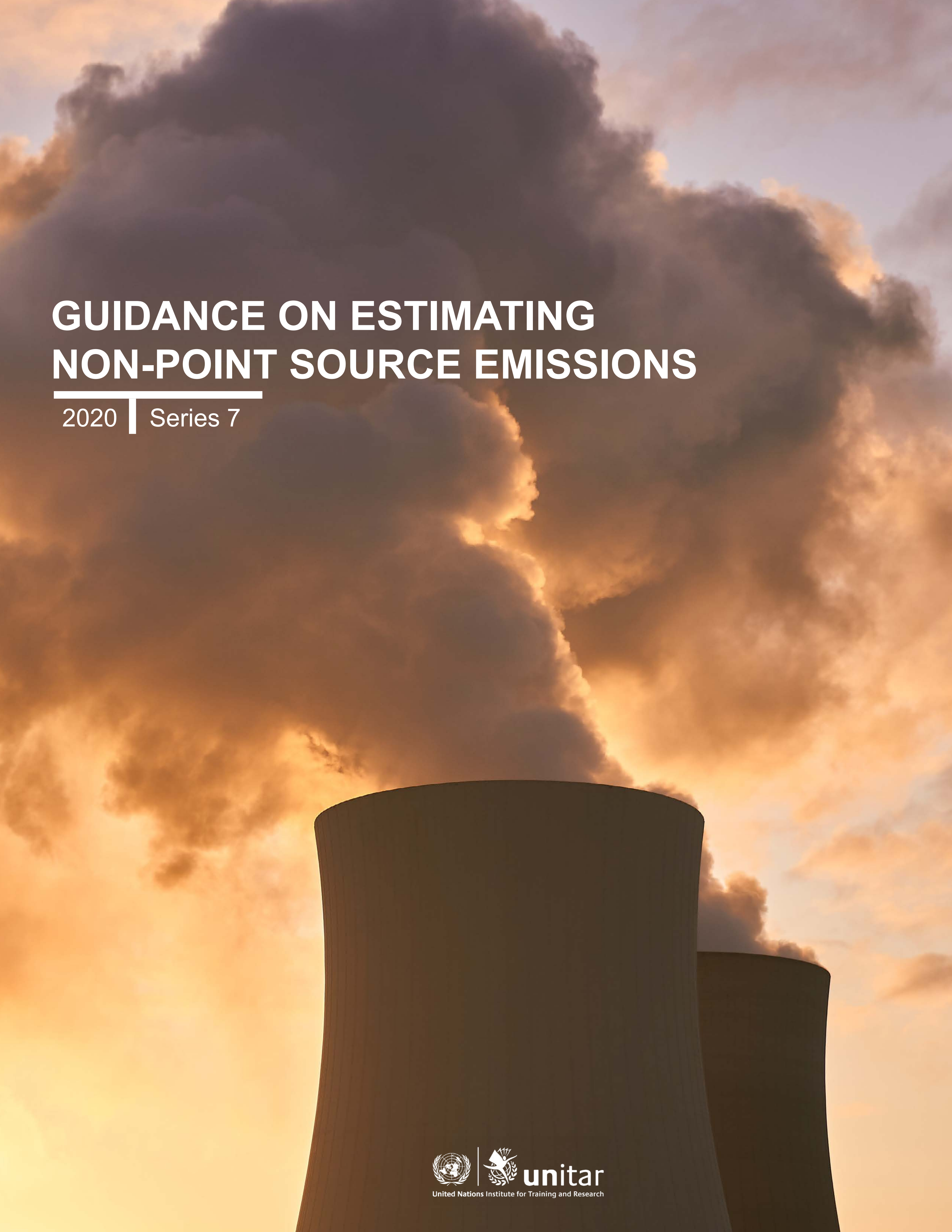

GUIDANCE ON ESTIMATING NON-POINT SOURCE EMISSIONS

2020 | Series 7

United Nations Institute for Training and Research

Welcome to UNITAR's Guidance Series for Implementing a National Pollutant Release and Transfer Register (PRTR) Design Project

Based on the lessons learned through ongoing activities supporting PRTR development world-wide, UNITAR has developed the following documents in a guidance series intended to facilitate the design and implementation of Pollutant Release and Transfer Registers (PRTRs):

- Implementing a National PRTR Design Project: A Guidance Document
- Series 1: Preparing a National PRTR Infrastructure Assessment
- Series 2: Designing the Key Features of a National PRTR System
- Series 3: Implementing a PRTR Pilot Reporting
- Series 4: Structuring a National PRTR Proposal
- Series 5: Addressing Industry Concerns Related to PRTRs
- Series 6: Guidance for Facilities on PRTR Data Estimation and Reporting
- **Series 7: Guidance on Estimating Non-Point Source Emissions**

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For additional information, please contact:
Chemicals and Waste Management Programme
United Nations Institute for Training and Research (UNITAR)
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List of Acronyms

AEDT	Aviation Environmental Design Tool
EMEP	European Monitoring and Evaluation Programme
EEA	European Environment Agency
IPCC	Intergovernmental Panel on Climate Change
LTO	landings/take-off cycles
MOVES	MOtor Vehicle Emission Simulator
OECD	Organization for Economic Cooperation and Development
PRTR	Pollutant Release and Transfer Register
RET	Release Estimation Techniques
SMEs	Small and Medium Sized Enterprises
TIM	Time in Mode
TNO	Netherlands Organisation for Applied Scientific Research
UNECE	United Nations Economic Commission for Europe
UNITAR	United Nations Institute for Training and Research
US EPA	United States Environmental Protection Agency
VKT	Vehicle Kilometer Traveled
VOC	Volatile Organic Compound

1 Introduction

Countries around the world are adopting Pollutant Release and Transfer Registers (PRTRs) to characterize the quantity and nature of the environmental releases and off-site transfers of specific chemical substances. Under a typical PRTR system, annual pollutant release and transfer data for listed chemicals are estimated by facilities and reported to the government, which then makes them publicly available, such as through an online searchable database and documents summarizing analyses of the PRTR data. As such, a PRTR is a tool for promoting efficient and effective policies for environmental protection and sustainable development.

A PRTR system generally covers releases and transfers from point sources of pollutants, such as industrial facilities. Pollutant emissions data from these point sources are usually obtained from information collected or generated at the facility level through direct measurement of emissions and transfers, or through the use of methods for estimating or calculating the emissions[1]. In addition to accounting for point sources of pollution, countries might also consider including in their PRTR systems the emissions contributed by non-point or diffuse sources of pollutants.

This document provides an introduction to and overview of methods to estimate pollutant emissions from non-point sources for national or regional pollutant registers or inventories. It aims to inform PRTR designers about appropriate methods and data requirements for estimating non-point source emissions suitable for a national PRTR system.

Part A of the document is an introduction to non-point source emissions estimation. It explains some of the terminology used and outlines key issues with regard to the inclusion of non-point source emissions in a PRTR system.

Part B introduces a number of methods for estimating emissions from non-point sources including: domestic activities and consumer product use; transportation and traffic; agriculture; small- and medium-sized enterprises; and natural sources. For each category, information is provided on the types of activities and pollutants typically involved, followed by an overview of the data needed and explanations of the available methods for estimating the emissions. Examples and simple calculations are provided throughout to illustrate the basic principles behind the estimation methods presented and the types of data needed.

Part C provides practical suggestions for determining whether and how to incorporate non-point source emissions into a PRTR. Part C also identifies some useful tools for estimating and making use of non-point source emissions data.

[1] Updated link tbc

PART A: Introduction to Non-Point Source Emissions Estimation

1 What Are Non-Point Sources of Pollutants?

Non-point or diffuse sources of pollutants usually include emissions arising from agricultural activities, vehicular traffic, industrial activity of small- and medium-sized enterprises (SMEs), product use by consumers, and natural sources (e.g., wildfires). These sources of pollutants generally consist of a collection of individual and small-scale polluting activities which for practical reasons cannot be treated as point sources of pollution when compiling a national or regional emissions inventory. Non-point sources are also referred to as "diffuse" sources, but the term "non-point" sources will be used in this document.

The exact definition of what is considered a non-point source within a PRTR is dependent on the purpose and scale of the emissions inventory. For an emissions inventory for a small town, for example, it may be possible to calculate or even measure emissions from every small industrial operation in the area, using statistical emission factors if necessary. However, on a regional or national level, such small sources, for practical reasons, are typically treated as non-point sources. For road traffic, measurements for every individual vehicle are not feasible on any level but a calculation for individual roads using traffic intensity and statistical emission factors is possible on all levels.

2 Why Consider Including Non-Point Sources In A National PRTR?

In many countries, non-point sources of pollutants represent a significant contribution to the total national emissions of certain substances. In such countries, inclusion of non-point release estimates in the national PRTR system is considered important. For example, in countries with intensive agricultural practices involving large scale application of agrochemical inputs, or in regions where there are many small-scale industrial enterprises, these sources are likely to represent an important part of total industrial emissions. In such cases, accounting for the contribution of these nonpoint sources of pollutants in the national emissions inventory is necessary to obtain an accurate portrayal of total emissions. The pollutant contribution of non-point sources and their potential health and environmental impacts may also be of importance on a local or regional level. For example, in cities where numerous small-scale industrial operations are located throughout the urban landscape, or where vehicular emissions are the largest source of air pollution, an inventory of non-point emissions from these sources may provide valuable data for local impact/mitigation studies and policy applications.

3 How To Approach The Estimation Of Emissions From Non-Point Sources?

Estimating the emissions from non-point sources requires a different approach and different types of data than those which are needed for point sources. Sources of information for estimating the contribution from non-point sources include statistical data on economic activities, demographic data, remote sensing data, emission factors and engineering data. Tools which can facilitate the estimation of emissions from non-point sources include geographical information systems (GIS) and computer models (e.g. hydrology/water flow models, transportation models).

The general approach for estimating the contribution of non-point sources is to construct appropriate emission factors the type of source and suitable for use with source parameters that are known or easily obtained. These source parameters could be, for example, the number of employees or output, the number of vehicle miles travelled, the size and composition of cultivated area in the case of agriculture, the tonnage of pesticide or fertilizer use and the locations where these chemicals are applied. Following this approach, a reasonable estimate of aggregate emissions arising from non-point sources of certain pollutants can be constructed starting from simple parameters that are readily measured or obtained for each source type.

The manner in which non-point source emissions are included in the PRTR, the types of sources which can be feasibly estimated, and the level of accuracy to be achieved will be largely determined by the types and quality of available information. Because the availability of information needed for estimating non-point source emissions may vary greatly between countries and for different regions within a country, an important first step in considering what non-point sources can feasibly be included in the national PRTR system is to evaluate the availability and accuracy of information for each type of non-point source. The type of data which are available always constitute a practical constraint in generating an accurate non-point emissions estimate. However, when using this approach, it is useful to perform quick field tests to validate and calibrate source parameters as they are critical inputs to the non-point source emissions estimate.

PART B: Estimating Emissions from Non-Point Sources

1 Domestic Activities and Use of Consumer Products

1.1 Overview

What are the major source types?

The most common and significant emission sources arising from domestic activities and use of consumer products include:

- combustion emissions from space heating and cooking;
- emissions of volatile organic compounds from solvent containing products;
- emissions to water from cleaning and sanitary processes;
- miscellaneous emissions that can be related to population density, e.g. emissions from corrosion processes, domestic animals, etc.; and
- generation of solid waste.

What are the major pollutants involved and their health and environmental effects?

Indoor space heating and cooking, depending on the technology and fuel, might produce emissions of respirable particulates, carbon moNOxide (CO), carbon dioxide, nitrogen oxides (NOx), volatile organic compounds (VOCs), sulfur oxides (SOx), nitrous oxide (N_2O), methane, polycyclic aromatic hydrocarbons, metallic compounds, and organic hazardous air pollutants (HAPs). These emissions may result in air concentrations that exceed ambient and guideline levels by several orders of magnitude, particularly when wood is used as fuel. Indoor exposure to these pollutants may cause decreased lung function and chronic respiratory disease.

The use of solvents and other solvent containing products results in releases of VOCs some of which are known to have carcinogenic and mutagenic effects. These effects might be compounded by the fact that indoor air can be more polluted than outdoor air, even in cities of poor air quality. Solvent-based consumer products include: household cleaning products; personal care products; adhesives and sealants; pesticides and herbicides; and coatings and related products.

Emissions to water from cleaning and sanitary processes, emissions (including leachates) from solid waste, and the other miscellaneous emissions mentioned above mainly cause environmental problems through contamination of surface waters and groundwater. The pollutants involved may range from organic waste to synthetic organics and heavy metals, depending on the composition of cleaning products or the constituents of the solid waste leachate.

Why are domestic activities and consumer product use treated as non-point sources?

Emissions from domestic activities and product use can be important sources of pollution, especially on a local or even personal level. However, the individual sources of these emissions are either too small and/or too numerous to be identified and measured as separate point sources within the inventory. Thus, the emissions from domestic activities and product use, which typically arise from a collection of individual activities within a given area, are generally treated as a diffuse source in an emissions inventory.

What is the relevance of these sources in the context of a national PRTR?

