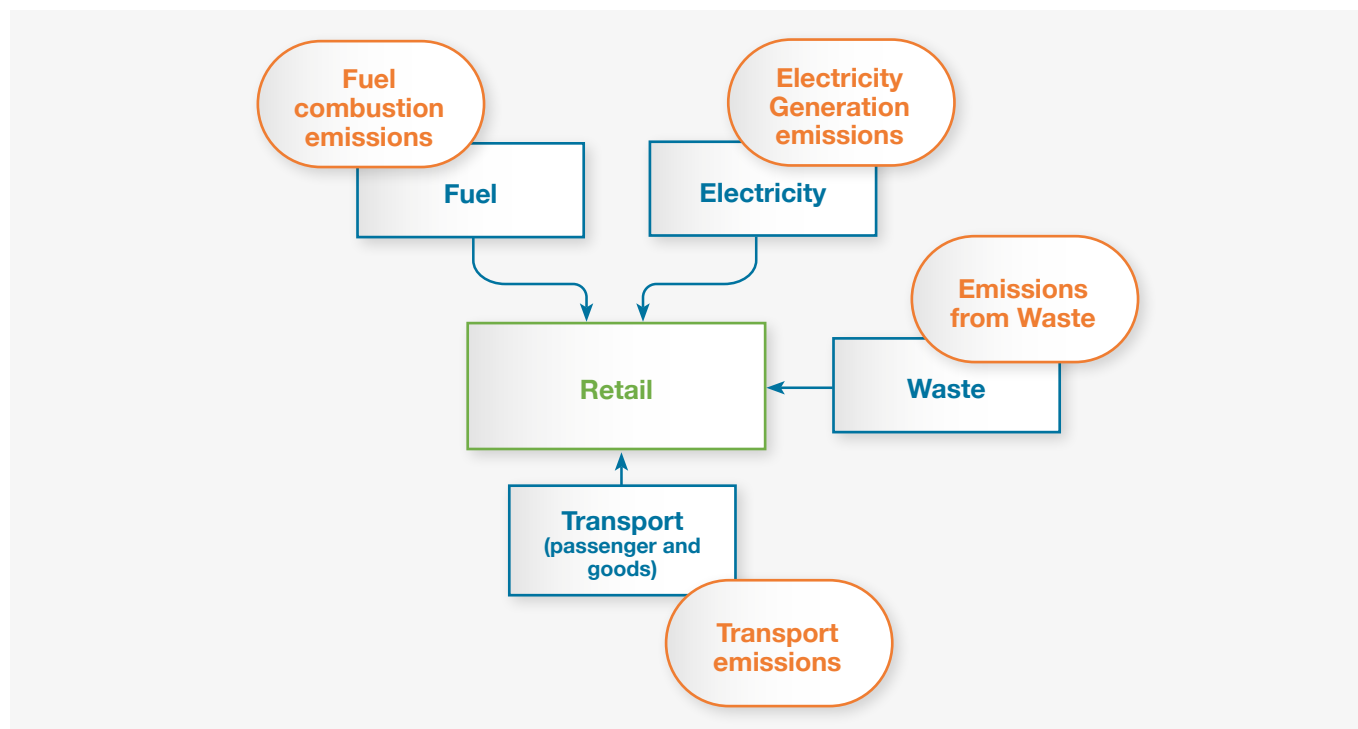


Figure 3.7: Overview of inputs for the Retail stage of the generic value chain.

Table 3.6: Possible sources of air pollutant emissions within Retail.

Source	Description	Methodology for quantifying emissions	Section with emission quantification methodology
<b>Stationary fuel combustion</b>	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	4.2
<b>Electricity Generation</b>	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	4.1
<b>Transport</b>	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 Table 4.1	4.3
<b>Waste</b>	Emissions related to waste management and disposal	See Table 4.1	4.6

### 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.

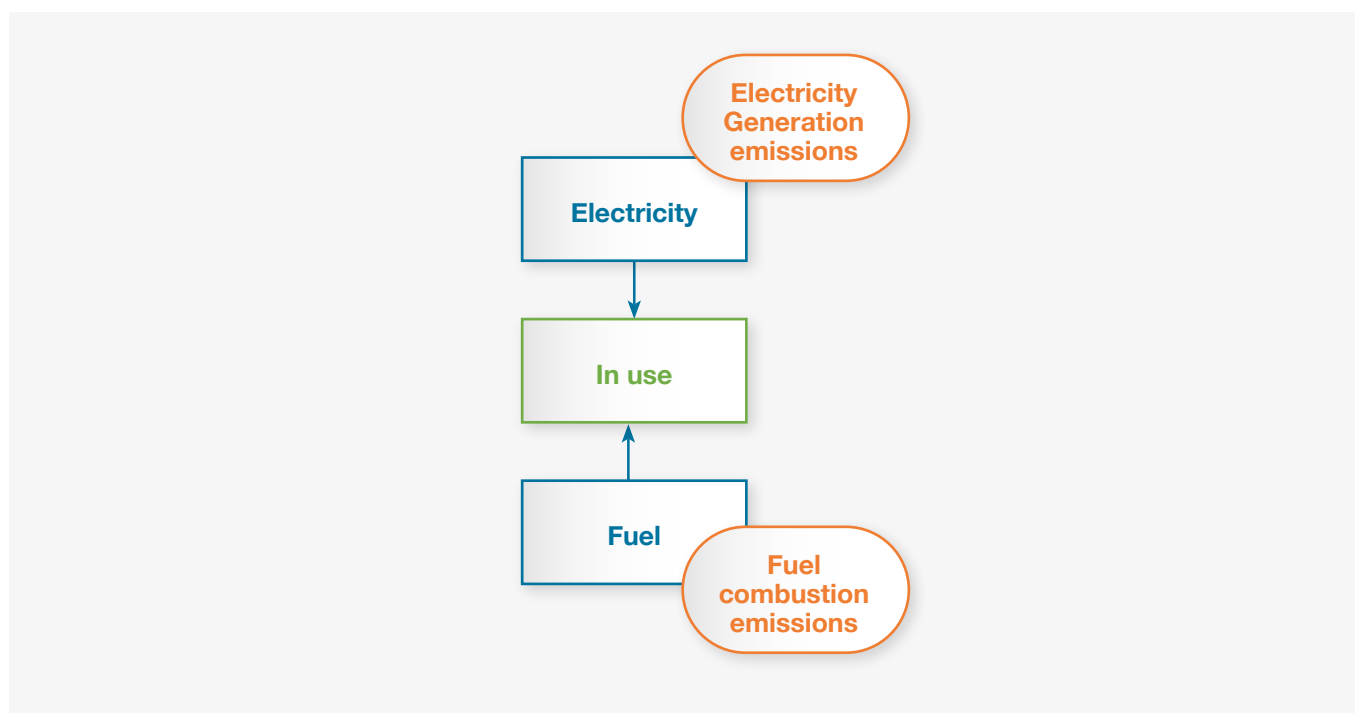


Figure 3.8: Overview of inputs for In Use.

Table 3.7: Possible sources of air pollutant emissions within In Use.

Source	Description	Methodology for quantifying emissions	Section with emission quantification methodology
<b>Stationary fuel combustion</b>	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	<b>4.2</b>
<b>Electricity Generation</b>	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	<b>4.1</b>

### 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.

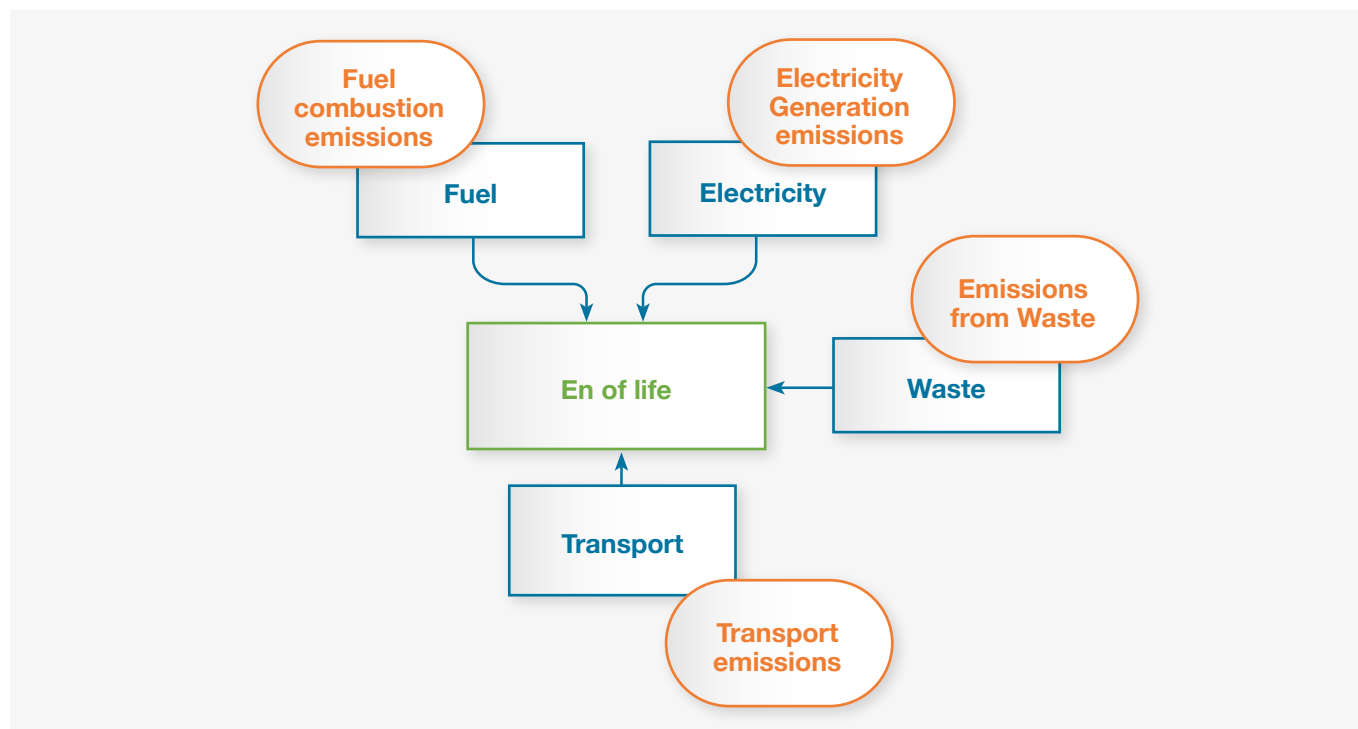


Figure 3.9: Overview of inputs for End of Life.

Table 3.8: Possible sources of air pollutant emissions within End of Life.

Source	Description	Methodology for quantifying emissions	Section with emission quantification methodology
<b>Stationary fuel combustion</b>	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	<b>4.2</b>
<b>Electricity Generation</b>	Electricity consumed in the process of waste disposal	Fuel combusted to generate electricity consumed multiplied by pollutant- and/or technology-specific emission factors	<b>4.1</b>
<b>Transport</b>	Emissions produced from the transport of products at the end of their life to waste disposal facilities	See Table 4.1	<b>4.3</b>
<b>Waste</b>	Emissions related to waste management and disposal	See Table 4.1	<b>4.6</b>

**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 factors are calculated ratios relating emissions to a proxy measure of activity at an emissions source. The IPCC guidelines (IPCC, 1996; 2019) refer to a hierarchy of calculation approaches and techniques ranging from the application of generic emission factors to direct monitoring. 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 purchased quantities of commercial fuels (such as natural gas and heating oil) using published emission factors.

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 miles and published or third-party 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.

Industrial companies may be faced with a wider range of approaches and methodologies. They should seek guidance from the sector-specific guidelines on the GHG Protocol website (if available) or from their industry associations (e.g., International Aluminium Institute, International Iron and Steel Institute, American Petroleum Institute, WBCSD Sustainable Cement Initiative, International Petroleum Industry Environmental Conservation Association).

### Choice of Tiers

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 determine the choice of the Tier.

The Guide 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. They also recommend that for other pollutants, the EMEP/EEA air pollutant emission inventory guidebook (EMEP/EEA, 2019) is used.

Both the IPCC and EMEP/EEA guidebook use three Tiers in order to estimate GHG and air pollution accordingly.