Depending on its particular situation, a country might consider accounting for emissions associated with domestic activities and product use in its national PRTR system using the approaches described in this section. For nationwide emission inventories, significant contributions to total air emissions of VOCs may arise from domestic and consumer activities and sources related to product use. Phosphates and organics from consumer product use, as well as from solid waste, may also contribute significantly to water pollution. Solid waste itself and leachate emissions from landfills, which represent major environmental management challenges for many countries, could also be accounted for and tracked over time through the PRTR. In the context of a national PRTR system for example, a solid waste module could draw upon information available from a solid waste inventory, which the country may already have in place for planning purposes.

Emissions from domestic activities and product use may also be relevant for policy applications or programs that specifically target the local level. For example, indoor air quality is found to be mainly determined by emissions from heating and cooking as well as use of solvent containing products. The types of emission factors that need to be calculated to estimate the emission contribution of non-point source domestic and consumer product use can be used both for national and local level applications.

1.2 Estimating Emissions from Domestic Activities and Consumer Products

1.2.1 Data needed

To estimate emissions from domestic activities and consumer product use, two types of data are needed: emission factors relating the quantity of emissions to the number of inhabitants, and the population density in a defined geographic area. The common characteristic for domestic activity and product use sources is that pollutant emissions (kg of pollutant released) can be directly related to population density (number of inhabitants per unit area) through the use of per capita emission factors (kg of pollutant released per inhabitant) and marketing statistics (e.g. sales and product use data). Commercial activities, local traffic and some categories of small enterprises are additional examples of sources for which emission output can be related to population density for a specified geographic area (see also Sections 2 and 4).

Text box:

Canada NPRI emission factors (e.g. combustion) are based on the type of equipment, with the activity data being fuel consumption or period of operation, not population density (which is a proxy, and less directly related to the emissions). See the UNECE EMEP/EEA Guidebook).

In most countries, information is usually available on the number of inhabitants and their geographical distribution. Using this information, the population density (number of inhabitants/unit area) can be calculated for a defined area within the inventory region.

In some cases, emission factors that link emissions from domestic and consumer product use activities to the population can be calculated from nationwide statistical information. For example, the calculation of a combustion emission factor relating emissions to residential energy consumption involves disaggregating nationwide or regional residential energy consumption statistics and allocating them according to population for each geographic area. The emissions associated with this residential energy consumption can then be derived with the help of fuel related emission factors available from the literature which are specific to the type of fuel used.

Emission factors for emissions associated with the use of solvent containing products are determined by the composition of the products. In some countries regulations require manufacturers or importers to provide this type of information. Countries where this information is not available may be able to use emission factors from other countries with comparable situations or may derive suitable emission factors by adjusting those which are available. Otherwise, default estimations based on expert judgement should be made. These emission factors are then combined with statistics on the use of solvent containing products according to population in order to arrive at an estimate of these non-point source emissions.

In the case of emissions arising from solid waste, statistics about solid waste production and estimates of the composition of the waste in question are required to calculate appropriate emission factors. Where no data are available, undertaking local activity surveys might be a feasible approach to derive an appropriate emission factor. For example, local data for a given consumer product use activity may be available from local sources such as local trade groups, distribution companies, government agencies or retailers. A household or commercial survey by questionnaire could also be carried out to obtain the basic data needed to calculate an emission estimate.

References for data sources include:

- The OECD guidance document, Summary of Techniques for Estimating Releases of Chemicals from Products[2], includes a compilation of air, water, and soil emission factors for dozens of products. The document also describes how to apply the emissions factors.

[2] http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=env/jm/mono(2017)2/ann&doclanguage=en

- The European Environmental Agency's Air Pollutant Emission Inventory Guidebook[3] includes default emissions factors in a technical appendix for solvent and product use, and for fuel combustion.

- The OECD guidance document, Summary of Techniques for Diffuse Sources[4], includes information on estimation techniques and sources of emissions factors for domestic solid fuel combustion. The document also describes how to apply the emissions factors.

1.2.2 Estimation methods

The estimation of emissions for all the consumer and product use related sources mentioned follow similar principles. The emissions can be estimated by multiplying the appropriate "per inhabitant" emission factor by the population density and the area being considered as follows:

emission factor (kg emissions/ inhabitant) x **population density** (inhabitants/ unit area) x **area of diffuse** source (total area) = **emission estimate** (Kg emissions)

The emission factor used above is specific to the particular type of source being estimated and the particular pollutant being considered for each of these sources. If a finer geographical resolution of estimated emissions is desired, the total area being considered as a diffuse source should be broken down into smaller areas in which the population density is known, and separate estimates can be generated for each of these smaller areas.

An alternative method for calculating emission estimates for domestic sources and sources related to product use is to use an emission factor directly related to unit area instead of a "per inhabitant" emission factor. The calculation in this case is as follows:

emission factor per unit area (kg emissions/unit area) x **area of diffuse** source (total area) = **emission estimate** (Kg emissions)

The examples provided at the end of this section (Examples 1A, 1B and 1C) illustrate the calculation of emission factors as well as how these are combined with population density statistics to estimate emissions from domestic activities and consumer product use.

[3+4] https://www.eea.europa.eu/publications/emep-eea-guidebook-2016

1.2.4 General applications and uses of the estimates

Even preliminary emission estimates for domestic activities and consumer product use provide valuable context regarding the contribution of these sources to total national emissions for inventory purposes. A more detailed analysis of these sources and a refinement of the emission estimates may be of interest for local level public and environmental health studies investigating indoor air pollution, for example, or residential discharges of water pollutants. Emission estimates of this type can also be combined with pollutant diffusion modelling applications enabled through computer models which can be used to estimate exposures and other studies. One such example is an investigation into how the pollutant plume from solid waste landfill leachate might be contaminating a groundwater reservoir or aquifer.

Example 1A: Emissions of VOCs from solvent use in City X

Scenario:
City X's environmental authorities are seeking an estimate of volatile organic compounds (VOC) emissions contributed by domestic solvent use. Since population density data is available from a recent census, the authorities decide to calculate an emission factor per inhabitant for domestic VOC emissions from solvent use as a basis for undertaking the estimation.

The following data are also available from the census: City X's urban core has a population density of 300 inhabitants per km^2 and an extension of 15 km^2. City X's urban periphery has a population density of 175 inhabitants per km^2 and covers an area of 50 km^2.

Sample emissions estimation:
The first step is to calculate a suitable per capita VOC emission factor for domestic solvent use using nation-wide information. This will enable authorities to use the available population density data to produce an emission estimate. To obtain data for calculating the emission factor, a local survey is conducted. The results of the survey show that the average annual domestic use of cleaning solvents in City X is on average 100 kg yearly per household. The average household size from the City X census data is 4 persons per household. The compositional data for the VOC contained in these commercial cleaning solvents was also determined to be on average 80% of product content by weight. It is assumed that all VOC contained in the solvent evaporates as emissions.

Example continues on the next page

From the above data a per capita VOC emission factor from domestic solvent used can be calculated as follows:

First convert the solvent use data to per capita basis:
100 kg yearly solvent used/household x 1 household/4 persons = 25 kg average yearly solvent use/per person

Using the solvent compositional data, we can now obtain a per capita emission factor for yearly VOC emissions arising from domestic solvent use:

25 kg solvent used/person x 80% VOC emissions/kg solvent used = 20 kg VOC emissions/per person/year

With this calculated emission factor and the given population density data, we can use the formula provided in the text to obtain an emission estimate for City X as follows:

For City X's core: 20 kg VOC/person-year x 300 inhabitants/km^2 x 15 km^2 = 90,000 kg VOC emissions or approximately 90 tons per year

For City X's periphery: 20 kg VOC/inhabitant-year x 175 inhabitants/ km^2 x 50 km^2 = 175,000 kg VOC emissions or approximately 175 tonnes per year

Estimation result:
In total for City X we obtain: 90 + 175 = 265 tonnes per year of VOC emissions contributed by domestic solvent use

Example 1B: Nationwide emissions from consumer product use

A top-down estimate of VOC emissions from product use by consumers could also be calculated on a national scale. Information about the use of solvent-containing products like cosmetics, paints and coatings for in-house use, and other consumer products, can sometimes be obtained from commercial marketing data. Combining this product use information with product composition information obtained from the literature, it is possible to estimate the overall amount of solvents (VOC) evaporating from the household use of these products in the geographic area being considered. The overall VOC emission estimate can then be divided into the number of inhabitants in the area in order to obtain an approximation of the per capita contribution of VOC emissions from consumer product use.

Example 1C: Emissions from space heating in City Y

Scenario:
Environmental authorities for City Y are interested in estimating the NOx emission contribution of domestic heating systems. In City Y these heating systems are limited to two types: fuel oil and natural gas. It is decided that a per capita emission factor for NOx will need to be calculated in order to take advantage of available population density data in undertaking the desired estimation.

In order to gather data for calculating a suitable NOx emission factor, a local survey is conducted to determine average yearly fuel consumption for space heating. It is found that annual consumption of natural gas is 0.1 tonne per capita, and that annual consumption of fuel oil is 200 kg per capita. In addition, data for the amount of NOx released during combustion of each of these fuels is obtained,

i.e. 0.2 tonne NOx/tonne of natural gas burned, and 3 kg NOx/tonne of fuel oil burned.

Census data for City Y shows a uniform population density of 200 inhabitants/km^2 and an extension of 70 km^2, with natural gas users clustered around the newer suburbs (20 km^2) and fuel oil users spanning the rest of the urban area (50 km^2).

Sample emission estimation:
Using the above data, a per capita NOx emission factor can be calculated for each fuel type as follows:

The fuel consumption data is multiplied by the factor giving the weight of NOx released per unit of fuel consumed to obtain a per capita NOx emission factor:

For natural gas: 0.1 tonne/person-year x 2 kg NOx/tonne used = 0.2 kg NOx/person-year

For fuel oil: 0.2 tonne/person-year x 3 kg NOx/tonne used = 0.6 kg NOx/person-year

Example continues on the next page

With these calculated emission factors and the given population density data we can estimate the annual NOx emissions arising from space heating in City Y as follows:

For natural gas users: 0.2 kg NOx/person-year x 200 inhabitants/km^2 x 20 km^2 = 800 kg NOx emissions per year

For fuel oil users: 0.6 kg NOx/person-year x 200 inhabitants/km^2 x 50 km^2 = 6,000 kg NOx emissions per year

Estimation result:
In total we obtain for City Y 800 + 6,000 = 6,800 kg per year or 6.8 tonnes of NOx emissions contributed by domestic heating combustion in City Y. To test its accuracy, the estimate can be compared with overall national figures in order to check if the estimated emission contribution of City Y as compared to total national emissions is in line with the city's relative size and importance within the country.

2 Transport and Traffic

2.1 Overview

What are the major source types?

Common categories of non-point emissions from transportation sources include:

- road traffic (e.g. exhaust emissions, defrosting roads, solid waste, corrosion);
- shipping (e.g. exhaust emissions, water pollution, corrosion);
- emissions to water from cleaning and sanitary processes;
- railroads (e.g. fuel combustion, corrosion of electrical wires); and
- air transport (e.g. emissions to air, noise).

What are the major pollutants involved and their health and environmental effects?

Transport and traffic related non-point sources contribute to total air emissions of major air pollutant categories (VOCs, NOx, CO, SO_2, PM_{10}), and in particular nitrogen oxides and hydrocarbons. Transport activities and traffic are also sources of hazardous air pollutants, such as, benzene, 1,3-butadiene, formaldehyde and acetaldehyde. Heavy metals such as Pb, Cr, Cd, Cu and other metallic compounds present in fuel or lubricant additives are also emitted. In addition to air pollution, these sources can also contribute to water and soil pollution if the penetration of modern catalysts is low. Significant emissions of lead (Pb) are released by vehicle fleets.
Corrosion and wear may also release heavy metals into the environment.

The health effects of the air pollutants listed above vary according to the intensity and duration of exposure and the health status of the population exposed. Among the documented effects of SO_2, particulates and NOx are increased mortality and deficits in pulmonary function. CO is linked to cardiovascular and neurobehavioral effects. Hydrocarbons of heavy molecular weight such as benzene have been shown to have carcinogenic and mutagenic effects. Exposure to airborne Pb may cause subtle neurobehavioral effects, especially in children.

In terms of environmental effects, NOx and SO_2 form acidic precipitation, which affects plants and hence crop yields. These pollutants also contribute to corrosion and damage to structures and materials exposed to the atmosphere. The deposition of many air pollutants, particularly synthetic organics and trace metals, have significant adverse impacts on the marine environment. It is now widely acknowledged that CO_2 and O_3 are greenhouse gases that contribute to climate change.

Why are transport activities and traffic treated as non-point sources?

The emissions arising from transportation and traffic are generally treated as diffuse sources caused by a collection of individual transportation vehicles that circulate within a defined area. The sheer number of vehicles and their mobility make it impractical to measure or estimate their emissions on an individual basis.

What is the relevance of these sources in the context of a national PRTR?

Transport and traffic related non-point sources may comprise a significant portion of total air emissions for major air pollutant categories (VOCs, NOx, CO, SO_2, PM_{10}). Air pollutant emissions from transport activities and traffic may in some cases represent the main source of air pollution, particularly at the local level in urban areas. Thus, particularly if the PRTR is intended to provide a comprehensive inventory of air emissions, including in large cities, countries should consider accounting for transport and traffic related non-point sources in their national PRTR systems using the approaches described in this section.

Aside from exhaust and evaporative fuel losses which can be conveniently accounted for in a PRTR, the solid waste produced by cars might present a problem in its own right that has yet to be adequately solved in many countries. However, accounting for solid waste is outside the scope of most PRTR systems, which in general are focused on releases and transfers of chemical substances. Vehicle solid waste can be taken into account outside the context of a PRTR system through specific solid waste inventories.

What are the potential challenges and resource requirements when estimating emissions?

The estimation of emissions from transport and traffic sources estimation methods are among the most complex of those used in emissions inventories and can demand considerable time and skill. Methods involve the collection of activity data which reliably reflects the local use of different transport vehicle categories, and inputting this information into an existing model, or applying emission factors. There is a considerable range in the skill and time required, as well as the accuracy of the results, depending on the method used. Through technological developments and emissions research, both models and emissions factors are frequently updated. Always consult regularly updated online resources to verify that the emission factors and/or model version are the most current. While this guidance document provides the general steps in estimating emissions from transportation sources, the specific method used will depend on the data available and the method may need to be adjusted accordingly.

What are the general applications and uses of these estimates?

Determining the contribution of emissions from traffic and transport activities will be important for most countries; these sources need to be included in the inventory in order to obtain a complete picture of national emissions. Emission estimates for specific transport and traffic source categories may also be undertaken in the context of more specific local level studies, for example developing an air pollution control programme for a large city to target buses or passenger car fleets. Another example would be studies focusing on air quality in the vicinity of an airport or port to derive appropriate emission mitigation measures from airplanes or shipping activities.

2.2 Road Traffic

Road traffic emissions are caused by passenger vehicles, trucks and motorcycles which generally use fuels such as petrol, diesel and liquefied petroleum gas (LPG).

2.2.1 Data needed

Two types of data are needed to estimate the emissions from road vehicles. The first type consists of emission rates on a mass per vehicle kilometer traveled (VKT) basis. The unit emission rate gives the quantity (kg) of pollutant emitted per each kilometer traveled by a vehicle of a particular class. The second type of data consists of statistics on distance traveled for each vehicle type and travel mode, as explained below. Factors affecting emissions include vehicle type; type and composition of fuel used; vehicle age; type of travel (e.g. highway or city); and types of roads where vehicles travel.

Regarding the first type of data, a unit emission rate on VKT basis needs to be calculated for each class of vehicle being considered in the estimation. The vehicle fleet in the area being considered will typically comprise several classes of vehicles. The mean emission rate for an average traveling vehicle of each class should be calculated using available data. The data needed for the calculation of these emission rates includes:

- the distribution and amount of fuel use over the different vehicle types (petrol, diesel, LPG);
- engine combustion characteristics for each vehicle class;
- emissions to water from cleaning and sanitary processes;
- the age and size of the vehicles; and
- the extent of catalyst use.

Beyond emission rates on a VKT basis, the second type of data needed for the estimation of emissions arising from road traffic consists of statistics on distance traveled by vehicle type and travel mode. The travel mode categories include highway traffic, town traffic, and traffic on other roads. Statistics for each of these travel modes and for each type of vehicle (i.e. passenger cars, trucks, and motorcycles) need to be obtained to undertake the VKT-based emission estimation. These statistics might be available from transport planning and traffic authorities, although this is not always the case.

From these travel mode statistics for each vehicle type the traffic production can be obtained. The traffic production is the aggregate Vehicle Kilometers Traveled (VKT) in the area being considered. For example, the traffic production for individual roads can be determined by counting the number of cars passing by and multiplying it by the length of the road belonging to the measured intensity assuming all cars travel the full length.

VKT data need to be further resolved according to travel mode (i.e. highway, town traffic and traffic on other roads), vehicle type (passenger vehicles, commercial vehicles, heavy duty vehicles and motorcycles), fuel use (petrol, diesel and LPG) and vehicle age (for example a vehicle may be considered vintage after 20 years; however, each country has different legislation in place). This resolution is needed since a different emission rate applies for each combination of travel mode, vehicle type and age, and fuel use.

2.2.2 Estimation methods

Emission rates on a VKT basis have to be calculated for each travel mode/vehicle type/fuel use combination, yielding an emission rate on a VKT basis for each combination category. The product of these unit emission rates times the total vehicle-kilometers traveled in each category is equal to the total vehicle exhaust emissions, as follows:

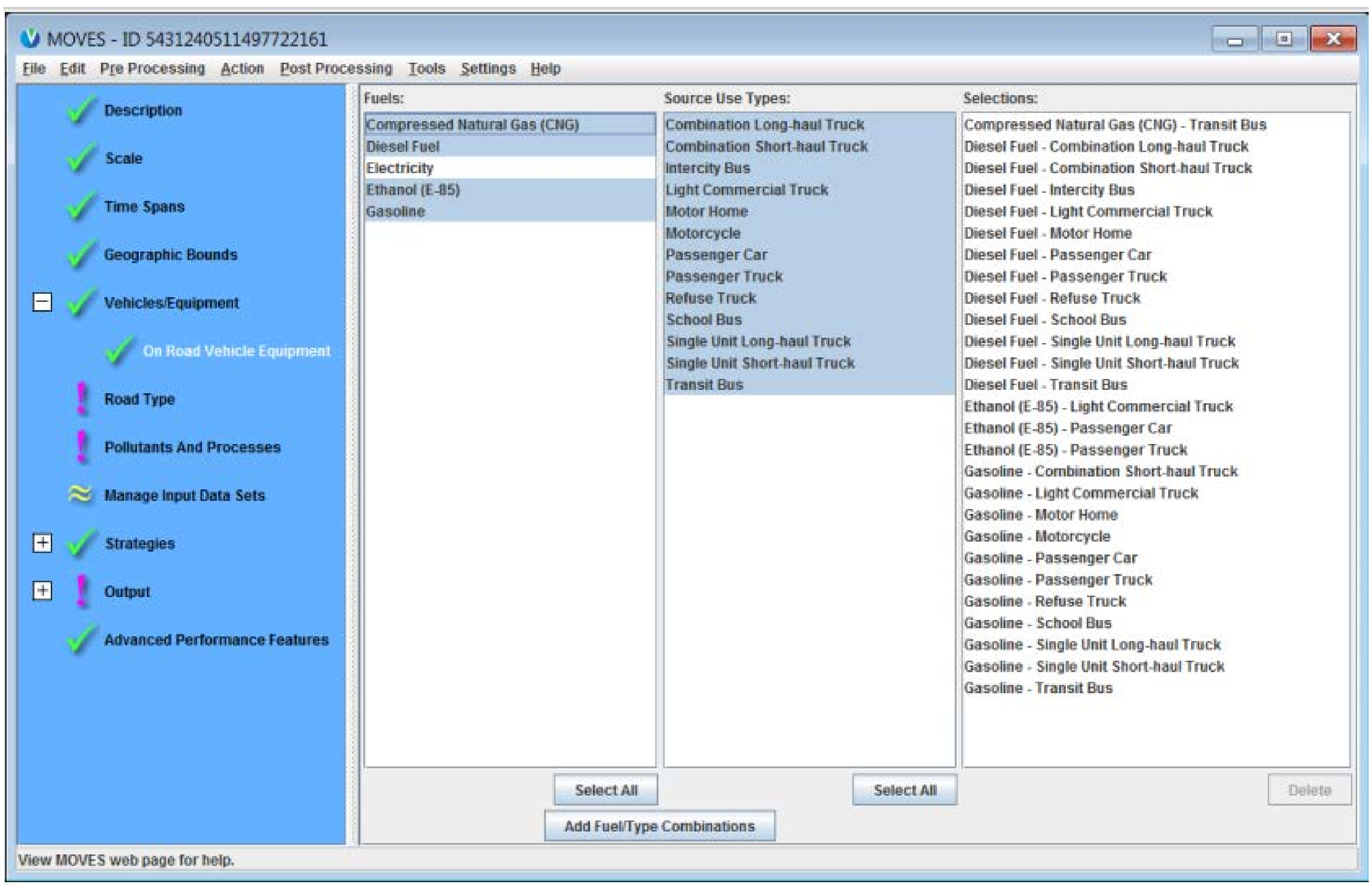
emission rate on VKT basis (kg emissions/ vehicle-km-traveled)	x	**vehicle-kilometers traveled** (vehicle-km-traveled)	=	**emissions per travel mode/ vehicle type/fuel use category** (kg of air emissions per category)

To obtain total air emissions from road traffic in the area under consideration, the above emission estimates need to be aggregated across all categories (travel mode/vehicle type/fuel use) present in the area in question. The sum would give an estimate of the contribution to air emissions from road traffic. An illustration of this estimation method is provided in Example 2A.

An alternative approach to arrive at rough nationwide traffic production estimations involves the use of information about national fuel consumption, such as gasoline sales (see Examples 2B and 2C). The aggregate fuel consumption figure for road vehicles can be very roughly translated into an approximate emission estimate in combination with knowledge about the composition of the vehicle fleets, travel patterns, etc. by expert judgement. It should be kept in mind that such estimates may be of limited use when local level accuracy is desired.

When local or country-specific emissions factors are not collected or otherwise available, models can be used to estimation emissions based on data inputs such as VKT, number of vehicles by type and age, and fuel information. The U.S. Environmental Protection Agency (EPA) has a well-known software package called MOtor Vehicle Emission Simulator (MOVES), used to calculate exhaust and evaporative emissions for the U.S. passenger and commercial fleet. MOVES is a state-of-the-science emission modeling system that estimates emissions for mobile sources at the national, county, and project level for criteria air pollutants, greenhouse gases, and air toxics. In Europe, the COPERT model has been developed and made available through the European Environment Agency. The COPERT model takes into account the composition of the vehicle fleet, the annual kilometers driven, and specific emission factors per kilometer driven in urban, rural and highway traffic. For either model, input data are required such as on: VKT, number of vehicles by vehicle type; vehicle age distribution; fuel information; and temperatures. An example of the MOVES user interface is shown below.

Figure 1: Example from MOVES user interface



The EMEP/EEA Air Pollutant Emission Inventory Guidebook[5] summarises several other estimation approaches ranging from most complex where numerous variables are considered (e.g. speed dependent hot emissions and cold starts, road types, trip lengths and temperatures) to the simplest, such as SO_2 emission based on fuel consumption only.

2.2.3 Level of accuracy and resource requirements

Use of an existing model is comprehensive and detailed but its accuracy and reliability depend on the quality of the data used. For each model, consider the assumptions made and their potential impact on the results for the country. For additional information on the assumptions and methods used in models mentioned here and others, see The OECD guidance document, Summary of Techniques for Diffuse Sources[6].

Example 2A: Air emissions from a single road

Scenario:
Local authorities are interested in estimating the yearly NOx and VOC emissions contributed by road traffic in a single stretch of road measuring 100 km. The following data is available for this road:

- the road is used by only two types of vehicles (agricultural trucks and cars);
- available VKT-based emission factors for agricultural trucks are given as .00223 kg SO_2/VKT and .00314 kg NOx/VKT for the two pollutant categories of concern;
- VKT-based emission factors for cars are given as .00105 kg SO_2/VKT and .00231 kg NOx/VKT;
- the road is used by 300 trucks and 150 cars every day of the year.

Sample emission estimation:
With the above road use information, the vehicle-km-travelled (VKT) during the year can be calculated for this road as follows:

Annual VKT for agricultural trucks:
300 trucks/day x 365 days/year x 100 km = 10.950 million VKT

Annual VKT for cars:
150 cars/day x 365 days/year x 100 km = 5.475 million VKT

Once the respective VKT is calculated for each vehicle type, we can proceed to estimate emissions using the formula given in the text.

[5] https://www.eea.europa.eu/publications/emep-eea-guidebook-2016

[6] www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?doclanguage=en&cote=env/jm/mono(2003)14

Example 2A continued

Emissions contributed by agricultural trucks:

.00223 kg SO_2/VKT x 10.95 million VKT = 24,419 kg SO_2 per year
.00314 kg NOx/VKT x 10.95 million VKT = 34,383 kg NOx per year

Emissions contributed by cars:

.00105 kg SO_2/VKT x 5.48 million VKT = 5,749 kg SO_2 per year
.00231 kg NOx/VKT x 5.48 million VKT = 12,647 kg NOx per year

Estimation result:
The total contribution of traffic activity on this road is therefore approximately:

24,419 kg SO_2 per year (trucks) + 5,749 kg SO_2 per year (cars) = 30,167 kg SO_2 per year

34,383 kg NOx per year (trucks) + 12,647 kg NOx per year (cars) = 47,030 kg NOx per year

Example 2B: Emissions from a small town in which annual fuel use and vehicle fleet composition data are available

Scenario:
Authorities in Town X are interested in estimating the annual traffic-related emissions of several air pollutant categories (NOx, SO_2, and VOC). The following statistics are available for the town:

- 1200 tonnes of gasoline are used yearly by municipal buses and 1000 tonnes of gasoline are used yearly by passenger cars within the urban area;

- The vehicle fleet composition is fairly uniform and limited to municipal buses and passenger cars of recent make.

- Emission factors for the two vehicle engine types and fuel given are available from the literature. For municipal buses the emission factors are: 24 kg VOC/tonne of fuel; 27 kg NOx/tonne of fuel; and 20 kg SO_2/tonne of fuel. For passenger cars the emission factors are: 27 kg VOC/tonne of fuel; 22 kg NOx/tonne of fuel; and 20 kg SO_2/tonne of fuel.