A **Tier 1** method is a simple method relying on existing activity data and default emission factors, this method usually comes with a significant level of uncertainty. Tier 2 and Tier 3 are more demanding in terms of activity data required and emission factors, but they are generally considered to be more accurate with less uncertainty related to them. This method assumes a simple linear relation between activity data and emission factors (EF) following Equation (3.1):

$$Emissions = Activity \times Emission\ Factor \quad \text{Eq. 3.1}$$

The activity variable quantifies how big a particular sector 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 can be taken from existing and publicly available statistical information (sector specific and industry specific statistics, for example annual primary aluminum 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 EMEP/EEA emission inventory guidebook. In addition, for some sources, emission factors were taken from the scientific literature, and are included in the SI for each pollutant 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 (3.2):

$$E_{pollutant} = \sum_{technologies} AR_{production,technology} \times EF_{technology,pollutant} \quad \text{Eq. 3.2}$$

The variable 'AR<sub>production,technology</sub>' is the production rate of the specific activity within the source category, using a specific technology, and the variable 'EF<sub>technology,pollutant</sub>' 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 much more specific information and provides the highest level of granularity out of the three. It usually uses facility specific data, and more advanced calculations. It can account for abatement, different technologies or lines of production within the same facility etc.

The Guide 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.

#### Step 4: Identifying and collecting 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 likely that the data missing can 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). 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 categories/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.

#### Step 5: Identify Emission Factors

A list of all the emission factors related to the key pollutants covered in these guidelines is presented in section 4 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 is a rather straight forward task as there is one emission factor related to each air pollutant. This emission factor is then used as described in Equation (3.1). 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.

This Guide provides [Supplementary Information \(SI\)](#) where the full Tier 1, and where available, Tier 2 emission factors for the different air pollutants and the different Sections have been added. The Supplementary Information will take the user to EMEP/EEA data finder website, where all the emission factors can be downloaded in a csv format.

It should be noted that this Guide is using the available emission factors that are suggested by the EMEP/EEA Guidebook (2019) because this is a widely used and scientifically robust document. 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 EMEP/EEA emission factors that are included in the SI.

#### 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. Section 4 will provide a detailed description of the appropriate equations linked to the different Tier methods.

## 4. SOURCE SECTORS AND KEY POLLUTANTS COVERED IN THE GUIDE

The six broad air pollutant emission sources covered in this guidance cover all the major sources of air pollutants and are presented in sections 4.1 to 4.8. A description of the source is provided for every section, followed by the Tier 1 and Tier 2 methodology, and default activity data is

compiled and tables of the appropriate emission factors for the Tier 1 and Tier 2 methods. Table 4.1 provides a summary of the air pollutant emission sources, and the methods and key variables used in this Guide to quantify emissions.

**Table 4.1: Summary of the air pollutant emission sources, and the methods and key variables used in this Guide to quantify emissions.**

Source	Sub-sources	Calculation method	Variables Tier 1	Variables Tier 2	Key resources
<b>Electricity Generation</b>	Electricity Generation due to business electricity consumption from grid. Emissions occur from generation of electricity using: Coal Natural Gas Diesel Heavy Fuel Oil Biomass Industrial waste Agricultural Waste	The fuel consumed to generate the electricity consumed by businesses is calculated based on i) the electricity consumed by the business, ii) the proportion of electricity production by different power plants (e.g., coal, oil, gas, hydro, renewables), and iii) the efficiency of different power stations. The fuel consumed is multiplied by fuel- (and technology-) specific emission factors to estimate emissions.	<ul style="list-style-type: none"> <li>- Electricity consumption by business</li> <li>- Percentage of grid electricity generated by different power stations (disaggregated by fuel type)</li> <li>- Efficiency of electricity generation for different types of power stations (by fuel)</li> <li>- Emission factor specific to pollutant</li> </ul>	<ul style="list-style-type: none"> <li>- Electricity consumption by business</li> <li>- Percentage of grid electricity generated by different power stations (disaggregated by fuel and technology)</li> <li>- Efficiency of electricity generation for different types of power stations (by fuel and technology)</li> <li>- Emission factor</li> </ul> <p>In this instance the variables need to be category/technology and/or country specific</p>	<p>EMEP/EEA (2019)</p> <p>Databases of electricity matrices</p> <p>Databases of efficiencies</p>
<b>Stationary Fuel Combustion</b>	Combustion of fuels including: Natural gas LPG Diesel Gasoline Coal Heavy Fuel Oil Kerosene Biomass Industrial or Agricultural waste Charcoal	The fuel consumed by a specific technology is multiplied by the emission factor for the specific technology and pollutant	<ul style="list-style-type: none"> <li>- Fuel consumed</li> <li>- Emission factor specific to pollutant</li> </ul>	<ul style="list-style-type: none"> <li>- Fuel consumed</li> <li>- Emission factor</li> </ul> <p>In this instance the variables need to be category/technology and/or country specific</p>	EMEP/EEA (2019)



Source	Sub-sources	Calculation method	Variables Tier 1	Variables Tier 2	Key resources
Transport	Road Transport	<b>Detailed method</b>	Total number of tonnes-km transport using the specific transport mode.		EMEP/EEA (2019)
	Freight Road Transport Passenger	<p>The number of tonnes-km is calculated by multiplying the tonnes of material/product transported on road by the average distance travelled by a shipment.</p> <p>The tonnes-km are disaggregated by vehicle standards based on the percent of vehicles meeting different Euro standards.</p> <p>The tonnes-km is multiplied by a fuel-specific (e.g., diesel, gasoline) and technology-specific (e.g., Euro standard) energy intensity (fuel consumption per tonne-km) to estimate the total fuel consumed by fuel and technology.</p> <p>Fuel - and technology-specific emission factors are then multiplied by the fuel consumed to estimate the air pollutant emissions</p> <p><b>Simplified method</b></p> <p>Collect information on the number of different types of vehicles used. Disaggregate each type of vehicle by type of fuel used. The amount fuel consumed (kg) for different types of vehicles is multiplied by pollutant-specific emission factors.</p> <p><b>Detailed Method</b></p> <p>The number of passenger-km is calculated by multiplying the number of people visiting businesses by the average distance travelled to get to the business by mode (cars, buses, motorcycles, non-motorised).</p> <p>The passenger-km for each mode is disaggregated by vehicle standards based on the percent of vehicles meeting different Euro standards.</p> <p>The 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.</p> <p>Fuel- and technology-specific emission factors are then multiplied by the fuel consumed to estimate the air pollutant emissions</p> <p><b>Simplified method</b></p> <p>Collect information on the number of different types of vehicles used. Disaggregate each type of vehicle by type of fuel used. The amount fuel consumed (kg) for different types of vehicles is multiplied by pollutant-specific emission factors.</p>	<ul style="list-style-type: none"> <li>- Euro standard for vehicles (if available)</li> <li>- Emission factor for specific pollutant and for vehicle type, fuel, and emission standard</li> <li>- Total amount of fuel consumed by the different types of vehicles</li> <li>- Emission factor specific for each pollutant and type of fuel</li> <li>- Total number of passenger-km using the specific transport mode.</li> <li>- Euro standard for vehicles (if available)</li> <li>- Emission factor for specific pollutant and for vehicle type, fuel, and emission standard</li> <li>- Total amount of fuel consumed by the different types of vehicles</li> <li>- Emission factor specific for each pollutant and type of fuel</li> </ul>		

Source	Sub-sources	Calculation method	Variables Tier 1	Variables Tier 2	Key resources
<b>Transport</b>	Railways Freight Railways Passenger	<p>The number of tonnes-km is calculated by multiplying the total tonnes of freight transport by rail by the average distance travelled by using rail.</p> <p>The tonnes-km is multiplied by a fuel-specific (e.g., diesel, electricity, coal) energy intensity (fuel consumption per tonne-km) to estimate the total fuel consumed from rail transport.</p> <p>Fuel-specific emission factors are then multiplied by the fuel consumed to estimate the air pollutant emissions</p> <p>The passenger-km travelled using rail powered by each type of fuel is multiplied by the fuel consumption for rail using each type of fuel and with a pollutant specific emission factor for each type of fuel.</p>	<ul style="list-style-type: none"> <li>- Total number of tonnes-km transport using the specific transport mode.</li> <li>- Pollutant and fuel specific emission factor</li> <li>- Total number of passenger-km travelled using the specific transport mode.</li> <li>- Pollutant and fuel specific emission factor</li> </ul>		EMEP/EEA (2019)
<b>Transport</b>	International Shipping (Freight)	<p>The number of tonnes-km is calculated by multiplying the total tonnes of freight transport by ship by the average distance travelled by using ship.</p> <p>The tonnes-km is multiplied by a fuel-specific (e.g., diesel, fuel oil, coal) energy intensity (fuel consumption per tonne-km) to estimate the total fuel consumed from ship transport.</p> <p>Fuel-specific emission factors are then multiplied by the fuel consumed to estimate the air pollutant emissions</p>	<ul style="list-style-type: none"> <li>- Total number of tonnes-km travelled using the specific transport mode.</li> <li>- Pollutant and fuel specific emission factor</li> </ul>		EMEP/EEA (2019)
<b>Transport</b>	Aviation (Freight)	<p>The number of tonnes-km is calculated by multiplying the total tonnes of freight transport by plane by the average distance travelled using aviation.</p> <p>The tonnes-km is multiplied by a fuel-specific (e.g., diesel, fuel oil, coal) energy intensity (fuel consumption per tonne-km) to estimate the total fuel consumed from aviation transport.</p> <p>Fuel-specific emission factors are then multiplied by the fuel consumed to estimate the air pollutant emissions</p>	<ul style="list-style-type: none"> <li>- Total number of tonnes-km transport using the specific transport mode.</li> <li>- Pollutant and fuel specific emission factor</li> </ul>		EMEP/EEA (2019)
<b>Transport</b>	Non-Road Transport	<p>The total amount of non-road vehicles is disaggregated by machinery type, fuel type and engine.</p> <p>The amount of non-road vehicles disaggregated by machinery type, fuel type and engine type is then multiplied by a machinery-, fuel-, engine- specific air pollutant emission factor to estimate air pollutant emissions.</p>	<ul style="list-style-type: none"> <li>- The total amount of non-road vehicles</li> <li>- The percentage of the different types of machinery type</li> <li>- The percentage of fuel type and engine for each type of machinery</li> </ul>	<ul style="list-style-type: none"> <li>- The total amount of non-road vehicles</li> <li>- The percentage of the different types of machinery type</li> <li>- The percentage of fuel type and engine for each type of machinery</li> <li>- The age of the different types of machinery disaggregated by fuel and engine type</li> </ul>	EMEP/EEA (2019)

Source	Sub-sources	Calculation method	Variables Tier 1	Variables Tier 2	Key resources
<b>Industrial Processes and Product Use</b>	This section covers emissions from the categories: cement production, lime production, glass production, quarrying and mining minerals other than coal, construction and demolition, storage, handling and transport of mineral products, chemical industry and metal production.	Activity data on the annual production of each category (e.g., annual production of cement, annual production of aluminium) is multiplied by an emission factor, category and pollutant specific.	<ul style="list-style-type: none"> <li>- The annual production of the category (e.g., cement)</li> <li>- The emission factor of the relevant pollutant</li> </ul>	<ul style="list-style-type: none"> <li>- The annual production rate of the category (e.g., cement) using the specific technology within the source category</li> <li>- The emission factor specific to that technology and pollutant</li> </ul>	EMEP/EEA (2019)
<b>Agriculture</b>	Livestock	<p>The livestock specific meat/dairy/eggs (tonnes) used in the value chain is multiplied by the carcass weight of specific type of livestock (tonnes/livestock) to estimate the number of a specific type of livestock (e.g., dairy cattle).</p> <p>The number of specific type of livestock and the manure type (e.g., solid, slurry) needs to be accounted for. The number of the different type of livestock will be multiplied by an emission factor for the different types of manure.</p> <p>The total number of specific type of livestock under the different manure type (e.g., Dairy cattle, slurry) is multiplied by an emission factor, specific to the type of livestock, manure type and manure management system.</p>	The number of meat/dairy/eggs (tonnes) used in the value chain (or directly) the number of a specific type of livestock.	<ul style="list-style-type: none"> <li>- The number of meat/dairy/eggs (tonnes) used in the value chain (or directly) the number of a specific type of livestock</li> <li>- The percentage of livestock manure handled as solid or slurry</li> <li>- Time spent in different locations (grazing, yard, housing)</li> <li>- Nitrogen excretion rate (default values available)</li> </ul>	EMEP/EEA (2019)

Source	Sub-sources	Calculation method	Variables Tier 1	Variables Tier 2	Key resources
	Manure application to fields, Synthetic fertiliser application to fields	<p>A company may produce a variety of food products that each require a combination of different ingredients produced from different types of crop.</p> <p>The production 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.</p> <p>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.</p> <p>For NMVOC and PM:</p> <p>The area covered by the specific type of crop is multiplied by a pollutant specific emission factor.</p> <p>For NH3 and NO:</p> <p>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 for the specific type of crop.</p> <p>The amount of nitrogen in the fertiliser or organic waste used is then multiplied by a pollutant specific emission factor to estimate air pollutant emissions.</p>	Tonnes of product (consumed or produced) per different type of crop.		EMEP/EEA (2019)
	Open burning of agricultural waste	<p>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.</p> <p>The area burned is multiplied by a pollutant specific emission factor to estimate air pollutant emissions</p>	<p>Percentage of residue burned in the field</p> <p>Tonnes of product (consumed or produced) per different type of crop.</p>		EMEP/EEA (2019)
<b>Waste</b>		The total amount of waste produced is disaggregated by waste type and by the waste treatment processes used to dispose of the waste. The amount of waste treated using a specific process (e.g., amount of food waste incinerated) is multiplied by an emission factor.	<ul style="list-style-type: none"> <li>- Total amount of waste generated in the different stages of the value chain</li> <li>- Total amount of the different types of waste generated (e.g., food, plastic, paper)</li> <li>- Percentage of waste treated using different processes (e.g., landfill, incineration, open burning)</li> </ul>		EMEP/EEA (2019)

## 4.1 Electricity Consumption

### 4.1.1 Description of Source

The consumption of electricity from the national grid (i.e., not produced by the company) does not release air pollutant 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 air pollutant emissions. As shown in Section 3, electricity consumption can occur across the value chain, in the extraction of raw materials, manufacturing, retailing, when products are in use and at the end of their life. In cases where this electricity is consumed from the national grid, a common methodology can be applied to quantify the air pollutant emissions associated with this electricity consumption at different points along the value chain.