Example 2B continued

Sample estimation of emissions:
With the given data we can estimate emissions of each air pollutant category contributed by each vehicle type as follows:

Emission contribution of municipal buses:

24 kg VOC/tonne of fuel x 1200 tonnes = 28.8 tonnes of VOC 27 kg NOx/tonne of fuel x 1200 tonnes = 32.4 tonnes of NOx
20 kg SO_2/tonne of fuel x 1200 tonnes = 24.0 tonnes of SO_2

Emission contribution of passenger cars:

27 kg VOC/tonne of fuel x 1000 tonnes = 27.0 tonnes of VOC 22 kg NOx/tonne of fuel x 1000 tonnes = 22.0 tonnes of NOx
20 kg SO_2/tonne of fuel x 1000 tonnes = 20.0 tonnes of SO_2

Estimation result:
We aggregate the emission contribution across vehicle types to yield a total yearly estimate for the emission contribution from traffic in the small town for each air pollutant type:

28.8 + 27.0 = 55.0 tonnes of VOC
32.4 + 22.0 = 54.4 tonnes of NOx
24.0 + 20.0 = 44.0 tonnes of SO_2

Example 2C: Nationwide emissions from transport and traffic

The estimation approach for the small town described in the previous example is usually not practicable because the amount of fuel used in a single town by general traffic is rarely available. The approach is generally practicable only for city buses or other specific vehicle types for which authorities might have fuel use information for a particular town.

The total amount of fuel used, however, is usually available on a national scale, where statistics are often available for aggregate fuel use by each fuel type. Starting from these overall national fuel use figures, several estimation approaches are possible depending on what additional information is available. The additional information consists of the distribution or breakdown of the overall fuel use into the different driving modes.

Example 2C: Nationwide emissions from transport and traffic

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2.3 Shipping

Marine craft are an extremely diverse category ranging from small outboards to large international cargo ships. The chemical species emitted by this sector include the major categories of air pollutants: VOCs, NOx, CO, SO_2, PM_{10}; the same air toxics mentioned for road motor vehicles: benzene, 1,3-butadiene, formaldehyde and acetaldehyde; and heavy metals such as Pb, Cr, Cd, Cu, and other metallic compounds present in fuel or lubricant additives. Shipping activity may also contribute to water pollution through accidental spills, routine leakage of lubricants and/or as a result of ship cleaning and maintenance activities.

In most cases a detailed inventory of emissions due to shipping will only be required for local or regional studies for environmental or health applications, for example in the vicinity of ports or inland shipping routes where shipping activities may be causing health and environmental impacts.

2.3.1 Data needed

To estimate air emissions from marine craft, two types of information are needed: **emission factor data**, and **activity data**. Emission factors per engine type or per class of marine vessel need to be obtained. These emission factors reflect the quantity (in kg) of pollutants emitted per liter of fuel consumed or per horsepower-hour of engine use by vessel class, which vary by country. Emissions factors have been published by numerous sources including the U.S. EPA, European Environment Agency, and Lloyd's Register. For more information and citations for these sources, see OECD guidance document, *Summary of Techniques for Diffuse Sources*[7].

Activity data refer to statistics on hours of activity or fuel consumption which might be available from port authorities, ferry companies, and fishing regulatory bodies. For an emission inventory,

[7] www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?doclanguage=en&cote=env/jm/mono(2003)14

the relevant emissions will occur in the vicinity of the port. Port authorities are usually able to provide information on the number and types of ships which are docked and the period of time spent docked, approaching or leaving the port, as well as the quantities of freight being transferred. Lloyds Register is also an excellent source of information on the intensity of shipping traffic and its location, including inland routes of seagoing ships which can be combined with local information from harbour authorities for a detailed analysis of emissions due to the seagoing shipping mode.

The above information can be used as primary activity data for the estimation of emissions contributed by shipping activities in the vicinity of the port. Note that the majority of shipping fuel will be consumed at sea, therefore local port fuel sales will not accurately reflect emissions occurring in the airshed in the vicinity of the port. Activity data is therefore preferred for estimating emissions in the inventory region unless fuel consumption data is adjusted accordingly.

The emission factors and activity data discussed above allow the estimation of emissions for the major air pollutant categories. If for the purposes of the inventory more detailed estimates of certain air toxics or particulates are required, speciation profiles for the VOCs and particulates emitted for each category of marine vessels will also be needed to disaggregate the original estimates.

2.3.2 Estimation methods

The principles for the estimation are similar to those presented for road vehicles in that an appropriate emission factor for each marine vessel category is multiplied by a variable indicating the activity or fuel use for that vessel category in the inventory region, as follows:

emission factor for each vessel category (kg emissions/ horsepower-hour)	x	**activity variable in area being considered** (total horsepower-hours)	=	**emissions per vessel category** (kg of air emissions per vessel category)

An alternative approach, illustrated in Example 2D, is to calculate an emission factor directly related to fuel consumption, using the following equation:

emission factor for each vessel category (kg emissions/ unit fuel consumed)	x	**fuel consumed within area being considered** (total fuel used)	=	**emissions per vessel category** (kg of air emissions per vessel category)

This approach gives an emission estimate for each vessel category for the major types of air pollutants. If the air pollutant estimates need to be further speciated, that is, broken down into their constituent chemical species, the speciation profile for VOC and particulates for different vessel categories can be used to break down these first estimates into a series of emission estimates for each relevant species. Once the appropriate estimates are calculated for each marine vessel category within the area being considered, the estimates can be aggregated to obtain an overall estimate for the emission contribution due to shipping activities.

An estimate of emissions from inland shipping can be based on the amount of fuel used and the traffic production of certain shipping routes. In this case it can be assumed that the majority of the fuel consumed is turned into emissions in the inventory region that the inland shipping route crosses. Traffic production data (number of vessel-kilometre-travelled) for each vessel category in the shipping route can also be used in a similar approach as the one presented for road vehicles. Water pollution due to oil losses in inland shipping routes can also be estimated based on the number and vessel categories present on the routes.

Example 2D: Emissions for one vessel category for which fuel consumption data is available

Scenario:
Authorities in Port X are interested in estimating the yearly air emissions contributed by the main vessel category, in this case fishing trawlers. The following data are available:

- Yearly fuel consumption data for this vessel category in the vicinity of the port is estimated to be 15,000 tonnes of fuel oil;

- Most fishing trawlers at Port X are of the same size and type of engine;

- Emission factors per unit of fuel consumed for the engine type common to this vessel category are available from the literature for the major air pollutant types. These emission factors are: 35 kg VOC/tonne of fuel; 27 kg NOx/tonne of fuel; 23 kg SO_2/tonne of fuel; and 3.0 kg Pb/tonne of fuel consumed.

Sample emission estimation and result:
Using the data given we can directly apply the formula in the text to estimate the yearly air pollutant emissions contributed by the fishing trawler category in the vicinity of the port. The estimation consists of multiplying the emission factor times the amount of fuel consumed, as follows:

35 kg VOC/tonne of fuel x 15,000 tonnes = 525 tonnes of VOC 27 kg NOx/tonne of fuel x 15,000 tonnes = 405 tonnes of NOx
23 kg SO_2/tonne of fuel x 15,000 tonnes = 345 tonnes of SO_2
3.0 kg Pb/tonne of fuel x 15,000 tonnes = 45 tonnes of Pb

2.3.3 Level of accuracy and resource requirements

The overall accuracy of the technique described is low due to the numerous uncertainties in the emission factors, activity data, and in the speciation profiles used to estimate toxic emissions. If reliable activity data are not available, significant time and effort is needed to collect it. An appropriate distinction should be made between seagoing, inland, and recreational shipping. For example, in areas where recreational shipping is the predominant activity the estimation is complicated by the fact that the activity is very much determined by seasonal variations. Therefore, the estimations of actual activity and fuel use data require expert judgement and are difficult to obtain.

2.4 Railroads

Railway locomotives are a diverse category although not as varied as shipping vessels. The emissions from this sector include the major categories of air pollutants (VOCs, NOx, CO, SO_2, PM_{10}), the same air toxics mentioned for road vehicles and shipping (benzene, 1,3butadiene, formaldehyde and acetaldehyde), and heavy metals such as Pb, Cr, Cd, Cu, and other metallic compounds present in fuel or lubricant additives.

2.4.1 Data needed

Estimating the emissions to air from railway locomotives requires two types of data: **emission factors by engine type** for the local locomotive fleet, and **fuel consumption by engine throttle** position (or travel mode). Emission factors for railway locomotives available from the U.S. EPA are divided into three classes based on the scale of railway operations and either line haul or yard use. The same document provides methods to tailor these emission factors to suit a fleet differing from the US average. For this adjustment the composition and engine types of the local fleet are required. In particular, an accurate adjustment will require the composition of the local fleet to be specified in terms of locomotive type, engine type, and mode of service. As emissions factors are regularly updated, also consult the most recent version of the technical documentation for U.S. EPA's National Emissions Inventory[8].

Fuel consumption for the inventory area may be available from state rail networks. If not, fuel consumption may have to be estimated based on the relative freight carried through the area being considered. For an accurate estimate, the fuel consumption data should be specified in terms of fuel consumption by engine throttle position, and percentage of time in each position for line haul and yard operations. In many cases this data is available from railway companies.

[8] https://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei

2.4.2 Estimation methods

The principles for the estimation are similar to those presented for road vehicles. An appropriate emission factor for each locomotive class is multiplied by a variable indicating the fuel consumed by that class within the geographical area covered by the inventory, as follows:

emission factor for each locomotive class (kg emissions/ unit fuel consumed)	x	**fuel consumed in area being considered** (total fuel used)	=	**emissions per locomotive class** (kg of air emissions per locomotive class)

This approach gives an emission estimate for each locomotive category for the major types of air pollutants. If the air pollutant estimates need to be further speciated, that is, broken down into their constituent chemical species, the speciation profile for VOC and particulates for different locomotive classes can be used to breakdown these first estimates into a series of emission estimates for each relevant species. Unfortunately, only limited data are available on the emission of toxic chemicals as a fraction of exhaust and evaporative VOC.

Emissions from electrified railroads are limited to copper emissions from wear of overhead wires. The railroad companies usually can derive this information from the wear losses at their replacement programme.

2.4.3 Level of accuracy and resource requirements

The overall accuracy of the technique described is low given the numerous uncertainties in the emission factors and fuel consumption data, and the limited data on speciation profiles used to estimate toxic emissions. In addition, the amount of time needed to collect reliable fuel consumption data by engine throttle position and to adjust international emission factors to reflect the composition of the local locomotive fleet can be considerable.

2.5 Air Transport

The emissions from aviation are considered only in the vicinity of airports. More specifically, exhaust emissions from aircraft are considered for idling, taxiing, taking off, ascent to the mixing layer height, descent from mixing layer height, landing and taxiing to the terminal. The taxi/idle phase is in general the most polluting stage.

The emissions of aircraft include the major categories of air pollutants (VOCs, NOx, CO, SO_2, PM_{10}) and a wider range of air toxics than those mentioned for other transport activities. These air toxics include: 1,3-butadiene, formaldehyde, other aldehydes, acetone, benzene, toluene, benzene, ethyl benzene, xylene, styrene and phenol.

2.5.1 Data needed

Calculation of emissions from air traffic are based on the number of **landings/take-off cycles (LTO)** per aircraft type. Normally airport records indicate aircraft movements in the form of single take-off or landing, which represent a half landing/take-off cycle. Most aircraft during a full LTO go through a similar sequence of operations characterized by fairly standard power settings for given aircraft categories. Thus, from the number of LTOs for each aircraft category, the time spent in each engine power setting mode, or **time in mode (TIM)**, for each aircraft category needs to be determined in the vicinity of the airport. LTOs and TIMs are activity data analogous to the activity data previously described for road vehicles and shipping. The third type of data needed are **emission factors** for specific aircraft engines at each of the power settings that aircraft go through during a take-off/landing cycle (LTO). These emission factors are available from the International Civil Aviation Organisation[9]. In the U.S., the Federal Aviation Administration has developed the Aviation Environmental Design Tool (AEDT)[10] which is a software system that models aircraft emissions in scope from a single flight at an airport to scenarios at the regional, national, and global levels. AEDT also models aircraft performance in space and time to estimate fuel consumption, noise, and air quality consequences. A purchased site license is needed to use the model. The U.S. EPA uses its MOVES emissions modelling system (as described in the Road Traffic section above) to estimate emissions from all non-road mobile sources.

2.5.2 Estimation methods

Estimation methods range from use of modelling software to simpler methods based on emission factors and national statistics on LTO and aircraft/engine types. A detailed approach based on emission factors and activity data is described in Australia's National Pollutant Inventory Manual titled, Emission Estimation Technique Manual for Aggregated Emissions from Aircraft[11]. The data required are as follows:

- location of airports, runways, landing and approach flight paths and associated ground movements;
- number of LTO cycles for each aircraft type at each airport;
- prevalence of different types of engines (and their numbers) and auxiliary power units used by each aircraft type;
- time spent in each of the four operating modes listed above by aircraft type for each airport; and

[9] https://www.easa.europa.eu/easa-and-you/environment/icao-aircraft-engine-emissions-databank
[10] https://aedt.faa.gov/
[11] http://www.npi.gov.au/resource/emission-estimation-technique-manual-aggregated-emissions-aircraft-version-22

- time spent operating auxiliary power units at the airport.

The steps in estimating aircraft emissions depend on the activity data available, but may include:

1. Identify all airports to be included in the inventory.
2. Determine the mixing height to be applied to the LTO cycle (i.e., the boundary height).
3. Define the fleet make-up for the aircraft category using each airport.
4. Determine airport activity as the number of LTOs for each aircraft category.
5. Select emission factors for each aircraft category.
6. Estimate a time in mode or power setting (TIM) for each aircraft category at each airport, keeping in mind that the taxi/idle mode for the same aircraft category might vary for different airports depending on the airport's size.
7. Calculate the inventory emissions based on the airport activity (LTOs), TIM, and aircraft category emission factors.

After calculating (a) the LTOs for each aircraft category and (b) the TIMs for each aircraft category, the emission estimation can then be carried out. An emission factor specific for each aircraft engine category and operating mode is multiplied by the time spent on that operating mode and the corresponding fuel flow for that engine category. The result of this multiplication is an estimate for the emissions contributed by the aircraft engine category during the time spent in the operating mode being considered. The procedure, which is illustrated in Example 2E, is as follows:

Emission factor for taxi/idle mode for each aircraft category (kg emissions/ 1000 kg fuel) x **time in taxi / idle mode** (TIM minutes) x **fuel flow** (kg fuel/min) = **emissions for taxi/idle mode** (kg of air emissions)

The same calculation is repeated for each of the three operating modes (TIMs), i.e. taxi/idle mode, take-off and approach/climb out. Next, the calculated emissions for the three operating modes are aggregated for each aircraft category to arrive at an emission estimate per category. Finally, by summing the emissions estimated for each aircraft category the total emissions estimate for the airport being considered is obtained.

2.5.3 Level of accuracy and resource requirements

Individual airports and aviation control bodies generally keep sufficient records to enable the required activity data required (LTOs and TIMs) to be reliable and of high quality. Emission factors based on engine testing are available for most aircraft engines at the required power setting and/or operating modes from the International Civil Aviation Organisation[12]. These emission factors are also generally of high quality. If care is taken in the analysis of activity data (LTOs and TIMs), the estimation of aircraft emissions through these techniques can be fairly accurate. In general, using simpler methods involves making broad assumptions about the aircraft fleet and times in mode, so accuracy will be reduced.

It should be noted, however, that the estimation of aircraft emissions involves several analytical steps, and that obtaining and analysing activity data can be complicated. Sometimes activity data may not be available in a ready-to-use form, or it may vary widely for different airports. For all these reasons, considerable professional time can be spent in undertaking an analysis of this nature.

Example 2E: Estimating emissions for one aircraft category for which LTO and TIM data are provided

Scenario:
Authorities are interested in estimating the aggregate air pollutant emissions from air traffic in the vicinity of Airport X which serves an agricultural town. The following data are available:

- Air traffic activity in Airport X consists of 5000 LTO (landing-take-off) cycles per year of small mono-motor aircraft.

- The times is each engine operating mode (TIM) for this aircraft category during each LTO cycle are: taxi/idle TIM 8 minutes, take-off TIM 3 minutes, approach/climb out TIM 10 minutes.

- The emission factors for each engine operating mode (TIM) for this aircraft category as given in the literature are: 360 kg/tonne fuel in taxi/idle mode; 480 kg/tonne fuel in take-off mode; 230 kg/tonne fuel in approach/climb out mode.

[12] https://www.easa.europa.eu/easa-and-you/environment/icao-aircraft-engine-emissions-databank

Example 2E continued

(...) These emission factors give the aggregate weight of air pollutant emissions (VOC, NOx, CO, SO_2 etc.) per tonne of fuel used. A pollutant speciation profile, which is specific to the fuel used, needs to be used later to break down the aggregated estimate of air pollutant emissions into its constituent estimates for each air pollutant category.

- The fuel flow during each engine operating mode (TIM) for this aircraft category are obtained from the literature as: 0.22 kg/min in taxi/idle mode; 0.65 kg/min in take-off mode; 0.15 kg/min in approach/climb out mode.

Sample emission estimation:
Using the above data, the formula given in the text is directly applied to estimate yearly aggregate air pollutant emissions in the vicinity of the Airport X for the mentioned aircraft category. Care should be taken in correctly aggregating the partial results to arrive at the total emissions estimate. The first step is to apply the formula to estimate emissions for each aircraft engine operating mode (TIM) during a single LTO cycle as follows:

Emissions from taxi/idle operating mode during each LTO cycle:
360 kg/tonne fuel x 8 min x .00022 tonne fuel/min = .63 kg

Emissions from take-off operating mode during each LTO cycle:
480 kg/tonne fuel x 3 min x .00065 tonne fuel/min = .94 kg

Emissions from approach/climb out operating mode during each LTO cycle:
230 kg/tonne fuel x 10 min x .00015 tonne fuel/min = 35 kg

These intermediate results are then summed to obtain an emission estimate for one complete LTO cycle as follows:

.63 + .94 + .35 = 1.92 kg of aggregate air pollutant emissions per each LTO cycle.

Finally, to obtain the estimated yearly air emissions which occur in the vicinity of the airport, we simply multiply this figure by the total number of yearly LTO cycles in Airport X:

1.92 kg air emissions/LTO x 5,000 LTO cycles in the year = 9,600 kg of yearly air emissions

Estimation result:
The resulting estimate is 9,600 kg of aggregate air pollutant emissions per year. An emission speciation profile can then be used to break down this total into its constituent air pollutant categories (i.e. VOC, NOx, SO_2, CO, PM etc.)

3 Agriculture

3.1 Overview

What are the major source types?

The following categories of non-point source emissions from agriculture-related activities can be distinguished:

- use of fertilizers, pesticides, herbicides, and fungicides;
- manure management;
- burning of waste biomass;
- enteric fermentation; and
- combustion emissions from use of tractors, harvesters and other motorized equipment, heating of greenhouses, etc.

What are the major pollutants involved and their health and environmental effects?

Direct pollution from agricultural activities is mainly related to fertilizer and pesticide use. Fertilizer nutrients contribute to eutrophication in surface water, nitrate accumulation in ground water, acidification of soil, and emissions of N_2O (a gas that contributes to the greenhouse effect). Leaching of nitrate to ground water and surface water also threatens drinking water sources in many areas. Nitrogen (N) and phosphate (P) losses to surface waters contribute to eutrophication of lakes, rivers, and shallow seas. The use of waste organics as fertilizer, such as manure and sewage sludge, may also cause accumulation of heavy metals in soils.

Pesticides, herbicides and related agrochemicals (particularly the organochlorine variety) may be transported by wind or water, resulting in hazardous concentrations in the surface water and in soils. Pesticides that do not degrade easily or disappear by volatilization or adsorption may cause long-term health and environmental effects. These pesticides and their metabolites may also migrate to groundwater systems, thereby contaminating present and future drinking water resources. Pesticides also may affect non-target organisms such as pollinating insects and the pests' natural predators and parasites, thereby disturbing natural regulating mechanisms. Another problem is the development of pest resistance to specific pesticides which can lead to a vicious cycle of higher dosages being used to combat ever more resistant pest species.

Very severe local water pollution can often result from the discharge of organic waste (solids, organic matter leading to high oxygen demand, and bacteriological agents) resulting from the processing of agricultural crops or waste from animal farms. The burning of agricultural waste can also contribute to local air pollution. Anaerobic degradation of organic waste (e.g. straw in rice paddy fields, or landfills) releases CH_4 which, together with CO_2, contributes to the global greenhouse effect.

Why are the agriculture-related sources treated as non-point sources?

The emissions arising from agriculture-related activities are treated as non-point sources because they are caused by a collection of individual events which are periodic and too numerous to consider identifying as separate point sources within the inventory, nor can they be measured separately for practical reasons. These events range from the application of agrochemicals and use of motorized equipment in farming operations to the release of excess animal manure.

What is the relevance of these sources in the context of a national PRTR?

Agriculture related non-point sources may represent important contributions to total national pollutant emissions, particularly in countries where the use of agrochemicals and modern agricultural production techniques is widespread. In areas where agricultural production is intensive, the primary application of agrochemicals such as pesticides, herbicides, and fertilizer can cause significant pollutant loading of catchment waters via runoff containing residues from these applications. Eutrophication is a widespread phenomenon that affects water bodies receiving nitrates and phosphates in this manner. In areas where animal husbandry practices are intensive, these activities usually become important sources of conventional water pollutants such as solids, biological oxygen demand, nutrients and bacteriological agents.

In most countries the contribution of agriculture to national pollution is mainly caused by pesticide and fertilizer use. The burning of biomass waste and the use of motorized agricultural equipment are often only of local importance. Manure production tends to cause problems only in those countries whose practices are so intensive as to disrupt the natural absorption of this material as soil fertilizer.

What are the potential challenges and resource requirements?

Rough estimates of pollutant emissions from agriculture-related activities can often be obtained from primary production and use data. These include information on the types and quantities of crops produced, the formulation and volumes of pesticides and fertilizer used, animal counts, etc. For calculation of estimates from primary data, the level of skill and time requirements should be moderate. However, because these methods allow only limited geographical resolution of emissions and do not provide a detailed speciation of pollutant categories, they are of limited use beyond the purposes of a very general emissions inventory. For example, for studying the pollutant loading caused by agriculture related-sources in watersheds and catchment waters, which tend to be the main concerns in relation to agricultural sources, a finer level of detail would be required.

If the estimation of diffuse water pollutant emissions is to go beyond rough aggregate estimates to a localization of pollutant flows in watersheds and national water bodies, it will require the use of runoff or diffuse water pollution computer models. The more detailed agriculture-related emission estimation methods are inherent components of runoff and diffuse water pollution models applied by watershed managers or agencies interested in the overall pollutant loading of relevant watersheds or catchment waters. The use of these techniques is both time and skill intensive and will probably have to be undertaken in collaboration with regional water and agricultural authorities who may have the required local level information necessary to run these models.

A further difficulty in the context of estimating emissions to water from agricultural diffuse sources is that it may double count certain atmospheric emissions of pollutants which settle on land surfaces and subsequently contribute to water pollution via runoff. In addition, the emission estimation techniques and models available for these sources tend to concentrate on conventional water pollutants (i.e. solids, biological oxygen demand, nutrients and bacteriological agents) and tend not to specifically address toxic pollutants, which are usually the prime concern of PRTR systems.

What are the general applications and uses of these estimates?

For countries facing challenges of water pollution and eutrophication, undertaking an analysis of agricultural sources of emissions and their impact on national water bodies in the context of a national PRTR system could be a useful step in assessing baselines and developing appropriate sectoral policy responses. Also, if an inventory of greenhouse gases is to be included in the national PRTR system, the contribution of greenhouse gases from agricultural activities is likely to be relevant. An inventory of agricultural pollutant emissions can also be an invaluable resource for land use and water planning purposes as well as local level environmental quality studies.

3.2 Pesticide Use

Pesticides are unique as environmental contaminants because they are specifically designed as biocides which are deliberately released to the environment for purposes of pest management and weed control, both in agriculture as well as in the urban environment. Pesticides can be divided into major classes including insecticides, fungicides, herbicides and other minor groups. Pesticides may contain synthetic or naturally occurring organics, inorganic compounds, and petroleum solvents used as carriers for the active compound.

Pesticides are normally formulated as liquids, aerosols, or as dry powder or pellets. Both the solvent carrier and the active compound usually vaporize and contribute to VOC emissions. However liquid formulations can either be water or solvent based mixtures of the active compound, so that the VOC content of the formulation can vary substantially from product to product.

3.2.1 Data needed

There is a range of techniques available for estimating pesticide emissions to the environment. The amount of data required for technique varies in accordance with its level of sophistication. For rough estimates based on manufacturing/formulation processes and use data, the basic data set consists of the volumes of pesticides used. This information can be estimated from sales data, import data and, where available aerial spraying records and/or license records that reflect volumes of pesticide applications. If the volumes of pesticide used can be further disaggregated by location of application, some degree of geographical resolution or apportioning of the estimates by region becomes possible. To further develop these estimates of pesticide volumes used into emissions by environmental compartment (e.g. air, water, soil), partitioning ratios applicable under local conditions are required.

Next in terms of accuracy are the estimation techniques based on pesticide residue data generated through monitoring programs. These techniques require monitoring data for pesticide residues in air, soil and water, in addition to the basic data set mentioned above. Access to this data depends on the availability and comprehensiveness of local pesticide monitoring studies.

Finally, there are the estimation techniques based on mathematical models. There are several types of computer models available, of which many are proprietary. The types of data required would vary according to the particular model and model type.

3.2.2 Estimation methods

For the estimation of emissions based on the volume of pesticides used, a top-down as well as a bottom-up approach can be used. In the top-down approach, which is illustrated in Example 3A, statistical information about production, sales and the import/export of pesticides is gathered to determine the volume of pesticides used, preferably disaggregated by the geographical areas under consideration. From the initial calculation of pesticide sales, the actual amounts being applied should be estimated. This step is complicated by the fact that pesticides sales for a particular year do not necessarily equal pesticide usage in the same period since pesticide application is driven by pest pressure and the given amounts sold may be used during subsequent years.

Once the pesticide volumes used in the areas being considered are calculated, emissions can be estimated for each class of pesticide based on partitioning ratios that give the estimated emissions to air, soil, and water expected from these pesticide applications. However, taking the estimation to this level of detail requires that partitioning ratios, which are highly dependent on the particular nature of the environment where the pesticide is being released, are available. Because this data is often not available for local use conditions, the top-down approach will often not yield much detail on individual substances being released to various environmental media. Rather, the focus is generally on the categories of pesticides being applied in a particular area.