Quantifying the air pollutant emissions requires that the percentage of electricity consumed at a particular part of the value chain that is generated using different types of fuels and technologies are estimated. For each type of electricity generation, fuel and/or technology-specific emission factors can be applied to estimate the emissions of air pollutants. Specific technologies can be applied to power plants to reduce emissions of air pollutants from the stacks of power stations. Knowledge of whether, and where these abatement technologies are applied can substantially enhance the robustness of the air pollutant emission estimates. For electricity consumed that was generated using renewable energy sources such as hydro, wind and solar, there are no air pollutant emissions associated with the generation of electricity from these sources. The fuels which are consumed to generate electricity, and for which methods are included in this section include the following fuels:

- 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)

### 4.1.2 Methodologies for Quantifying Emissions

For the Tier 1 and Tier 2 methods the starting point for quantifying emissions is to quantify the electricity generated from different types of power stations as shown in Equation 4.1.

$$EG_n = EC_T * P_n \text{ (Eq. 4.1)}$$

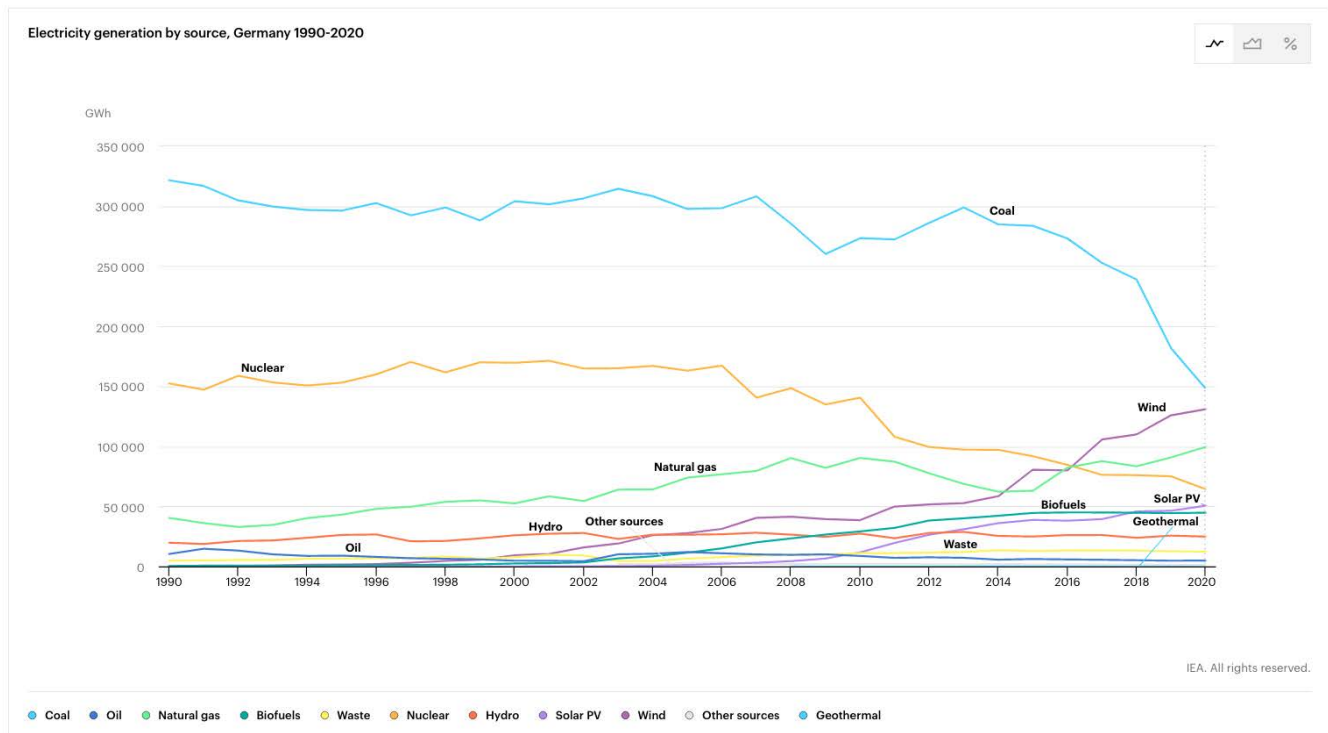
Where  $EG_n$  is the electricity generation using fuel and technology  $n$  (units: KWh),  $EC_T$  is the total electricity consumed at a particular part of the company's value chain, and  $P_n$  is the proportion of the consumed electricity that is generated using fuel and technology  $n$ .

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 ( $EC_T$ ) 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 ( $P_n$ ) can be substantially different across different countries. Therefore, to estimate ( $P_n$ ), the user needs to identify the appropriate data for the electricity generated using different types of fuel and technologies ( $P_n$ ) 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](#).

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 4.1



**Figure 4.1: Electricity generation (GWh) by source, Germany 1990-2020. Source, IEA (2022).**

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 guidelines (see Tables 4.4 and 4.5).

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 guidance (e.g., hard coal, heavy fuel oil).

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). 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 4.4). 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 4.2 provides an example of the mapping of the fuel classification as provided by the IEA dataset, against the EMEP/EEA 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 4.2 in conjunction with Table 4.4 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 (2019) guidance.



**Table 4.2: Example of mapping of the International Energy Agency (IEA) fuel classification against the EMEP/EEA (2019) 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)
Coal	Hard Coal	93% Hard Coal 7% Brown Coal
Oil	Heavy Fuel Oil	66% Heavy Fuel Oil 34% Light fuel
Natural gas	Gaseous fuels	Gaseous fuels
Biofuels	Biomass	Biomass
Waste	Biomass	Biomass
Renewables (e.g., wind, solar)	Not applicable	Not applicable
Nuclear	Not applicable	Not applicable

Therefore, Equations 4.1, and 4.2 (below) should be applied, where possible, disaggregated by countries where a company undertakes different activities across its value chain to ensure that the 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<sub>n</sub>) using Equation 4.1, 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 EG<sub>n</sub>, as shown in Equation 4.2.

$$FC_n = EG_n * Eff_n * 0.0036 \text{ (Eq. 4.2)}$$

Where FC<sub>n</sub> is the fuel consumption for fuel and technology *n* (units: GJ), Eff<sub>n</sub> is the efficiency of technology *n* in generating

electricity (fraction), and 0.0036 is the conversion from KWh to GJ.

The efficiency of different power stations (Eff<sub>n</sub>) is used to estimate the quantity of fuel consumed to generate 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/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 Eff<sub>n</sub> values are not available, then default values summarised in Table 4.3 below could be applied, which provides an average efficiency of different types of power stations.

**Table 4.3: Default efficiency values for power stations disaggregated by fuel (% efficiency)**

Fuel	Efficiency (%)	Source
Coal	33%	(World Coal Association, 2014)
Natural Gas	49%	
Heavy Fuel Oil	40%	
Diesel	35%	
Biomass	80%	(IEA, 2012)

Having estimated the fuel consumption associated with the electricity consumption across different parts of a company's value chain, air pollutant emissions are then calculated by multiplying this 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 4.3.

$$Em_k = FC_n * EF_{n,k} \quad (\text{Eq. 4.3})$$

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 3.5 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 4.4 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 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, 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 technology used to generate the electricity used across a company's value chain.

**Table 4.4: Tier 1 emission factors (g/Gj) for the different types of fuel and the different pollutants [Source: EMEP/EEA, 2019].**

	CO g/Gj	NMVOCs g/Gj	NOx g/Gj	SO <sub>2</sub> g/Gj	PM <sub>10</sub> g/Gj	PM <sub>2.5</sub> g/Gj	BC % of PM <sub>2.5</sub>	OC
<b>Hard Coal</b>	8.7	1.0	209	820	7.7	3.4	2.2	
<b>Brown Coal</b>	8.7	1.4	247	1680	7.9	3.2	1	
<b>Gaseous Fuel</b>	39	2.6	89	0.281	0.89	0.89	2.5	
<b>Heavy Fuel Oil</b>	15.1	2.3	142	495	25.2	19.3	5.6	
<b>Light Oil</b>	16.2	0.8	65	46.5	3.2	0.8	33.5	
<b>Biomass</b>	90	7.31	81	10.8	155	133	3.3	

### Tier 2

The Tier 2 method requires knowledge of the specific fuel used but also, of the different technologies that consume the fuel. Combustion technology and the relevant fuels described under this section are those technologies for which default technology and fuel-specific emission factors are identified in the EMEP/EEA national air pollutant emission inventory guidebook:

- **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

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.,  $P_n$ ) disaggregated by fuel and technology. This allows the total fuel consumption to generate this electricity (FC) to be derived disaggregated by fuel and technology. Due to a lack of default data at this

level of detail, the inventory compiler would need to identify the power stations within the electricity grid that is serving the company's value chain to apply the Tier 2 approach. Equation 4.4 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 air pollutant emissions from electricity consumption across the company's value chain.

$$Em_k = \sum_t FC_{n,t} \times EF_{t,k} \quad (\text{Eq. 4.4})$$

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 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 emissions from the different types of technologies consuming different types of fuels to generate electricity are shown in Table 4.5.

**Table 4.5: Tier 2 emission factors (g/Gj) for the different combustion technology, the relevant fuels and the different pollutants. [Source: EMEP/EEA, 2019].**

	CO g/Gj	NMVOCS g/Gj	NOx g/Gj	SO <sub>2</sub> g/Gj	PM <sub>10</sub> g/Gj	PM <sub>2.5</sub> g/Gj	BC % of PM <sub>2.5</sub>
<b>Dry bottom boiler</b>							
Coking coal, steam coal and sub-bituminous coal	8.7	1.0	209	820	7.7	3.4	2.2
Brown Coal/ Lignite	8.7	1.4	247	1680	7.9	3.2	1
Residual Oil	15.1	2.3	142	495	25.2	19.3	5.6
Natural Gas	39	2.6	89	0.281	0.89	0.89	2.5
Wood and Wood Waste	90	7.31	81	10.8	155	133	33.
<b>Wet Bottom Boiler</b>							
Coking coal, steam coal and sub-bituminous coal	8.7	0.7	244	820	6.0	3.1	2.2
Brown Coal/ Lignite	8.7	1.4	247	1680	7.9	3.2	1
Fluid Bed Boilers							
Hard Coal	313	0.9	82.5	820	7.7	5.2	2.2
Brown Coal	13	1	60	1689	6.9	2.8	Not estimated
<b>Gaseous Fuel</b>							
Gas Turbine	4.8	1.6	48	0.281	0.2	0.2	2.5
Gas Oil	1.49	0.19	398	46.5	1.95	1.95	33.5
<b>Large Stationary CI Engines</b>							
Gas Oil	130	37.1	942	46.5	22.4	21.7	78
Natural Gas	56	89	135	0.5	2	2	2.5

## 4.2 Stationary Fuel Combustion

### 4.2.1 Description of Source

Stationary fuel combustion is the burning of fuels 'on-site' in manufacturing, retail or other parts of a business's value chain. Stationary fuel combustion, and the air pollutant emissions associated with it is distinct from electricity consumption, in which the emissions are produced during electricity generation, which may not be part of the business's operations (e.g., if the electricity consumed comes from the national grid). It is also distinct from transport air pollutant emissions that occur along a company's value chain. Transport emissions are also produced from the combustion of fuels but are a mobile air pollutant emission source. The stationary fuel combustion category includes combustion at a fixed site. In the EMEP/EEA national air pollutant emission inventory guidance, sub-sectors for which methods are included to quantify emissions from stationary fuel combustion include 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). 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 Section 3 (Figure 3.1).

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 air pollutant emissions from these sources are also included in this section. For all of these sources, the magnitude of 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 4.2.2 presents Tier 1 that can be used to quantify the 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 taken into account. Tier 2 methods accounting for technologies used in fuel combustion are also described in Section 4.2.2.

### 4.2.2 Methodology for Quantifying Emissions

#### Tier 1

Stationary fuel combustion may be a source of 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 4.5 is used to quantify the magnitude of air pollutant emissions. Equation 4.5 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 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.

$$Em_k = FC_n \times EF_k \quad (\text{Eq. 4.5})$$

Where:

$FC_n$  = the fuel n consumed within the source category (Gj)

$EF_k$  = the emission factor for this pollutant k (g/Gj)

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

The activity data i.e., fuel consumption, to estimate 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 4.6 includes Tier 1 default emission factors for stationary fuel combustion, taken from the EMEP/EEA 2019 national air pollutant emission inventory guidance. 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 technology can have a large impact on the magnitude of emissions from burning a particular fuel. The technology

determines the efficiency of combustion and may have different emission reduction technologies fitted to it which are expressly designed to minimise 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 4.6: Tier 1 emission factors (g/Gj) for the different types of fuel and the different pollutants [Source: EMEP/EEA, 2019].**

	CO g/Gj	NMVOCS g/Gj	NOx g/Gj	SO <sub>2</sub> g/Gj	PM <sub>10</sub> g/Gj	PM <sub>2.5</sub> g/Gj	BC % of PM <sub>2.5</sub>	OC	NH <sub>3</sub>
<b>Solid Fuels</b>	931	88.8	173	900	117	108	6.4		Not estimated
<b>Gaseous Fuels</b>	29	23	74	0.67	0.78	0.78	4.0		Not estimated
<b>Liquid Fuels</b>	66	25	513	47	20	20	56		Not estimated
<b>Biomass</b>	570	300	91	11	143	140	28		Not estimated

## Tier 2

As outlined in the EMEP/EEA national air pollutant emission inventory guidebook (2019), 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 4.5 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 4.5, 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 air pollutant emission inventory guidance. These emission factors are included in the SI.

$$Em_k = \sum_t FC_{n,t} \times EF_{t,k} \quad (\text{Eq. 4.6})$$

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)

### 4.3 Transport

As outlined in Section 3 (Figure 3.3), transport can be a source of air pollutant emissions at multiple points across a company's value chain. The movement of raw materials, as well as manufactured goods can contribute to 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 air pollutant emissions from freight transport, while the transport of customers to stores, either through private vehicles or public transport, can result in 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.

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

1. 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 (2019)
2. 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. This 'Tier 2' methodology, described in detail in EMEP/EEA (2019) is 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 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

air pollutant emissions from transport may not allow for an appropriate allocation of 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 for quantifying air pollutant emissions from transport activities within a company's value chain are aligned with approaches outlined in the GHG protocol for quantifying GHG emissions from businesses. Two key activity variables are used, across all transport modes (e.g., road, rail, sea and air) to characterise the 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 transport 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 demand for 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 includes two approaches that the user can use in order to quantify air pollutant emissions, a detailed and a simplified method. The detailed 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 simplified method can be used. The information needed in order to apply the simplified 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.
- **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.

- **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.

Within this section, methods to estimate the 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
  - Aviation
  - Shipping
- Mobile Machinery
- Passenger Transport
  - Road including private travel (cars) and public transport (buses)
  - Rail

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 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 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

To quantify 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 detailed method, which requires information on the vehicle type, fuel used by each type of vehicle, but also vehicle emission standard, and the simplified 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 air pollutant emissions, based on the data that is available to them.

#### Option 1: Detailed method for Road transport

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 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 air pollutant emissions.

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

The development of tonnes-km estimates 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 (a top-down approach) or ii) developing estimates of tonnes-km for different vehicle types independently (a bottom-up approach).

The categorisation of vehicles differ in different jurisdictions. Due to the default emission factors included in this Guide from the EMEP/EEA (2019) air pollutant emission inventory guidebook, we adopt the disaggregation of vehicles according to their categorisation method. For freight, the two key vehicle types in the EMEP/EEA guidebook are 'heavy-duty vehicles', which are vehicles greater than 3.5 tonnes and 'light commercial vehicles', less than 3.5 tonnes. The development of tonnes-km estimates for different vehicles type using either approach described above requires company-specific data on the mass of product/material transported, and the distance that these products are transport. 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 tonnes-km travelled by different vehicles.

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

Similarly for estimating emissions of GHGs, it is also necessary to disaggregate tonnes-km taken by different vehicles by the fuel used in these vehicles when estimating air pollutant emissions. This is done by multiplying the total number of tonnes-km taken using heavy duty vehicles or light duty vehicles by the fraction of those tonnes-km taken in these vehicle types which use different fuels. 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 4.1 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.

**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 air pollutants in their vehicle fleets. For example, since the early 1990s in Europe, the 'Euro' standards, now in their 6<sup>th</sup> 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 the 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.

**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 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 (2019) 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.

Equation 4.7 shows how air pollutant emissions are estimated for freight transport for a particular vehicle type, fuel, and emission standard:

$$Em_{k,v,f,s} = (tkm_{v,f,s} / Load\_Factor) * EF_{k,v,f,s} \quad (Eq. 4.7)$$

where:

$tkm_{v,f,s}$  = 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<sup>-1</sup>)

Load Factor = The load factor (tonnes freight vehicle<sup>-1</sup>)

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

Equation 4.7 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<sup>-1</sup>. The load factor is the conversion 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 inventory guidebook such as EMEP/EEA (2019). 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 4.7 below could be used with company-specific tonnes-km data.

**Table 4.7: Default load factors (tonnes freight vehicle<sup>-1</sup>) for different types of vehicles (Source: Network for Transport Measures; Road Transport, 2022)**

Vehicle type	Max Gross Weight (tonnes)	Vehicle Length (m)	Load capacity (tonnes)	Load Capacity Utilisation (w%)	Load Factor (tonnes)
<b>Heavy Duty Vehicles</b>					
Rigid Truck <= 7.5t	7.5	8	5	0.4	2
Rigid Truck 7.5-12t	12	11	6	0.4	2.4
Rigid Truck 12-14t	14	11	9	0.4	3.6
Rigid Truck 14-20t	20	12	12	0.4	4.8
Rigid Truck 20-26t	26	12	15	0.4	6
Truck with trailer 14-20t	20	12	12	0.4	4.8
Truck with trailer 20-28t	28	12	16	0.4	6.4
Truck with trailer 28-34t	34	17	22	0.5	11
Truck with trailer 34-40t	40	19	26	0.5	13
Truck with trailer 40-50t	50	16.50	33	0.5	16.5
Truck with trailer 50-60t	60	25.25	40	0.5	20
<b>Light Commercial Vehicles</b>					
Light commercial vehicle (pick-up)	2.5	5	0.6	0.2	0.12
Light commercial vehicle	3.5	7	1	0.2	0.2

The EMEP/EEA (2019) default emission factors for each pollutant, fuel and Euro standard are reproduced in the SI and can be applied using Equation 4.7 above, along with occupancy data and tonnes-km to estimate the air

pollutant emissions from a company’s freight transport within its value chain.

## Option 2: Simplified method for Road transport

If the only information available is the type of fuel consumed by each type of vehicle, then the above approach can be simplified and modified to include the following steps:

**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.

**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.

**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 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 (2019) for all relevant air pollutants, have units of gram pollutant emitted per vehicle-km travelled.

Equation 4.8 shows how air pollutant emissions are estimated for freight transport for a particular vehicle type and fuel:

$$Em_{k,v,f} = FC_{v,f} * EF_{k,v,f} \quad (\text{Eq. 4.8})$$

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<sup>-1</sup>)

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

## Rail

When estimating air pollutant emissions from freight transported by rail, the activity data (tonnes-km) should be disaggregated by fuel (e.g., diesel, electricity). 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 taken using electric rail in a company's value chain should also be estimated, and air pollutant emissions from the electricity generation accounted for. The reader should therefore use the methods outlined in Section 4.1 to estimate the 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 tonnes-km of freight transported by diesel rail, there are direct emissions of air pollutants as the freight is transported. Equation 4.9 below can be used to estimate the air pollutant emissions associated with freight transport by rail:

$$Emissions_{k,f} = tkm_f * FC_f * EF_{k,f} \quad (\text{Eq. 4.9})$$

where:

$tkm_f$  = 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<sup>-1</sup>)

$FC_f$  = Fuel consumption for rail using fuel  $f$  (kg fuel tonne-km<sup>-1</sup>)

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

The application of Equation 4.9 converts the number of tonnes-km transported using rail 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. 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 4.8 which contains default values for energy consumption ( $\text{MJ tonne-km}^{-1}$ ) derived from the Railway Handbook (2012, 2015, 2017). Dividing the energy consumption by the energy content of the fuel (e.g., diesel), fuel consumption ( $\text{kg fuel tonne-km}^{-1}$ ) 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 4.8: Default energy consumption ( $\text{MJ tonne-km}^{-1}$ ) (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 ( $\text{MJ/tonnes km}$ )	Energy Content ( $\text{MJ/kg}$ )	Fuel consumption ( $\text{Kg fuel tonne-km}^{-1}$ )
Diesel	0.3	42.91	0.006

EMEP/EEA Tier 1 emission factors are listed in Table 4.9 for rail transport using diesel.

**Table 4.9: Tier 1 emission factors for railways [Source: EMEP/EEA, 2019].**

	CO ( $\text{kg/tonne of fuel}$ )	NMVOCs ( $\text{kg/tonne of fuel}$ )	NOx ( $\text{kg/tonne of fuel}$ )	PM <sub>10</sub> ( $\text{kg/tonne of fuel}$ )	PM <sub>2.5</sub> ( $\text{kg/tonne of fuel}$ )	BC (% of PM <sub>2.5</sub> )	NH <sub>3</sub> ( $\text{kg/tonne of fuel}$ )
Gas oil/Diesel	10.7	4.65	52.4	1.44	1.36	0.65	0.007

To proceed to a Tier 2 approach, the number of tonnes-km taken by different types of locomotives need to be calculated. Equation 4.9 is then applied separately for each locomotive type, using locomotive specific fuel consumption, and emission factors to estimate air pollutant emissions from freight transport for each type of locomotive. The EMEP/EEA (2019) guide provides 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. Emission factors for the Tier 2 method are included in the SI.

### Aviation

When estimating 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 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 freight transported by aviation, Equation 4.10 below can be used to estimate the associated air pollutant emissions:

$$\text{Emissions}_{k,f} = \text{tkm}_f * \text{FC}_f * \text{EF}_{k,f} \quad (\text{Eq. 4.10})$$

where:

$\text{tkm}_f$  = tonnes-km travelled using air powered by fuel  $f$  (tonnes-km)

$\text{EF}_{k,f}$  = emission factor for pollutant  $k$  for air travel using fuel  $f$  ( $\text{g kg fuel consumed}^{-1}$ )

$\text{FC}_f$  = Fuel consumption for air travel using fuel  $f$  ( $\text{kg fuel tonne-km}^{-1}$ )

$\text{Emissions}_{k,f}$  = emissions of the specific pollutant  $k$  for air transport using fuel  $f$  (g)

The application of Equation 4.10 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 4.10 contains default values for energy consumption ( $\text{MJ tonne-km}^{-1}$ ) 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<sup>-1</sup>) can be estimated.

**Table 4.10: Default energy consumption (MJ tonne-km<sup>-1</sup>) (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 <sup>-1</sup> )
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 4.11 below.

**Table 4.11: Tier 1 emission factors for aviation [Source: EMEP/EEA, 2019].**

	CO (kg/tonne of fuel)	NMVOCs (kg/tonne of fuel)	NOx (kg/tonne of fuel)	SO <sub>x</sub> (kg/tonne of fuel)
Jet Gasoline and Aviation Gasoline	1200	19	4	1

The emissions factors above represent an average aircraft, according to EMEP/EEA (2019). A Tier 2 approach to estimating 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 4.10 is then applied separately for each aircraft, using aircraft specific fuel consumption, and emission factors to estimate air pollutant emissions from freight transport for each type of aircraft. The EMEP/EEA (2019) 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 air pollutant emission estimates.

In contrast to other modes of transport, the 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 EMEP/EEA (2019) air pollutant inventory guidance for national air pollutant emission inventories, estimation of aviation 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).