The bottom-up approach is based on an inventory of the different crops for which pesticides are used. Estimations based on expert judgement are made of the expected amount of a given pesticide used for these various crops in a given period. Where available, emissions factors can be applied for the air emission estimate. Emissions factors for a limited number of pesticides can be found in EMEP/EEA Air Pollutant Emission Inventory Guidebook[13]. Because the location and extent of the different crops often can be located through remote sensing, the geographical resolution of the estimation can be treated with greater accuracy. However, the approach is entirely dependent on local expert judgement of the volumes of pesticide used per crop variety.

3.2.3 Level of accuracy and resource requirements

Both the top-down and bottom-up approaches described above have their limitations, and a good fit between the estimation results and empirical data is not easy to achieve. The level of accuracy is affected by the availability and uncertainties in the data used for calculating volumes of pesticide used in each area. Another problem is that both methods can often only give the overall amounts used per pesticide category, not the distribution of emissions over the environmental compartments due to lack of data on partitioning ratios under local conditions.

To achieve this further level of detail, model calculations based on the pesticide application methods and the chemical properties of the active substance being applied are necessary. Available models tend to be proprietary and also tend to focus on pesticide run-off separately from pesticide emissions. However, because pesticide fate and transport is a highly complex process affected by a large range of local environmental variables, the characterization of pesticide emission estimates can often be misrepresented. Proper assessments can only be made with both field and laboratory data and making use of highly advanced mathematical models that endeavour to account for all environmental processes that could potentially affect the compound in question. Such approaches are very time consuming and expensive and are generally out of the question for the practical purposes of an emissions inventory.

Example 3A: Emission estimation using top-down approach with given pesticide volume used in a particular region

Scenario:

Authorities are interested in estimating the annual emissions caused by pesticide application in Region X where particularly intensive agricultural activity takes place. The following data are available:

- Only two types of pesticides (A & B) are used in Region X;

- The yearly volumes of these pesticides applied in Region X are known as 150 tonnes of pesticide A and 250 tonnes of pesticide B;

[13] https://www.eea.europa.eu/publications/emep-eea-guidebook-2013/part-b-sectoral-guidance-chapters/4-agriculture/3-d-f-other-use-pesticides/view

Example 3A continued

- Partitioning ratios are available from the literature for these pesticides to estimate the amounts of pesticide VOC emitted to air, the residues absorbed by soil, and the amount likely to wash off by water run off;

- Local technicians conducted a field test to calibrate these partitioning ratios to reflect local conditions;

- After calibration, the partitioning ratios for pesticide A are given as: 0.2 kg VOC emissions/kg of pesticide applied; 0.01 kg of non-soluble solid residue/kg of pesticide applied; 0.04 kg of soluble residue/kg of pesticide applied;

- For pesticide B, a water-based solution, the partitioning ratios are: 0.0 kg air emission/kg of pesticide applied; 0.02 kg of non-soluble solid residue/kg of pesticide applied; and 0.15 kg of soluble residue/kg of pesticide applied.

Sample emission calculation:

Using the above information, the emission calculation is straightforward and consists of simply multiplying the weight of applied pesticide (pesticide use data) by the corresponding partitioning ratio to obtain emission estimates for each environmental media (air, soil and water).

<u>For pesticide A:</u>

150,000 kg pesticide x 0.2 kg VOC emissions/kg pesticide = 30,000 kg of VOC emissions from pesticide A applications

150,000 kg pesticide x 0.01 kg solid residue/kg pesticide = 1,500 kg of non-soluble solid residue in soil from pesticide A applications

150,000 kg pesticide x 0.04 kg soluble residue/kg pesticide = 6,000 kg of soluble residue from pesticide A applications

<u>For pesticide B:</u>

250,000 kg pesticide x 0.0 kg VOC emissions/kg pesticide = 0 kg of VOC emissions from pesticide B applications

250,000 kg pesticide x 0.02 kg solid residue/kg pesticide = 5,000 kg of non-soluble solid residue in soil from pesticide B applications

Example 3A continues on the next page

250,000 kg pesticide x 0.15 kg soluble residue/kg pesticide = 37,500 kg of soluble residue from pesticide B applications

Estimation result :

To estimate the total emissions in Region X authorities, have to decide whether they wish to add together the emissions from the two types of pesticides. In the case where the pesticide residues and emitted compounds are quite different for each pesticide type, keeping the estimates for each type separate provides more information on the compounds emitted than adding them together. It has to be borne in mind that the above method provides very little geographical resolution. This is illustrated by the fact that we have obtained only aggregate estimates for the whole of Region X. If pesticide application data were available on a finer scale, for example for each municipality in Region X, then a finer geographical resolution (by municipality) of the estimates would have been possible.

3.3 Manure Management

Manure production by animal husbandry (e.g. cattle raising, piggeries, etc.) is in principle a component of the overall nutrient cycle and equilibrium of an agricultural system. If, however, animal husbandry is present on an industrial scale, ammonia emissions and emissions of nitrogen and phosphorus to water and soil from animal manure can cause environmental problems. Ammonia emissions, in particular, may be converted to nitric acid after atmospheric deposition and microbial conversion in the soil, making a significant contribution to total acid deposition in the soil in countries with intensive agricultural practices. In most countries, however, manure production does not disrupt the natural equilibrium of the nutrient cycle and its use as fertilizer remains an ecologically sound process.

3.3.1 Data needed

Data needed for manure production calculations are the number and type of animals, and the treatment methods being applied to the manure produced (i.e. composting, applied as soil fertilizer, discharged without treatment, discharged after treatment, etc.). These data should be apportioned as specifically as possible within the area being considered for the inventory. Appropriate emission factors for each type of manure/treatment method combination and manure characterization are also needed to estimate emissions of relevant pollutants caused by manure production. Some international emission factors are available from the EMEP/EEA Air Pollutant Emission Inventory Guidebook, Manure Management[14]. An accurate estimation will require cross checking with local studies (if available) due to differences in waste characterization and treatment methods between countries.

[14] https://www.eea.europa.eu/publications/emep-eea-guidebook-2016/part-b-sectoral-guidance-chapters/4-agriculture/3-b-manure-management-2016/view

3.3.2 Estimation methods

Once specific manure production and treatment method data by area are obtained, the estimation consists of applying an appropriate emission factor for each type of manure/treatment method combination to estimate emissions of relevant pollutants per environmental media. For example, emissions of ammonia to air will require the multiplication of a specific emission factor (quantity of ammonia released per kg of manure) by the amount of manure spread over the land as fertilizer. To estimate the release of nutrients to water (N and P) from manure sources, a different emission factor must be used.

If local manure production exceeds the carrying capacity of the land, the treatment will include dewatering and drying of the material. These operations very often result in the incorporation of high concentrations of metals, for example copper in piggery waste in places where copper is added to pig feed. If the accumulation of heavy metals in soil from treated manure sources is to be estimated, yet a different emission factor must be used for that particular purpose.

3.3.3 Level of accuracy and resource requirements

The examples above illustrate the specificity of the emission factors used which causes the accuracy of this estimation technique to highly dependent on the quality of the available data and emission factors. Obtaining reliable manure production, characterization and treatment data is both time and skill intensive and will probably require expert judgement and/or field tests. Once the data is obtained the actual estimation of emissions is fairly simple.

3.4 Burning of Waste Biomass

Burning of waste biomass is related to certain crops such as potato cultivation or orchards. In other cases, biomass burning may be related to deforestation and land clearing for grazing or crop cultivation purposes. This is the case particularly in tropical forested areas where slash and burn agricultural practices are used or population pressure causes encroachment of forests. The smoke from biomass burning is likely to cause local air pollution problems due to the particulates and CO_2 emitted, and may contribute to the global greenhouse effect, particularly in the case of large scale burning occurring mostly in the tropics.

3.4.1 Data needed

Ideally, **statistical information on the quantity (weight) of biomass burned** should be obtained, but in practice it is seldom available. In the case of burning practices associated with particular crops, expert judgment and the experience of other countries could be used to produce **an estimation of the quantity of biomass burned**. The estimation would be based on knowledge of the quantity and location of these crops being produced in the country. In the case of large scale biomass burning linked to deforestation and land clearing, **remote sensing data and geographical information systems (GIS)** could be used to give an indication of the extent of burning from which an estimation could be produced.

3.4.2 Estimation methods

The estimation of emissions could proceed in various ways depending on the type of primary data obtained. For example, in the case of crop associated burning, the calculated total weight of waste biomass burned can be multiplied by an emission factor relating the quantity released of CO_2, particulates, and other air pollutants of interest per unit weight of waste burned, as in the following equation. The necessary emission factors can be obtained from *EMEP/EEA Air Pollutant Emission Inventory Guidebook*, *Field Burning of Agricultural Residues*[15] or from the Australian NPI Manual's *Emission Estimation Technique Manual for Aggregated Emissions from Bush fires and Prescribed Burning*[16] which includes a section on determining emissions of NPI substances from agricultural burning.

emission factor specific to biomass type and air pollutant (kg emissions/ tonne burned)	x	biomass burned in area (total tonnes burned)	=	emissions of air pollution due to biomass burned (kg of air emissions per pollutant emissions)

Alternatively, if the primary data is obtained via remote sensing, it would usually consist of area (km^2) of forest or grassland burned. In this case a different emission factor would have to be obtained relating emissions expected from the burning of the vegetation mass in question per unit area burned. This emission factor would have to be multiplied by the total area burned, as indicated by the remote sensing data, by applying the following equation. An example of an estimation of this type is provided in Example 3B.

emission factor specific to vegetation type being burned (tonne air emissions/ unit km^2)	x	total area burned (total km^2 burned)	=	estimated air emissions due to biomass burned (tonne of air emissions

3.4.3 Level of accuracy and resource requirements

The uncertainties in the emission factors used, the fact that total combustion of the material often does not happen in practice, and the difficulties in the collection of reliable data on crop burning practices, particularly in the crop specific case described, cause the accuracy of this estimation technique to be low. However, this method can be used to obtain rough estimates of air emissions due to burning.

[15] https://www.eea.europa.eu/publications/emep-eea-guidebook-2016/part-b-sectoral-guidance-chapters/4-agriculture/3-f-field-burning-of/view
[16] http://www.npi.gov.au/system/files/resources/cf3d7ecb-b57f-70d4-e976-03cb241c888e/files/burningff.pdf

Example 3B: Emissions from forest burning given total area burned

Scenario:
Authorities in City Y are interested in estimating the annual contribution of air pollutant emissions occurring in the vicinity of the city due to biomass burning. In the area surrounding City Y, this type of burning is due to tropical forest clearing for cattle raising and small-scale agriculture. The incidence of these two informal activities has increased in the past several years and the air emissions produced are causing public health concerns in City Y.

The following data are available to city authorities:

- The forest department and local university have determined the following emission factors per unit area burned based on the type of vegetation prevalent in the region and its combustion profile: 30 tonne CO/km^2 burned, 60 tonne PM/km^2 burned.

- The annual estimate of burned vegetation area around City Y is 150 km^2.

Sample emission estimation and result:

Using the given data, we can directly apply the formula in the text above to estimate the air emissions from the biomass being burned around City Y, as follows:

30 tonne CO/km^2 burned x 150 km^2 burned per year = 4,500 tonnes of CO per year

3.5 Enteric Fermentation

Enteric fermentation is fermentation that takes place in the digestive systems of animals. In particular, ruminant animals (cattle, buffalo, sheep, goats, and camels) have a large “fore-stomach”, or rumen, within which microbial fermentation breaks down food into soluble products that can be utilized by the animal. The process for estimating releases from enteric fermentation is described in the OECD guidance document, Summary of Techniques for Diffuse Sources[17], and summarized here.

Methane is produced in the rumen by bacteria as a by-product of the fermentation process. This CH_4 is exhaled or belched by the animal and accounts for the majority of emissions from ruminants. Methane is also produced in the large intestines of ruminants and is expelled.

[17] www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?doclanguage=en&cote=env/jm/mono(2003)14

There are a variety of factors that affect CH_4 production in ruminant animals, such as: the physical and chemical characteristics of the feed, the feeding level and schedule, the use of feed additives to promote production efficiency, and the activity and health of the animal. It has also been suggested that there may be genetic factors that affect CH_4 production. Of these factors, the feed characteristics and feed rate have the most influence.

3.5.1 Data needed

Data needed for enteric fermentation emissions estimates are the number and type of animals. Depending on the method used, data on the feed and animal characteristics may also be required.

3.5.2 Estimation methods

The general approach to estimate CH_4 emissions from livestock is to multiply the number of animals by an emissions factor as follows:

$$CH_4 \text{ Emissions} = \text{Number of Animals} * CH_4 \text{ Emissions Factor}$$

The steps to estimate methane emissions for livestock are as follows:

1. Collect animal population and animal characteristics data;
2. Estimate the emissions factor for the animal type; and
3. Multiply the emission factor estimate by the population to get the total methane emission estimate for the population. The first two steps can be completed at various levels of detail and complexity.