### Shipping

When estimating 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 4.11 can be applied to estimate the air pollutant emissions associated with freight transport by ships:

$$Emissions_{k,f} = tkm_f * FC_f * EF_{k,f} \quad (\text{Eq. 4.11})$$

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<sup>-1</sup>)

$FC_f$  = Fuel consumption for vessel using fuel  $f$  (kg fuel tonne-km<sup>-1</sup>)



Emissions<sub>k,f</sub> = emissions of the specific pollutant *k* for rail transport using fuel *f* (g)

The application of Equation 4.11 converts 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 4.12 contains default values for energy consumption (MJ tonne-km<sup>-1</sup>) derived from the IEA (2016). Dividing the energy consumption by the energy content of the fuel (diesel), fuel consumption ((kg fuel tonne-km<sup>-1</sup>) can be estimated.

**Table 4.12: Default energy consumption (MJ tonne-km<sup>-1</sup>) (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 <sup>-1</sup> )
<b>All types (IEA)</b>	0.08	40.19	0.0019
<b>Domestic (ADB)</b>	0.178	40.19	0.004
<b>International (ADB)</b>	0.1197	40.19	0.002

The EMEP/EEA Tier 1 emission factors are listed in Table 4.13 below.

**Table 4.13: Tier 1 emission factors for shipping [Source: EMEP/EEA, 2019].**

	CO (kg/tonne of fuel)	NMVOCs (kg/tonne of fuel)	NOx (kg/tonne of fuel)	PM <sub>10</sub> (kg/tonne of fuel)	BC (kg/tonne of fuel)	PM <sub>2.5</sub> (kg/tonne of fuel)	SO <sub>2</sub> (kg/tonne of fuel)
<b>Bunker fuel oil</b>	3.67	1.67	69.1	5.2	0.09	-	19.2
<b>Marine Diesel Oil/ Marine Gas oil</b>	3.84	1.75	72.2	1.07	0.04	-	1.82
<b>LNG</b>	13.8	2.00	4.92	1.24 E-03	2.49 E-05	1.06 E-03	0.00
<b>Gasoline</b>	573.9	181.5	9.4	9.5	0.05 <sup>1</sup>	9.5	20 <sup>2</sup>

The emissions factors above represent an average ship, according to EMEP/EEA (2019). A Tier 2 approach to estimating 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 taken by different types of ships with different types of engines need to be calculated. Equation 4.11 is then applied separately for each engine/fuel type combination, using engine- and fuel-specific fuel consumption, and emission factors to estimate air pollutant emissions from marine freight transport. The EMEP/EEA (2019) guide provides 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 air pollutant emissions.

### Emission controls

In shipping, 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 guidance (2019) emission controls can include the following categories:

- Improved engine design, fuel injection systems, electronic timing, etc. to obtain optimum efficiency (optimising CO<sub>2</sub> 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 NOx emission reduction of 10–30 % can be found. This technique has not yet been in regular service for ships

<sup>1</sup> (fraction of PM<sub>2.5</sub>)

<sup>2</sup> SOx instead of SO<sub>2</sub>

- Selective catalytic reduction (SCR) where a reducing agent is introduced to the exhaust gas across a catalyst. Hereby NO<sub>x</sub> is reduced to N<sub>2</sub> and H<sub>2</sub>O. However, this technology imposes severe constraints on the ship design and operation to be efficient. A reduction of 70–95 % in NO<sub>x</sub> 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<sub>x</sub> 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 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 4.14, 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 4.14: Emission reduction percentage of different emission control technologies. Source: EMEP/EEA (2019).**

Emission control technology	Fuel	CO (%)	NO <sub>x</sub> (%)	SO <sub>2</sub> (%)	NM VOC (%)	PM (%)
<b>Wet scrubber</b>	<b>Bunker fuel oil</b>	-3.61	5.84	98.8	52.2	31.6
	<b>MDO/MGO</b>	N/A	N/A	N/A	N/A	N/A
<b>SCR</b>	<b>Bunker fuel oil</b>	-63	89.6	23.5	68.6	34.8
	<b>MDO/MGO</b>	-55.8	70.2	6.57	78.3	6.1
<b>DOC</b>	<b>Bunker fuel oil</b>	42.9	-0.63	-1.3	50	50
	<b>MDO/MGO</b>	99.2	20.4	0	97.2	-113
<b>DPF</b>	<b>Bunker fuel oil</b>	N/A	N/A	N/A	N/A	N/A
	<b>MDO/MGO</b>	0	0	-1.5	0	91.7
<b>SCR+Scrubber</b>	<b>Bunker fuel oil</b>	-119	80.1	99.7	68.6	34.8
	<b>MDO/MGO</b>	N/A	N/A	N/A	N/A	N/A
<b>SCR+DPF</b>	<b>Bunker fuel oil</b>	N/A	N/A	N/A	N/A	N/A
	<b>MDO/MGO</b>	-55.8	92	4	78.3	96
<b>DPC + Scrubber</b>	<b>Bunker fuel oil</b>	42.9	5.66	99.1	50	50
	<b>MDO/MGO</b>	N/A	N/A	N/A	N/A	N/A

Therefore, to account for emission controls using the Tier 2 method a corrected emission factor needs to be applied as per Equation 4.12 below:

$$RevEF_{k,f,e} = \sum_c (EF_{k,f,e} (1 - C_c) \times f_c) \quad (\text{Eq. 4.12})$$

where:

RevEF<sub>k,f</sub> = revised fuel consumption-specific emission factor of pollutant k, fuel type f [kg/tonne] and engine type e

EF<sub>k,m,e</sub> = 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).

C<sub>c</sub> = correction factor for emission control technologies.

f<sub>c</sub> = distribution of emission control technology on the considered fleet (estimated as fleet with specific emission technology divided by the total number of vessels in the fleet)

### Non-road mobile machinery

The EMEP/EEA Guidelines are providing methods to estimate air pollutant emissions occurring from combustion and evaporative emissions for selected non-road mobile machinery sources. The types of equipment covered by the EME/EEAP 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 air pollutant emissions from non-road mobile machinery are outlined below.

**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 Section 3 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.

**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

**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 EMEP/EEA guidelines for the different NFR categories are Diesel, LPG, Gasoline (two-stroke), Gasoline (four-stroke) and Gasoline.

**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.

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

#### Tier 1 methodology

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 4.13:

$$Emissions_{k,v,f,s} = FC_{c,f,e} * EF_{k,v,f,s} \quad (Eq. 4.13)$$

where:

$FC_{v,f,s}$  = 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  $e$  ( $\mu\text{g}/\text{kg}$  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 Tier 1 emission factors for non-road mobile machinery are included in the SI.

## Tier 2 methodology

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 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.

$$E_k = \sum_r \sum_y FC_{j,c,e,y} * EF_{k,e,y} \quad (\text{Eq. 4.14})$$

where:

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

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

$E_k$  = emissions of the specific pollutant  $k$  (kg)

The Tier 2 emission factors for non-road mobile machinery are included in the SI.

## Passenger transport

The methods for quantifying air pollutant emissions from passenger (i.e., customer, employee) travel are outlined below separately for different transport modes (road, and rail). For both transport modes, the activity variable is the total number of passenger-km 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 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 detailed method, which requires information on the vehicle type, fuel used by each

type of vehicle, but also vehicle emission standard, and the simplified 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 air pollutant emissions, based on the data that is available to them.

### Option 1: Detailed method for Road transport

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 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 with emission factors to estimate air pollutant emissions.

#### 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 (a top-down approach) or ii) developing estimates of passenger-km for different vehicle types independently (a bottom-up approach).

The categorisation of vehicles differs in different jurisdictions. Due to the default emission factors included in this guide from the EMEP/EEA (2019) air pollutant emission inventory guidebook, we adopt the disaggregation of vehicles according to their categorisation method. 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 vehicles type 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.

#### 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 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 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 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 4.1 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.

**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 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 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.

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

Steps 1-3 derive the activity data (passenger-km) in a sufficient level of detail to allow 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 (2019) for all relevant 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 4.15 shows how air pollutant emissions are estimated for freight transport for a particular vehicle type, fuel, and emission standard:

$$Emissions_{k,v,f,s} = (pkm_{v,f,s} / Occupancy) * EF_{k,v,f,s} \quad (Eq. 4.15)$$

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<sup>-1</sup>)

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 4.15 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<sup>-1</sup>. The occupancy rate is the conversion 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 vehicle-km estimates, consistent with the default emission factors



available in international 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 4.15 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 4.15: 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 4.15 above, along with occupancy data and passenger-km to estimate the air pollutant emissions from a company's customer travel.

### Option 2: Simplified method for Road transport

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:

**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).

**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, and for the L-category it's petrol.

**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 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 EMEP/EEA (2019) for all relevant

air pollutants, have units of gram pollutant emitted per vehicle-km travelled.

Equation 4.16 shows how air pollutant emissions are estimated for freight transport for a particular vehicle type and fuel:

$$Em_{k,v,f} = FC_{v,f} * EF_{k,v,f} \quad (\text{Eq. 4.16})$$

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<sup>-1</sup>)

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

### Rail

When estimating air pollutant emissions from 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 bottom-up approach).

The total number of passenger-km that are taken using electric rail should also be estimated, and air pollutant



emissions from the electricity generation accounted for. The user should therefore use the methods outlined in Section 4.1 to estimate the 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 air pollutants as the freight is transported. Equation 4.17 below can be used to estimate the air pollutant emissions associated with freight transport by rail:

$$Emissions_{k,f} = tkm_f * FC_f * EF_{k,f} \quad (\text{Eq. 4.17})$$

where:

$tkm_f$  = 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<sup>-1</sup>)

$FC_f$  = Fuel consumption for rail using fuel  $f$  (kg fuel tonne-km<sup>-1</sup>)

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

The application of Equation 4.17 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 4.16 which contains default values for energy consumption (MJ tonne-km<sup>-1</sup>) 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<sup>-1</sup>) 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 4.16: Example of default energy consumption (MJ passenger-km<sup>-1</sup>) (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 (kg fuel passenger-km <sup>-1</sup> )
<b>Diesel</b>	1.15	42.91	0.02

EMEP/EEA Tier 1 emission factors for rail transport using diesel are listed in Table 4.17.

**Table 4.17: Tier 1 emission factors for railways [Source: EMEP/EEA, 2019].**

	CO (kg/tonne of fuel)	NMVOCs (kg/tonne of fuel)	NOx (kg/tonne of fuel)	PM <sub>10</sub> (kg/tonne of fuel)	PM <sub>2.5</sub> (kg/tonne of fuel)	NH <sub>3</sub> (kg/tonne of fuel)
<b>Gas oil/Diesel</b>	10.7	4.65	52.4	1.44	1.36	0.007

To proceed to a Tier 2 approach, the number of passenger-km taken by different types of locomotives need to be calculated. Equation 4.14 is then applied separately for each locomotive type, using locomotive specific fuel consumption, and emission factors to estimate air pollutant emissions from freight transport for each type of locomotive. The EMEP/EEA (2019) guide provides 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.

## 4.4 Industrial Processes

Emissions from industrial processes cover 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 particular industrial processes are accounting for using the methods outlined in Section 4.2 for the category ‘Stationary Fuel Combustion’. Industrial processes which emit non-fuel combustion-related 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 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<sub>10</sub> and PM<sub>2.5</sub>), 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. A comprehensive description of all potential air pollutant emissions sources within the Industrial Processes category is included within the EMEP/EEA (2019) air pollutant emission inventory guidebook.

It should be noted that, as stated in Chapter 1, this Guide is focusing on the source of 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 air pollutants from each process. The following sections describe, in general terms, the Tier 1 and Tier 2 methods that can be applied across Industrial Processes sub-sectors to quantify 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 differs, then this is specifically highlighted, and the alternative methodology outlined.

### Tier 1 Methodology for Industrial Processes

The Tier 1 method for quantifying air pollutant emissions from industrial processes along a company's value chain is based on the EMEP/EEA (2019) methods for developing national air pollutant emission inventories from Industrial Processes. The EMEP/EEA (2019) 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 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 4.18:

$$Emissions_{k,p} = M_p * EF_{k,p} \quad (\text{Eq. 4.18})$$

where:

$M_p$  = 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<sup>-1</sup>)

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

In applying the Tier 1 approach for quantifying air pollutant emissions from Industrial Processes, it is necessary to obtain company-specific data on the amount of materials that are used within their value chain, e.g. within the manufacture of particular products. Default emission factors for all 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 4.18 to estimate air pollutant emissions from industrial processes along a company's value chain. The default emission factors, from EMEP/EEA (2019) are summarised in Table 4.18 below.

**Table 4.18: Summary of default emission factors for Tier 1 method for quantifying air pollutant emissions from industrial processes [Source: EMEP/EEA, 2019].**

Sector	Sub-sector	Units <sup>3</sup>	CO	NO <sub>x</sub>	SO <sub>2</sub>	PM <sub>10</sub>	PM <sub>2.5</sub>	BC % of PM <sub>2.5</sub>	OC	NMVOCS	NH <sub>3</sub>
<b>Mineral</b>	Cement	g/Mg <sup>4</sup> clinker				234	130	3%			
	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				
<b>Chemical Industry</b>	Ammonia production	kg/t of NH <sub>3</sub>	0.1	1							
	Nitric acid production	g/Mg produced, 100% acid		10000							
	Adipic acid production	kg/Mg	0.4	8							
<b>Metal</b>	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						
<b>Other Industry Production</b>											
	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	

<sup>3</sup> Please note the units change throughout this table.<sup>4</sup> Mg = Megagram = 1000 kg = 1 metric tonne

Sector	Sub-sector	Units <sup>3</sup>	CO	NOx	SO <sub>2</sub>	PM <sub>10</sub>	PM <sub>2.5</sub>	BC % of PM <sub>2.5</sub>	OC	NMVOCs	NH <sub>3</sub>
Other Solvent and product use											
	Domestic solvent use including fungicides	kg/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 2 Methodology for Industrial Processes

The 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 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 4.19 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 4.18) 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 (2019).

$$Emissions_{k,p,t} = M_{p,t} * EF_{k,p,t} \quad (\text{Eq. 4.19})$$

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<sup>-1</sup>)

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

### Sub-sector specific methods

This section is covering the categories of Construction and Demolition, and Solvent use that are included under Industrial Processes according to the EMEP/EEA guidelines, but their methods are different compared to the methods described in Section 4.4.

### 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 Guidelines describe nice subdivisions of emission sources under this emission source:

- Fat, edible and non-edible oil extraction
- Preservation of wood
- Creosote preservatives
- Water-borne 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 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

4.20) is similar to one described under Industrial Processes (Equation 4.18). However, in this case, there is one key difference. Equation 4.20 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 (2019) methods for developing national air pollutant emission inventories from Industrial Processes. The EMEP/EEA (2019) Tier 1 method multiplies the annual **use** of solvents (kg) by a pollutant emission factor. The Tier 1 method is shown in Equation 4.20:

$$Emissions_k = S * EF_k \quad (Eq. 4.20)$$

where:

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

EF<sub>k</sub> = emission factor for pollutant k (g/Mg product used)

Emissions<sub>k</sub> = emissions of the specific pollutant k (g)

The Tier 1 emission factors for other solvent and product use are included in Table 4.19 below:

**Table 4.19 Tier 1 emission factors for other solvent and product use (EMEP/EEA, 2019)**

Other solvent and product use	NMVOCs (kg/Mg of product used)
	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 product 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 4.21 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 4.20) 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 (2019).

$$\text{Emissions}_{k,i,t} = S_{i,t} * EF_{k,i,t} \quad (\text{Eq. 4.21})$$

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)

$\text{Emissions}_{k,i,t}$  = 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.

## Construction and Demolition

Construction and demolition of infrastructure and buildings can contribute significantly to the emissions of particulate matter,  $PM_{10}$  and  $PM_{2.5}$ . To estimate particulate matter emissions from construction and demolition the EMEP/EEA 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 (USA 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 4.21), with the total area affected by the construction and/or demolition of the specific structure and the average duration, according to Equation 4.22:

$$EM_{PM_{10}} = EFP_{PM_{10}} * A_{affected} * d * (1-CE) * (24/PE) * (s/9\%) \quad (\text{Eq. 4.22})$$

Where:

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

$EFP_{PM_{10}}$  = the emission factor for this pollutant emission (kg  $PM_{10}/[m^2 \cdot \text{year}]$ )

$A_{affected}$  = 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 Guidelines provide default data for some of these parameters as shown in Table 4.20 below:



**Table 4.20 Default data for key parameters needed for the Tier 1 approach for Construction and Demolition [Source: EMEP/EEA, 2019].**

	Duration (months)	Fractional overall control efficiency	Total affected area
<b>Construction of houses (all types)</b>	6	0	
Detached (single family)			300 (m <sup>2</sup> /house)
Detached (two family)			188(m <sup>2</sup> /house)
Terraced			120(m <sup>2</sup> /house)
<b>Construction of apartment buildings</b>	9	0	
Apartment, building basis			585(m <sup>2</sup> /building)
Apartment, unit basis			65(m <sup>2</sup> /building)
<b>Non-residential construction</b>	10	0.5	
<b>Construction of roads</b>	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 4.21: Tier 1 emission factors (kg/(m<sub>2</sub> \* year)) for the different types of construction Source: EMEP/EEA, 2019].**

	PM <sub>10</sub> kg/(m <sup>2</sup> * year)	PM <sub>2.5</sub> kg/(m <sup>2</sup> * year)
<b>Construction of houses</b>	0.086	0.0086
<b>Construction of apartment buildings</b>	0.30	0.030
<b>Non-residential construction</b>	1.0	0.1
<b>Construction of roads</b>	2.3	0.23

## 4.5 Agriculture

Agriculture is a source of air pollutants from both main types of agricultural activity, livestock and crop production. Agriculture is the main source of ammonia (NH<sub>3</sub>) emissions globally but can also contribute to emissions of nitrogen oxides (NO<sub>x</sub>), as well as particulate matter, volatile organic compounds and other air pollutant emissions. Within agriculture, the following specific sources of air pollutant emissions are covered in this Section:

- Livestock
  - Manure Management
  - Livestock Housing
- Crop production
  - Manure application to fields
  - Synthetic fertiliser application to fields
  - Open burning of agricultural residues

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  $\text{NH}_3$  and  $\text{NO}_x$ , 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 solid or slurry form have been measured from livestock production. In addition to manure management, silage stores are a major source 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  $\text{NH}_3$  and  $\text{NO}$  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  $\text{NO}_x$ ,  $\text{CO}$ , NMVOCs, PM and BC.

The 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 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 air pollutant emission methods for the agriculture sector to estimate a company's emissions from agricultural sources, based on those methods outlined in the EMEP/EEA national air pollutant emission inventory guideline.

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 4.23:

$$A_t = MP_{\text{type of livestock}} * CW_{\text{type of livestock}} \quad (\text{Eq. 4.23})$$

Where:

$A^t$  = The number of a specific type (t) of livestock (No of livestock)

MP = Livestock-specific meat, dairy or eggs used in a company's value chain (tonnes)

CW = Carcass weight of the specific type of livestock (tonnes/livestock)

The values for the carcass weight for the different types of livestock are available through the Food and Agriculture Organization (FAO) and are included in Table 4.21.

**Table 4.22: Carcass weight (kg/animal) (Source: FAOStat, <https://www.fao.org/faostat/en/#data/FBS>)**

	Cattle	Chicken	Goat	Pig	Sheep
<b>Region</b>					
Africa	152.8	1.2	10.7	43	14.9
Americas	307	2.1	13.5	93.3	18.5
Asia	162.6	1.4	13	60.6	16.5
Europe	267	1.7	11	92.4	16.4
Oceania	233	1.8	14.5	66.7	22.4

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 air pollutant emissions are calculated based on the tonnes of crop produced. Therefore, to derive the tonnes of a particular crop required for a particular product within a company's value chain, Equation 4.24 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.

$$CP_t = Product_x * Frac_t \quad (\text{Eq. 4.24})$$

Where:

CP = Crop production for crop t (tonnes)

Product<sub>x</sub> = Production of product x within a company's value chain (tonnes)

Frac<sub>t</sub> = 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 4.25:

$$Land\ area_{\text{type of crop}} = \text{Tonnes of product}_{\text{type of crop}} / \text{Yield}_{\text{type of crop}} \quad (\text{Eq. 4.25})$$

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 air pollutant emissions associated with the rearing of those livestock and production of those crops.

## Livestock

### Tier 1 methodology for Manure Management

The Tier 1 method for quantifying air pollutant emissions from manure management is based on the EMEP/EEA (2019) methods for developing national air pollutant emission inventories from Manure Management (3.B). The EMEP/EEA (2019) 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.

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

The livestock specific meat/dairy/eggs (tonnes) used in the value chain is multiplied by the carcass weight of a specific type of livestock (tonnes/livestock) to estimate the number of a specific type of livestock (e.g., dairy cattle) ( $A_t$ ) as shown in Equation 4.23.

**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.

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

The number of the different type of livestock with different handling of manure ( $A_{t,m}$ ) is multiplied by the pollutant specific emission factors that account for the different types of manure according to the equation (4.26)

$$Emissions_{k,At,m} = A_{t,m} * EF_{t,p,m} \quad (\text{Eq. 4.26})$$

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<sup>-1</sup>)

$Emissions_{k,t}$  = emissions of the specific pollutant  $k$  for the animal type  $t$   $m$  (g unit production<sup>-1</sup>)

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

**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 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.

**Crop production****Tier 1 methodology for manure, and synthetic fertiliser application to fields**

The Tier 1 method for quantifying air pollutant emissions from manure and synthetic fertiliser application to fields is based on the EMEP/EEA (2019) methods for developing national air pollutant emission inventories from Crop production (3.D). The EMEP/EEA (2019) 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 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.

**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 4.24.

**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 4.24:

**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 4.27:

$$Emissions_k = AR_{area} * EF_k \quad (\text{Eq. 4.27})$$

where:

$EF_k$  = emission factor for pollutant  $k$  (g unit production<sup>-1</sup>)

$Emissions_{k,t}$  = 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 4.23 below.

**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 4.28:

$$\text{Fertiliser applied}_{\text{type of crop}} = \text{Land area}_{\text{type of crop}} * \text{Application rate}_{\text{type of crop}} \quad (\text{Eq. 4.28})$$

**Step 5:** Estimating NH<sub>3</sub> 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 air pollutant emissions according to equation 4.29.

$$\text{Emissions}_k = \text{AR}(\text{N}_{\text{applied}})_{\text{type of crop}} * \text{EF}_k \quad (\text{Eq. 4.29})$$

where:

EF<sub>k</sub> = emission factor for pollutant k (g unit production<sup>-1</sup>)

Emissions<sub>k,t</sub> = emissions of the specific pollutant k (g)

AR(N<sub>applied</sub>) = 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 4.22 below.

**Table 4.23 emission factors for the Tier 1 methodology for manure and synthetic fertiliser [Source: EMEP/EEA, 2019]**

Pollutant	Value	Unit
NH <sub>3</sub> from fertiliser	0.05	kg NH <sub>3</sub> kg <sup>-1</sup> fertiliser N applied
NH <sub>3</sub> from sewage sludge	0.0068 or 0.13	kg NH <sub>3</sub> capita <sup>-1</sup> kg NH <sub>3</sub> (kg N applied) <sup>-1</sup>
NH <sub>3</sub> emission from other organic wastes	0.08	kg NH <sub>3</sub> (kg waste N applied) <sup>-1</sup>
NO from N applied in fertiliser, manure and excreta	0.04	kg NO <sub>2</sub> kg <sup>-1</sup> fertiliser and manure N applied
NO from sewage sludge	0.002	kg NO <sub>2</sub> capita <sup>-1</sup>
NO emission from other organic wastes	0.04	kg NO <sub>2</sub> kg <sup>-1</sup> waste N applied
NM VOC from standing crops	0.86	kg ha <sup>-1</sup>

**Tier 1 methodology for crop residue burning**

The Tier 1 method for quantifying air pollutant emissions from Crop residue burning is based on the EMEP/EEA (2019) methods for developing national air pollutant emission inventories from Crop residue burning (3.F). The EMEP/EEA (2019) 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 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 air pollutant emissions from crop residue burning using the Tier 1 method:

**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 4.24.

**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 4.22.

**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 4.24) 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 4.30.

$$\text{Mass of residue burned} = \text{Crop production}_i * \text{Residue to crop ratio}_i * \text{Dry matter fraction} * \text{Dry matter fraction} * \text{Fraction oxidised} \quad (\text{Eq. 4.30})$$



Table 4.24 includes the residue to crop ratios from the EMEP/EEA Guidelines (2019).

**Table 4.24: Residue to crop ratios [Source: EMEP/EEA, 2019] for the different types of crops.**

<b>Wheat</b>	1.3
<b>Barley</b>	1.2
<b>Maze</b>	1
<b>Oats</b>	1.3
<b>Rye</b>	1.6
<b>Rice</b>	1.4
<b>Peas</b>	1.5
<b>Beans</b>	2.1
<b>Soya</b>	2.1

#### Step 4: Estimating air pollutant emissions

The amount of residue burnt (kg of dry matter) is multiplied by a pollutant specific emission factor to estimate air pollutant emissions according to Equation 4.31.

$$Emissions_{k,t} = MR_{burned} * EF_{k,t} \quad (\text{Eq. 4.31})$$

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.