The emissions factors are an estimate of the amount of methane produced (kg) per animal. Emission factors are based on animal and feed characteristics data. Specifically, the emissions factors are based on the average energy requirement of the animal, the average feed intake to satisfy the energy requirements, and the quality of the feed consumed. There are two methods by which to estimate emissions factors. The Tier 1 method relies on the default emissions factors in the IPCC Guidelines for National Greenhouse Gas Inventories[18]. These emissions factors are highly uncertain because they are not based on country-specific information. The Tier 2 method involves collecting data to calculate the emissions factor. By using the Tier 2 method, uncertainty in the emissions factors is generally lower because these emissions factors are based on country-specific conditions. Tier 1 requires data on the number of animals only, while Tier 2 requires data on the number of animals and on feed and animal characteristics.

[18] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf

Example 3C: Methane emissions from enteric fermentation for swine

Scenario:
A developing country is estimating the methane emissions from enteric fermentation from swine. Based on the information available, they follow the estimation steps described in Section 10.3 in the IPCC Guidelines for National Greenhouse Gas Inventories. The Tier 1 method relies on the default emissions factors as follows:

Step 1: Collect animal population and animal characteristics data.
The government obtained an estimate of the swine population from national experts of 2.1 million heads. The swine population estimates considered the impact of production cycles and of seasonal influences. The swine population estimate did not include subgroups.

Step 2: Estimate the methane emissions factor for the animal type.
The country used the emission factor for developing countries of 1.0 kg methane/head/year from Table 10.10 of the IPCC Guidelines for National Greenhouse Gas Inventories.

Step 3: Multiply the emission factor by the population
Multiply the emission factor estimate by the population to calculate the total methane emission estimate for the swine population.

Methane emissions = Emission Factor x Swine Population
= 1.0 kg methane/head/year x 2.1 million head
= 2.1 million kg (or 2,100 tonnes) methane emissions for the year

3.5.3 Level of accuracy and resource requirements

Given that the Tier 1 IPCC emissions factors are not based on country-specific data, they may not represent accurately the livestock characteristics for each country. The emissions factors are highly uncertain as a result.

3.6 Combustion Emissions from Use of Motorized Equipment

The emissions arising from motorized agricultural equipment such as tractors, harvesters and other motorized equipment include the major categories of air pollutants (VOCs, NOx, CO, SO_2, PM_{10}), the same air toxics mentioned for road vehicles and shipping (i.e. benzene, 1,3-butadiene, formaldehyde and acetaldehyde), and heavy metals such as Pb, Cr, Cd, Cu, and other metallic compounds present in fuel or lubricant additives. However, the air emissions from the use of this equipment in most cases will only be relevant at the local level and will not represent significant contributions to national emissions relative to road vehicles.

3.6.1 Data needed

The data needed for estimating the combustion emissions from motorized agricultural equipment are analogous to those described for road vehicles. The **amount and type of fuel used by equipment category** would have to be obtained, as well as **appropriate emission factors per engine** type or equipment category.

Statistics about the fuel used by tractors and harvesters are rarely available. If no statistics are available, it is possible to relate the amounts of fuel used to the nature of the crop for which the motorized equipment is being used. Details about these crops can in many cases be derived from national statistics. This information, in combination with expert judgement, knowledge of farming practices and the types of equipment in use, can be used to estimate amounts of fuel consumed by equipment type. The emission factors by equipment class can be derived from the factors available for road traffic.

In countries where greenhouse farming is frequent, the amounts of fuel used for the heating of greenhouses are usually available from energy statistics. Emission factors for these greenhouse installations are usually available from the literature. If a rather clean fuel such as natural gas is used for greenhouse heating, the emission contribution of this activity is not likely to be significant.

3.6.2 Estimation methods

The principles for the estimation are similar to those presented for road vehicles, that is, an appropriate emission factor for each equipment category is multiplied by the fuel use estimated for that equipment category as follows:

emission factor for equipment category (kg emissions / unit fuel consumed)	x	**fuel consumed within area by equipment category** (total fuel used)	=	**emissions per equipment category** (kg of air emissions / category)

These estimates can in turn be aggregated across agricultural equipment categories to obtain an estimate of total air emissions contributed by the use of motorized equipment used in agriculture within the inventory region.

3.6.3 Level of accuracy and resource requirements

The overall accuracy of the technique described is low given the numerous uncertainties in the emission factors and fuel use data. Calculation of the emission estimates is fairly simple but the amount of time needed to collect reliable data can be considerable.

4 Small and Medium Sized Enterprises (SMES)

4.1 Overview

What are the major source types?

Small and medium sized enterprises (SMEs) can be divided into two categories for emission estimation purposes:

- enterprises engaging in industrial production process categories in which the bigger plants are commonly treated as point sources; and

- enterprises such as dry cleaners, bakeries or service stations whose activities are directly related to the population density in the area where they are located.

What are the major pollutants involved and their health and environmental effects?

Small scale industrial operations may be a source of all major air pollutant categories: VOC, NOx, CO, SO_2, and PM_{10}. They may also be a source of discharges of water pollutants to public sewer systems. Small scale industrial operations associated with food processing, beverages, textiles, packing and distribution of foodstuffs, among others, are sources of organic waste and suspended solids. In addition to these common pollutants, operations such as leather tanning and textile and apparel industries usually discharge oil, phenol, Cr, and sulfide as liquid wastes. Other operations involving metal works and electroplating may discharge heavy metals such as Fe, Zn, Cu, Ni, Al, as well as oil, SO_4, NaOH, and CN depending on the particular metal worked and the types of chemical baths and brightening agents used. Cleaning operations involving solvents, oils and detergents also contribute to water pollutant discharge in sewers.

As illustrated by the above list, the range of pollutants discharged by small and medium sized industrial operations is very broad, and so are their health and environmental effects. Some of these effects have been described in previous sections associated with particular groups of these pollutants. The populations most likely at risk from these emissions are the workers themselves who may be exposed to these pollutants in high concentrations at their daily working environment, and the general population living in the vicinity of the operation/enterprise.

Why are small and medium sized enterprises treated as non-point sources?

Small scale industrial operations tend to be too numerous and difficult to monitor and control as single point sources, and therefore, are treated as non-point sources. In the U.S., sources emitting less than 10 tons of VOCs, or 100 tons of NOx, CO, SO_2, or PM_{10} per year may be inventoried as non-point sources. But in practice no easy rule of thumb exists for countries to decide which scale of industrial operations should be treated as point sources and which as non-point sources for the purpose of an emission inventory. The key criterion is often pragmatism: authorities often decide based on the maximum number of industrial point sources they are able to handle individually, selecting only the larger plants for individual emission reporting and leaving the rest of the industrial sector's emissions to be estimated as non-point sources.

What is the relevance of these sources in the context of a national PRTR?

In many countries, small and medium scale industrial operations may represent a very significant combined source of pollutant emissions. This situation is aggravated by the fact that small and medium enterprises tend to be enmeshed in the fabric of the urban landscape and therefore may represent a significant source of exposure to pollutants for urban populations.

In general, the contribution of emissions from small and medium sized enterprises will vary according to their particular industrial activity or production process. For sub-sectors like the chemical industry where the bulk of production takes place in large plants, the contribution of SMEs to the total emissions may be minor. For categories such as the graphic arts and printing industry, the number of small enterprises greatly exceeds the number of large plants and therefore SMEs will contribute the bulk of emissions. Emissions from SMEs engaged in services are generally minor, but there are exceptions like dry cleaning where the emissions of halogenated hydrocarbons usually represent a significant contribution to national emissions.

These examples illustrate that the relative importance of emissions contributed by SMEs will depend on the prevalence and types of SMEs in the country. However, given the size of the SME sector in most developing countries, accounting for these emission sources will be important to achieve an accurate and comprehensive emissions inventory.

What are the potential challenges and resource requirements?

The calculation of appropriate emission factors per SME category is both time and skill intensive and usually requires expert judgement to adjust internationally available emission factors to local conditions. Obtaining an accurate estimation will often also require calibration and validation of the emission factors through field tests or surveys. Another challenge presented by the SME sector is that reliable production activity data for the various SME categories engaged in different production processes is often difficult to obtain. In some countries, SMEs may not be included in official statistics and data collection efforts.

What are the general applications and uses of these estimates?

Detailed pollutant emission estimates per SME category may provide baselines from which to develop specific policy interventions aimed at this sector, which usually remains outside of government pollution management efforts due to its informal operation. The interventions that the availability of detailed emission baselines make possible include actions which address the supply chain and input substances used, pilot demonstration and diffusion of abatement techniques specifically geared to each SME category, and training on simple pollution control practices. A periodic estimation would require increased data collection from this sector and the gradual build-up of databases for tracking the progress of SMEs and thereby the effectiveness of the policies deployed. SME emission estimates could also provide invaluable input for local level public and environmental health studies, particularly if the estimates are broken down with enough detail into individual chemical species. Such estimates could provide an important input into problem identification, priority setting, and local action.

4.2 Small and Medium Sized Enterprises in Industrial Sub-sectors in Which Larger Plants Are Commonly Treated as Point Sources

In some industrial sub-sectors, SMEs are engaged in similar production processes as the larger facilities, only on a smaller scale. Specific industrial sectors in which this situation is frequent are graphic arts/printing, surface coating operations, textile and apparel manufacturing, pottery and glassware manufacturing, fabricated metal products, food processing and canning, electroplating, and leather tanning, among others. Because the larger plants are normally treated as point sources, well-defined emission factors relating emissions to actual production may be available for these production processes or categories of industrial activity. This makes it possible to scale down the estimation methods used for the larger point sources so that they can be used for smaller scale enterprises undertaking similar production activities.

4.2.1 Data needed

In general, the estimation of emissions from small and medium sized enterprises engaged in different categories of industrial activity will require the collection of similar types of data. The first type are emission factors specific to the industrial process being examined. The second type consists of SME production activity data. Emission factors for the major standard industrial categories and processes are available in the literature. As noted in *Guidance for Facilities on PRTR Data Estimation and Reporting*[19], which is Series 6 in this UNITAR guidance series, guidance documents on release estimation techniques, including many industry-specific guidance documents are consolidated in a single online location through *OECD's Resource Centre for PRTR Release Estimation Techniques*[20]. The Resource Centre includes guidance documents from OECD, UN Environment, UNECE, and UNITAR, and from the following countries: Australia, Belgium, Canada, Israel, Japan, Spain (in Spanish), the United Kingdom, and the United States. RET guidance documents from are also included.

The second type of data needed are production activity data indicating the amount of production associated with small and medium sized enterprises for each category of industrial process being considered within the inventory region. Because plant level production information usually is not available for small and medium sized companies, a top-down approach is generally used. This top-down approach uses nationwide production statistics and allocates a portion of total production to SMEs after accounting for the contribution of the larger operations to the total. This method can be used to obtain a rough calculation of production activity data for SMEs.

[19] To be added
[20] http://www.prtr-rc.fi/

In many cases, however, national production statistics may not reflect production by small and medium enterprises, or the relation between total national production statistics and the processes used by small and medium enterprises will have to be provided by expert judgement or local activity surveys. An alternative approach, therefore, is to estimate production activity data from other statistics that could better reflect local small and medium industrial activities. The sources of these statistics may be at the municipal or city council level, or from trade associations, supplier and distributor groups, or any other available source of information on the SME sector.

4.2.2 Estimation methods

The principles for the estimation involve multiplying an appropriate emission factor, specific to the production process being used, by the production activity data (quantity of product produced) in each particular category of industrial activity undertaken by SMEs, as shown in the following equation and as illustrated in Example 4A.

emission factor specific to the production process (kg emissions / unit product)	x	**total quantity of product produced** (total units produced)	=	**emissions per SME production process category** (kg of emissions per SME production process category)

The estimation has to be performed separately for each SME production process category since different emission factors would apply to different categories. Also, in order to achieve some degree of geographical resolution, the estimation would have to distinguish between groups of SMEs located in different areas within the inventory region. These estimates can in turn be aggregated across production process categories to obtain an estimate of total emissions contributed by SMEs within the inventory region. In general, the geographical resolution of this approach will be fairly low given the difficulty of obtaining reliable and localized production activity data for SMEs.

In some cases, it may be possible to define emission factors on a "per employee" basis using expert judgement or local surveys of particular SME industrial sub-sectors or production processes. If "per employee" emission factors can be derived, and if data on the number of employees per each SME category is more reliable than production activity data, then this approach may yield a more accurate estimate. In countries where statistics on the number and location of workers engaged in SMEs are available, the "per employee" approach would enable a finer geographical resolution of the emissions estimated for SMEs.

The estimation of emissions on a "per employee" basis is illustrated as follows:

emission factor specific to the production process (kg emissions/employee)	x	total number of employees engaged in this SME production process category	=	emissions per SME production process category (kg of emissions per SME production process category)

The estimation, which is further illustrated in Example 4B, has to be performed separately for each SME production process category since different categories will have different "per employee" emission factors.

This method is often the only possibility for obtaining at least an initial estimation of emissions. The Netherlands, for example, uses this method to obtain an overall picture of emissions contributed by different branches of industry. The accuracy of the result is mainly determined by whether the technology and abatement techniques of the larger companies for which data is available are comparable to those used by the smaller facilities. The degree to which this is the case is different for different branches of industry.

Another down scaling approach can also be used for rough emission estimates from SMEs, in particular industrial sub-sectors in which an acceptable number of large plants are already inventoried. The approach, which is illustrated in Example 4C, consists of simply down scaling the emissions from the large plants inventoried as point sources by a factor proportional to the relative SME/large plant composition of the sector taking into account differences due to use of fewer abatement techniques and simpler technology used in the SME component.