## 4.6 Waste

As shown in Section 3, Figure 3.3 waste can be a source of air pollution 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. Waste is a significant source of air pollutants and short-lived climate pollutants.

Emissions of 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 the 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 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 air pollutant emission inventory guidance, the methodologies used for quantifying 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 air pollutant emission inventory and the Guide for businesses. 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 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 (2019)
2. The 'Tier 2' methodology, described in detail in EMEP/EEA (2019) 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 EMEP/EEA guidelines and the GHG protocol 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.

**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 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 4.31

$$\text{Waste} = \text{Material used} * \text{Fraction\_Waste} \quad (\text{Eq. 4.31})$$

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 have 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 are 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.

**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) contain some fossil carbon. Overall, the different types of waste contain different amount of fossil 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.

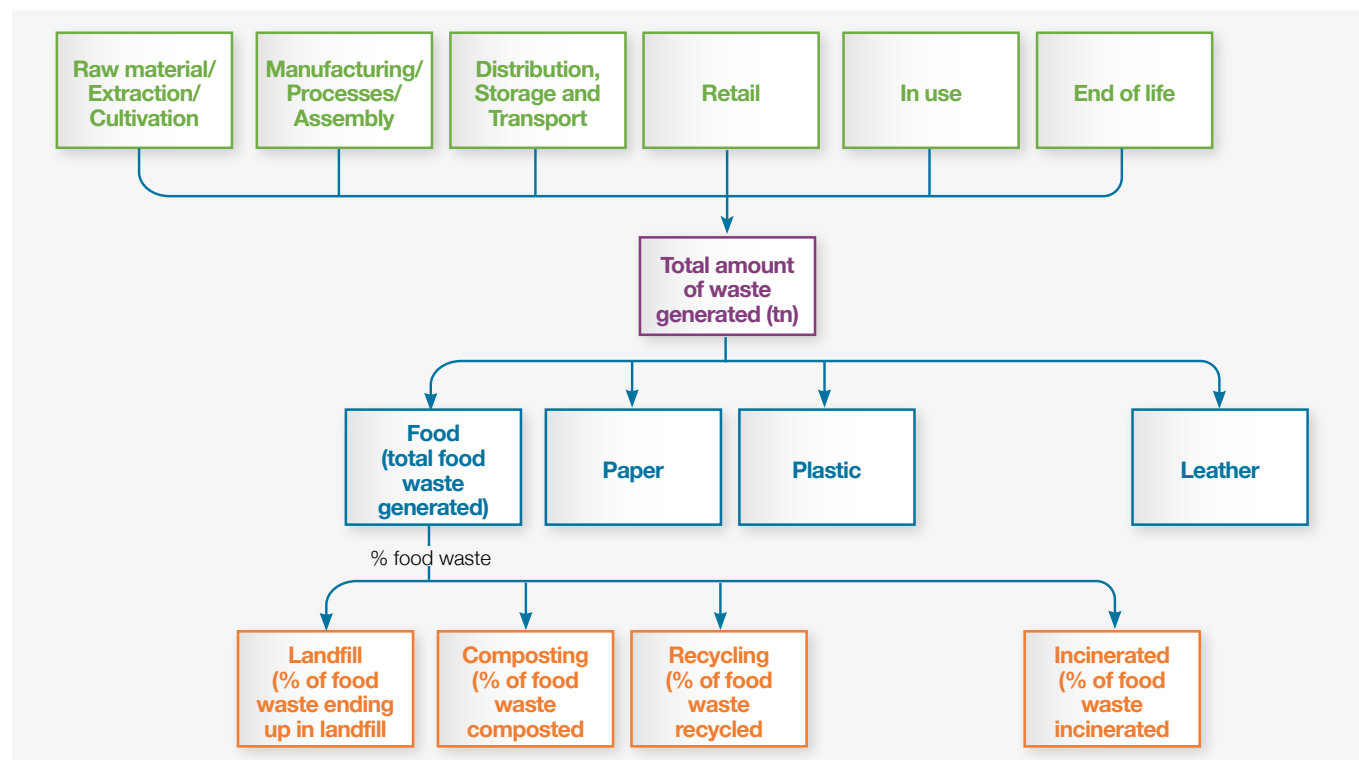
- food waste
- garden waste
- paper and cardboard
- wood
- textiles
- rubber and leather
- plastics
- metal
- glass
- other (e.g., ash, dirt, dust, soil, electronic waste).
- Industrial (hazardous waste and sewage sludge)
- Clinical waste

**Step 3:** Disaggregating the amount of different types of waste by waste disposal and treatment.

The total number of the different types of waste generated (food, paper, etc) needs to be further disaggregated by how it is being disposed and managed according to the categories below.

- Openly burned
- Landfill (Managed; anaerobic, semi-anaerobic, Unmanaged; deep, shallow, Uncategorised)
- Anaerobic digestion,
- Incineration
- Composting
- Recycling
- Other

An example flowchart of the different levels of disaggregation is shown in Figure (4.2).



**Figure 4.2: Flowchart demonstrating the different levels of disaggregation required for the Tier 1 methodology for waste.**

### Tier 1 Methodology for Waste

The Tier 1 method for quantifying air pollutant emissions from waste is based on the EMEP/EEA (2019) methods for developing national air pollutant emission inventories from waste. The EMEP/EEA (2019) 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 4.32:

$$\text{Emissions}_{k,t,c} = WD_c * EF_{k,t} \quad (\text{Eq. 4.32})$$

where:

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

$EF_{k,t}$  = emission factor for pollutant  $k$  for type of treatment  $t$  (g unit production<sup>-1</sup>)

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

The default emission factors, from EMEP/EEA (2019) are summarised in Table 4.25 below.

**Table 4.25: Summary of default emission factors for Tier 1 method for quantifying air pollutant emissions from waste [Source: EMEP/EEA, 2019]**

Waste treatment	Units	PM <sub>10</sub>	PM <sub>2.5</sub>	BC % of PM <sub>2.5</sub>	NMVOCs	CO	NH <sub>3</sub>	NO <sub>x</sub>	SO <sub>2</sub>
<b>Biological treatment of waste - Solid waste disposal on land</b>	kg/Mg of waste	0.033	0.219	-	1.56	-	-	-	-
<b>Biological treatment of waste- Composting</b>	kg/Mg of waste	-	-	-	-	0.56	0.66	-	-
<b>Municipal waste incineration</b>	g/Mg of waste	3	3	3.5	5.9	41	3	1071	87
<b>Open burning of waste</b>	kg/Mg of waste	4.51	4.19	42	1.23	55.83	-	3.18	0.11
<b>Industrial waste incineration</b>	kg/Mg of waste	0.007	0.004	3.5	7.4	0.07	-	0.87	0.047

## 5. 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 Section 4. Overall, the user will need to follow three steps in order to estimate 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
<b>Probability density function (PDF)</b>	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.
<b>Confidence Interval</b>	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 percent confidence interval is used in inventories. From a traditional statistical perspective, the 95 percent confidence interval has a 95 percent 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.
<b>Uncertainty</b>	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.

### 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.

#### Activity Data

The methods described in Chapter 4 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.

#### 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 were estimated based on a large number of measurements made at a large number of 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.

#### 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.

### 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 5.1) can then be derived for the uncertainty of the product, expressed in percentage terms:

$$U_{total} = \sqrt{U_1^2 + U_2^2 + \dots + U_n^2} \quad (\text{Eq. 5.1})$$

Where:

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

$U_i$  = 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 5.2) can be derived for the uncertainty of the sums:

$$U_{total} = \frac{\sqrt{(U_1 * X_1)^2 + (U_2 * X_2)^2 + \dots + (U_n * X_n)^2}}{X_1 + X_2 + \dots + X_n} \quad (\text{Eq. 5.2})$$

Where:

$U_{total}$  = 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;

$x_i$  and  $U_i$  = 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.

### 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<sub>3</sub>)). 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 5.1 (b)) distribution. These considerations and the different types of probability distribution functions are described under [Chapter 5](#), 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.

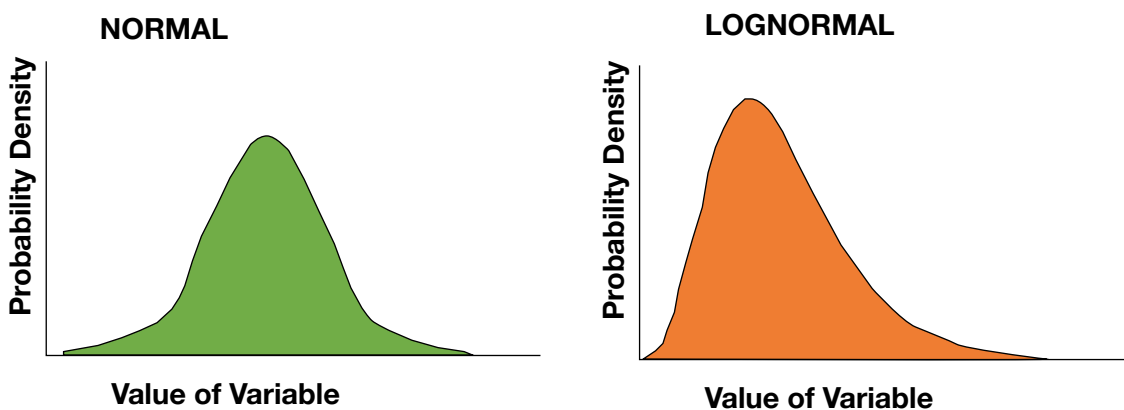


Figure 5.1: Normal (a) and log-normal (b) distributions

## 6. INTERPRETING AND USING THE EMISSION INVENTORY

Essentially, what an emissions inventory is, is a database that lists, by key emission source, the amount of air pollutants discharged into the atmosphere during one (or more) years. Governments use national emission inventories to help determine significant sources of air pollutants and to target regulatory actions. Developing an emissions inventory is an essential part of air quality management as it is a fundamental step in understanding the key sources of emission of the different pollutants.

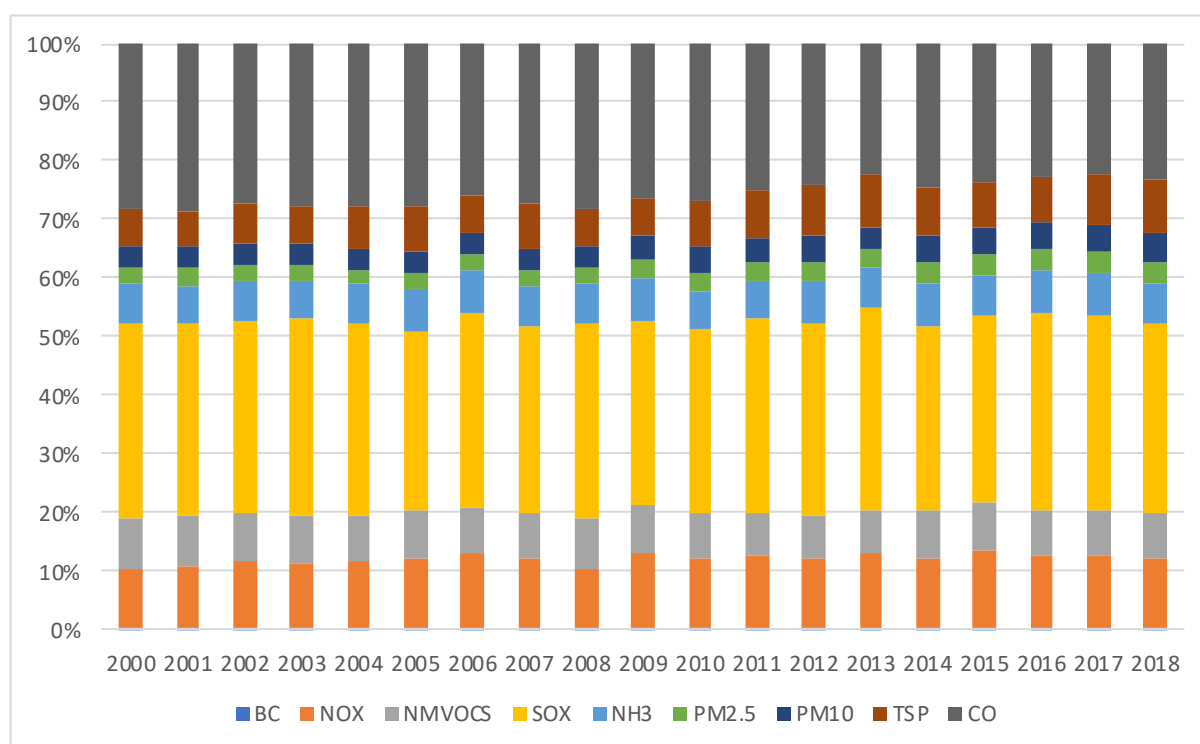
On a national level, an emissions inventory includes estimates of the emissions from various pollution sources in a geographical area and usually includes all pollutants associated with the air quality problems in the area. For a company's value chain, this will be slightly different in the sense that a value chain and its different stages (as described in Section 3), will possibly be spread across different countries and/or regions. Compiling an inventory is the first key step that is required to understand the contribution of air pollutant emissions from the different stages of a value chain. Once the user of this Guide has implemented the methods described in Sector 4, they will have produced a company specific air pollution inventory for a specified period of time.

### 6.1. How to use emission inventory results: Interpreting the results

Once the inventory results have been produced, the inventory compiler will be able to evaluate both the magnitude of air pollutant emissions in a specific year (or several years) from the key emission sources, but also, the relative contributions of the different air pollutants in a specific year (or over several years) from the different key emission sources.

Figures 6.1 – 6.2 aim to provide an example of that final product and give a brief overview of the sort of information that can be derived. These figures are taken from the Assessment of Short-Lived Climate Pollutant mitigation in Serbia and will be different from the results that will be produced from this Guide as they have been compiled for the national level and the key emission sources and sectors will differ from those presented in Section 4, but the principle remains the same.

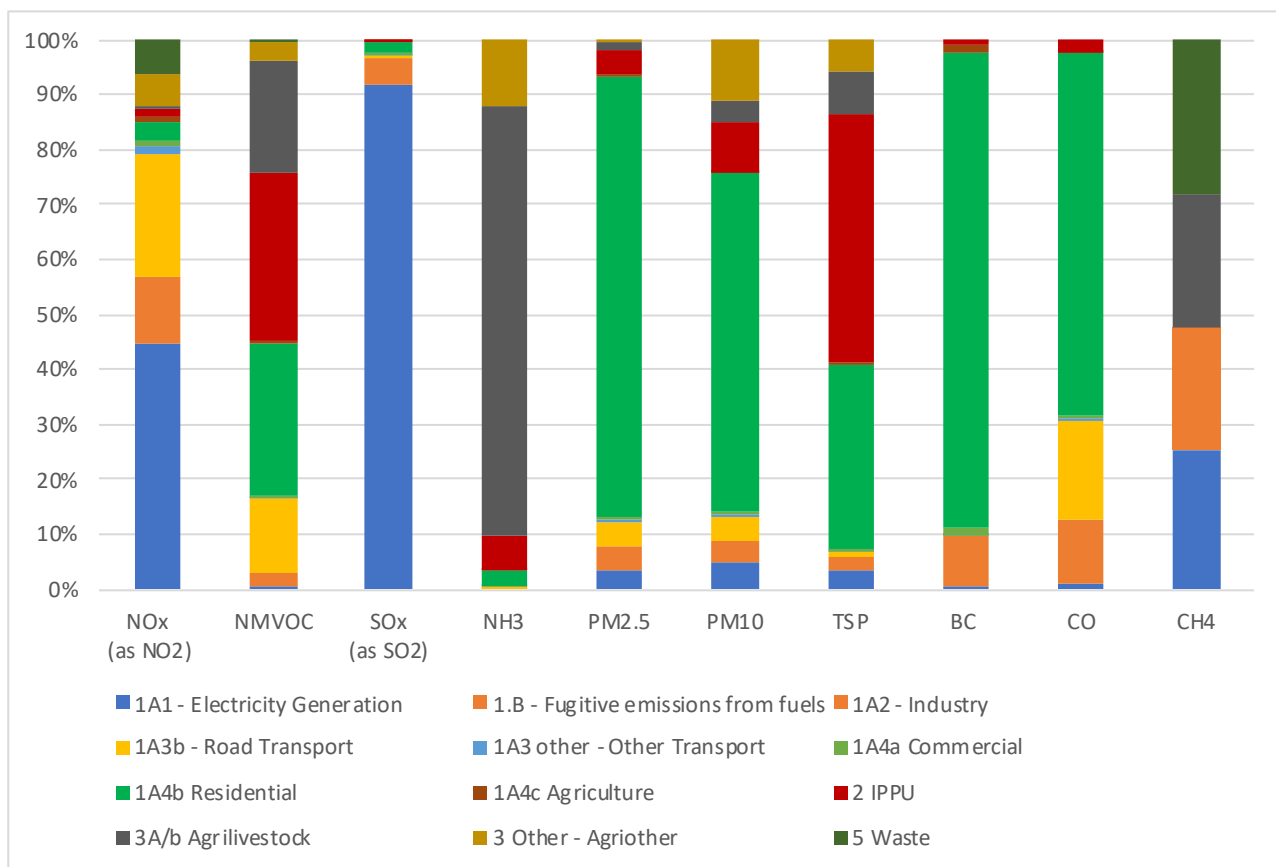
Figure 6.1 shows the relative contribution of the different air pollutants between 2000 and 2018.



**Figure 6.1: Relative contribution of the different air pollutants between 2000 and 2018 (Source: Assessment of Short-Lived Climate Pollutant mitigation in Serbia).**

Figure 6.2 shows the percentage contribution of the different GHG, SLCPs, and air pollutants from key sectors for 2014. This analysis allows the inventory compiler to evaluate which emission sources are responsible for

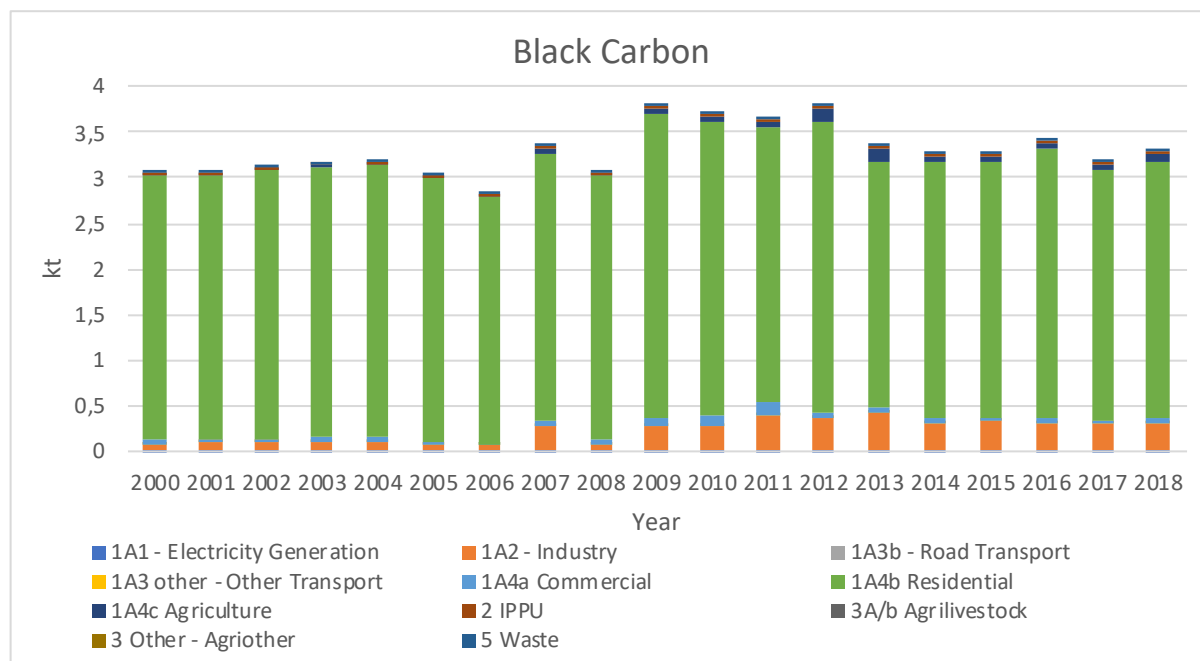
emissions of specific pollutants. For example, in 2014, the residential sector appears to be the main source of PM<sub>2.5</sub>, PM<sub>10</sub>, Black Carbon and CO. Electricity generation is the main source of NO<sub>x</sub> and SO<sub>x</sub>.



**Figure 6.2: Contribution of different sources to SLCP, air pollutant and GHG emissions in Serbia in 2014 (Source: Assessment of Short-Lived Climate Pollutant mitigation in Serbia).**

Apart from the magnitude of emissions of a specific pollutant, from a specific key source in one or more years, the inventory allows the user to evaluate emission trends over time. For example, in 2018 there were 3.2 kt of black carbon emitted to the atmosphere in Serbia. This value does not vary greatly from the 2000 value estimated to be ~3 kt. The residential sector is the largest contributor

of black carbon emissions, followed by industry. The agricultural sector also appears to be contributing to the BC emissions (Figure 6.3). This analysis allows the user to evaluate trends in the magnitude of emissions, but also trends in the contribution to the emissions from the different key sources.



**Figure 6.3: Black Carbon emissions in Serbia from the different key sectors between the years 2000 and 2018 (Source: Assessment of Short-Lived Climate Pollutant mitigation in Serbia, 2020).**

## 6.2. Mitigation actions

Once the inventory has been compiled the user will have an understanding of the magnitude of emissions of the different 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 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 or changes in consumption (e.g., reduced waste generation).

The methodologies under Sector 4 having 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 air pollutant emissions 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.

## 6.3. Approaches to implementation

Compared to an air pollution inventory that has been compiled on the national level, as already mentioned, there are some added complexities for an inventory that has been compiled for the value chain of a company. This is because the stages of a value chain, the company's activities and operations can be distributed across one, or more countries, and different regions of the world. And while this added level of complexity needs to be taken into consideration by the inventory compiler and decision makers, the policies that need to be developed and implemented are common at the national, sub-national region or urban scale. This means that can be widely applied regardless of the location of the source sector where emissions reductions need to be achieved.

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.

## 6.4. Use of emission inventory for decision making

There are several ways the inventory can contribute to decision making. The inventory provides the user with the magnitude of air pollutant emissions from the key sources and therefore identifies the areas of concern which is the key starting point to understanding air pollutant emissions within a value chain. A company specific inventory will allow the user to identify the sectors where action is needed but it will also allow the user to identify the type of action that is needed. It also provides a basis for monitoring those actions that are effective, setting goals and monitoring whether those goals can be achieved within a specified timeframe. While it is the key point for more detailed assessment and this assessment will also include the different types of mitigation measures that are being implemented under the key sources.

Finally, the methods provided in this Guide have been developed to be aligned, as much as possible with GHG reporting that might be used for the different companies. For the companies with existing GHG emission reduction strategies, including air pollution and integrating GHG and air pollutant emission reduction strategies can increase their ambition, and can contribute towards their sustainability agendas. These strategies, once integrated, can maximize the impact of the mitigation measures but also increase the benefits in other areas (e.g., human health). But in some cases, this higher level of ambition through the integration and alignment of the GHG and air pollutant emission strategies will already be taking place without being accounted for. For example, a company that is already implementing GHG emission reduction strategies through their value chain, and because several GHG and air pollutant emissions have common sources, is likely to also improve their air pollutant emissions.

An emission inventory by itself is not a full evaluation of all the impacts of air pollution (e.g., on human health, agriculture). However, having the inventory is the first step and the type of further development of an emission inventory developed within this Guide will include.

1. Spatial allocation of emissions
2. Creation of future air pollutant emission projections accounting for expected growth and expansion of business and value chain operations
3. Identification of mitigation options for the key emission sources
  - Technical options (post-combustion emission controls, fuel switching, electric vehicles etc.)
  - Efficiency improvements
  - Behaviour changes
4. Assessment of mitigation options to evaluate the impact of the different mitigation measures

## 7. LIMITATIONS AND FURTHER WORK

The aim of this Guide was to provide a comprehensive framework for the private sector companies to be able to quantify air pollutant emissions along their value chains. To achieve this, this Guide has been using methods and approaches that are also used by the IPCC Guidelines (2006; 2019), for greenhouse gas reporting, and the EMEP/EEA (2019) guidance 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 (2019) guidance 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, and those are of relevance to this work, this means categories that would be considered under a company's emissions inventory rather than an inventory produced for a country.

However, there are a few cases where the EMEP/EEA guidance currently do 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 (EMEP/EEA, 2019).

However, the purpose this work has always been to include more categories as part of this Guide but also to update and enhance the currently included emission factors. As this work develops, we are hoping not only to expand the categories and include more emission factors, but to also include more pollutants and expand the methods that have already been presented in Chapter 4.

Finally, it should be highlighted that this Guide is not considering any of the natural sources of emissions that are described under the EMEP/EEA (2019) guidance.



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