4.2.4 Level of accuracy and resource requirements

The specificity of the emission factors used, along with the uncertainties with regard to SME production activity, employee data and/or geographical distribution, cause the accuracy of these estimation technique to be highly dependent on the quality of available data and the degree to which the emission factors are suited to the SMEs in the inventory area. Obtaining these data and emission factors is both time and skill intensive and will probably require expert judgement and/or local field surveys. Once the data is available, the actual estimation of emissions is fairly simple.

Example 4A: Emission estimation for a city with two types of SMEs for which production data and process-based emission factors are available

Scenario:
Authorities in City Z are interested in estimating the annual emissions contributed by the sizable SME sector in the city. The following data is available:

- City Z's SMEs are only of two types: galvanizers and surface coaters.

Example 4A continued

- Production data is available for the two types of SMEs as follows: the annual production of galvanizers is 1,000 tonnes of galvanized sheet metal; the annual production of surface coaters is 450 tonnes of coated surfaces.

- From the literature and local field studies of the galvanizing and surface coating production processes, the following emission factors were obtained: For galvanizers: 0.8 kg of heavy metals liquid waste/tonne of product; and 0.07 kg of oil waste/tonne of product. For surface coaters: 80 kg of VOC/tonne of product; and 0.06 kg of oil waste/tonne of product.

Sample emission estimation:
Given the above data, the formula in the text can be used to yield the following emission estimates from SME production processes in City Z:

For galvanizing SMEs:

0.8 kg heavy metals/tonne product x 1,000 tonnes/year = 80 kg of heavy metal liquid wastes discharged per year

0.07 kg oil waste/tonne product x 1,000 tonnes/year = 70 kg of oil waste discharged per year

For surface coating SMEs:

80 kg VOC/tonne product x 450 tonnes/year = 36,000 kg VOC emissions per year

0.06 kg oil waste/tonne product x 450 tonnes/year = 27 kg of oil waste discharged per year

Estimation result:
The above emission results can be aggregated across galvanizers and surface coaters to obtain the total annual emission contribution of the SME sector in City Z as follows:

80 kg of heavy metal liquid waste discharges;
70 + 27 = 97 kg of oil waste discharges, and
36,000 kg of VOC air emissions

Example 4B: Example of top-down emission estimation for dry cleaning industries

The overall amount of tetrachloroethylene used in the dry-cleaning sector is usually available as a nationwide figure. This amount can be divided by the number of people working in the dry-cleaning sector to obtain an emission factor per employee which can be used at the local level to estimate emissions from dry-cleaning industries. If data is available on the actual amount of clothing that is dry cleaned on a nationwide as well as local scale, a finer approximation can be accomplished.

Example 4C: Example of top-down emission estimation for the printing industry

If data on production and number of employees are available for a few large printing plants, this information can be used for calculating an emission factor for the printing industry either on a per unit of production or per employee basis. The calculated emission factor can then be used to estimate emissions from the printing industry at the local level.

4.3 Small and Medium Sized Enterprises Whose Activities Can Be Directly Related to Population and Population Density

SMEs in this category are those which are engaged in process and service activities such as dry cleaners, bakeries or service stations. Given that the SMEs in this category typically serve residents of the surrounding neighbourhood, their activities can be directly related to the population density in the area where they are located.

4.3.1 Data needed

In general, the estimation of emissions from small and medium sized enterprises whose activities correlate well with population can be based on “per capita” emission factors and population data. Deriving per capita emission factors (quantity of emissions per inhabitant) requires the availability of data relating quantity of pollutants released to the size of the population in the surrounding area or population density. If sufficient data is available to derive per capita emission factors in some localities, their use can be extended to localities where no data are available, provided that adjustments are made for any substantial differences in activity levels that may exist between regions.

The other type of data needed for the estimation are population statistics which are generally available in most countries from population census or municipal or city registries.

4.3.2 Estimation methods

The estimation of emissions from SMEs whose activities can be directly related to population involves multiplying an appropriate per capita emission factor specific to the SME activity being considered by the total population in the area being considered, as follows:

per capita emission factor (kg emissions/inhabitant)	x	total population in area being considered (number of inhabitants)	=	emissions per SME activity in area being considered (kg of emissions per SME activity or category)

Alternatively, population density data can be used by applying the following equation and as illustrated in Example 4D:

per capita emission factor (kg emissions / inhabitant)	x	population in density in area being considered (number of inhabitants/km^2)	x	total area (total km^2)	=	emissions per SME activity in area being considered (kg of emissions per SME activity or category)

Both emission estimation formulations given above assume that the population density is constant in the area being considered. If the population density varies in the area, the total inventory area should be broken down into smaller areas in which the population density can be determined and then separate estimations should be performed for each of these smaller areas. This allows a more accurate geographical resolution of the estimated emissions. Otherwise a rough estimate for the total area being considered can be obtained simply by multiplying the appropriate per capita emission factor by the total population without attempting a finer geographical allocation of estimated emissions within the inventory area.

The estimation has to be performed separately for each SME production process category since different per capita emission factors would apply to different SME categories engaged in different activities (i.e. bakeries, dry cleaners, etc.).

4.3.3 Level of accuracy and resource requirements

Like other techniques described previously, these estimation techniques are highly dependent on the quality of the emission factors, thus the specificity of the per capita emission factors used for each SME production process category will determine the accuracy of the estimation results.

Deriving appropriate emission factors from the literature and adjusting them to local conditions requires time and skill. Expert judgement and local field surveys may also be needed. On the other hand, obtaining population data should not represent a major obstacle for most countries. Once the data is available the actual estimation of emissions is fairly simple.

Example 4D: Emission estimation for a city with two types of SMEs for which per capita emission factors are available

Scenario:
Authorities in City Z are interested in estimating the annual emissions contributed by the sizable SME sector in the city. The following data are available:

- City Z's SMEs are only of two types: dry cleaners and auto repair.

- Local field studies and census data reveal that on average there are 1 dry cleaning SME and 2 auto repair SMEs for each 5,000 inhabitants in City Z.

- The same studies determined that on average dry-cleaning SMEs emit 10 tonnes of VOCs per year and auto repair SMEs discharge 12 tonnes of heavy metals-oil contaminated liquid waste per year.

- City Z has a uniform population density of 500 inhabitants/km^2 and a total extension of 150 km^2.

Sample emission estimation:
Given the above data, a per capita emission factor for each SME can be calculated as follows:

For dry cleaning SMEs:

dry cleaning SME/5,000 inhabitants x 10 tonnes yearly VOC emissions/dry cleaner = .002 tonnes average yearly VOC emissions/ per capita from dry cleaning SMEs

For auto repair SMEs:

auto repair SMEs/5,000 inhabitants x 12 tonnes yearly liquid waste discharge/auto repair = .0048 tonnes average yearly heavy metals-oil waste from auto repair SMEs

Using the formula in the text, the calculated emission factors and population density data may be combined to yield emission estimates from dry cleaning and auto repair SMEs in City Z:

For dry cleaning SMEs:

.002 tonnes VOC emissions/per capita x 500 inhabitants/km^2 x 150 km^2 = 150 tonnes of VOC/year

For auto repair SMEs:

.0048 tonnes heavy metals-oil waste/per capita x 500 inhabitants/km^2 x 150 km^2 = 360 tonnes of heavy metals-oil liquid wastes discharged per year

Estimation result

Thus, the total annual emission contribution of the SME sector in City Z is estimated to be:

150 tonnes of VOC emissions per year by City Z dry cleaning SMEs;
360 tonnes of heavy metals-oil liquid wastes discharged per year by City Z auto repair SMEs;
80 kg of heavy metal liquid waste discharges;
70 + 27 = 97 kg of oil waste discharges; and
36,000 kg of VOC air emissions.

5 Natural Sources

5.1 Overview

What are the major source types?

Biogenic and geothermal phenomena may also cause emissions of certain substances to various environmental media. Living organisms such as vegetation and microbes are examples of biogenic sources, whereas volcanoes are geothermal sources of pollutants that can have impacts even on a global scale depending on the magnitude of the eruption. The oceans also play an important part in the overall natural cycle of atmospheric gases, including the contribution of natural biogenic emissions from the phytoplankton.

What are the major pollutants involved and their health and environmental effects?

VOC emissions occur naturally from vegetation and are emitted from the leaves and needles of trees. Vegetation is also found to emit numerous organic compounds. Soil processes, particularly in grasslands, may be a source of NOx emissions, although on a smaller scale than anthropogenic sources. VOC and NOx emissions from biogenic sources can contribute to the production of oxidants in rural and urban areas Other soil processes, especially in anaerobic situations, can contribute to emissions of hydrogen sulfide or nitrogen compounds. All of these biogenic emissions combined represent a source of organic acids which can contribute to regional acid deposition. Finally, emissions of air pollutants (particulates, ash, SOx, and other gases) from volcanic eruptions can affect the atmosphere on a worldwide scale, aside from the frequently devastating effect of eruptions at the local level.

Why are natural sources treated as non-point sources?

Biogenic sources are intrinsically diffuse and thus are treated as such for emissions estimation purposes. Volcanoes and other geothermal phenomena can be treated as either point- or non-point sources depending on the extent of the area giving rise to the emissions.

What is the relevance of these sources in the context of a national PRTR?

Natural sources are not generally accounted for in the context of national PRTR systems because the intensity or areal flux of their emissions is generally small relative to anthropogenic sources. In general, emissions from vegetation or soil only contribute to the background concentrations of particular pollutants. Exceptions may include certain densely wooded areas where "blue haze " may be present. Emissions from volcanoes, even though often relevant on a global scale, are not susceptible to policy action and are therefore rarely treated in a PRTR except perhaps for certain locations where a relatively constant background emission from geothermal phenomena may be present. The same applies for the emissions from oceans which are part of the natural cycle of atmospheric gases.

5.2 Estimating Emissions from Natural Sources

5.2.1 Data needed

The calculation of emissions from natural sources requires specific data particular to each local situation. In general, two types of data are required: **parameters describing the particular natural phenomena causing the emissions** and **location data describing the geographical extent of the source**. For example, emissions from soil and vegetation are determined by several factors including the properties of the specific soil or vegetation type, mean temperatures, regional meteorological conditions and other variables. Remote sensing and land use data are also required for a complete estimation of emissions from these sources. Estimation of emissions from geothermal sources may be undertaken from available geographic information and with the help of emission factors available from literature.

5.2.2 Estimation methods

The specificity of the emission estimation methods used for the various types of natural sources parallels the data requirements described previously. For example, for estimating VOC emissions from vegetation several approaches exist. The vegetative index approach consists of developing an index, representative of vegetation cover, from interpretation of satellite imagery and field surveys of actual canopy leaf volume. The appropriate vegetative index, ranging from negligible to densely wooded vegetation, is assigned to each grid cell within the inventory region. VOC emissions are then estimated based on the vegetation cover index.

Another approach makes use of highly specific VOC emission factors which require information on vegetation and soil type, leaf temperature and other variables depending on the particular model used. The emission factors are then applied on detailed maps of vegetation coverage. The use of these methods is constrained by the availability of local data and previous studies.

The estimation of NOx emissions from soils involves the use of models corresponding to land use categories. These emissions arise from microbial and chemical processes involving nitrification/denitrification cycles which are highly dependent on temperature. The approach used by most NOx soil emission models consists of developing empirical relationships based on field tests with the input variables being land use and soil temperature.

The EMEP EEA *Emission Inventory Guidebook*[21] contains additional emission estimation techniques and should be consulted for more information on the following sources:

- Volcanos
- Forest fires
- Non-managed and managed forests
- Natural grassland and other vegetation
- Wetlands and waters
- Animals
- Geological seepage
- Forest and grassland soils
- Lightning
- Changes in forest and other woody biomass stock
- Forest and grassland conversion
- Abandonment of managed land
- CO_2 emissions from or removal into soil

5.2.3 Level of accuracy and resource requirements

Given the specificity of the data and emission factors required, the accuracy of these methods depends entirely on the level of uncertainty in the required data inputs. For example, regarding vegetation types, some degree of aggregation and simplification of categories is always required for practical purposes. Local field samples or adjusted international data may not always be representative of the inventory region. Likewise, the estimation of mean soil or leaf temperatures is in itself not entirely reliable since these parameters undergo significant natural variability. Expert judgement and the availability of local studies is generally required for these estimations.

[21] https://www.eea.europa.eu/publications/emep-eea-guidebook-2016/part-b-sectoral-guidance-chapters/11-natural-sources

PART C: Non-Point Estimation Data in the Context of a National PRTR System

1 Incorporating Non-Point Source Emission Data In A National PRTR System

1.1 General Considerations

Deciding on the inclusion of non-point source emissions in the national PRTR

In the process of establishing a PRTR, it is important to undertake an overview of national environmental problems, the economic activities which contribute to them, and the substances or pollutants involved. The environmental and health-related problems of priority concern, and the economic activities which contribute to them, will differ from one country to the next. Thus, the nature and focus of a national PRTR will vary in accordance with each country's particular situation.

When considering the inclusion of non-point source emissions in a national PRTR system, a first step should be to conduct an inventory of the information available on the various economic activities which act as sources of pollutants. How many of them can be regarded as point sources? For those which are likely to be treated as non-point sources, is the amount and quality of the available information sufficient for a first estimation of total emissions?

For non-point sources in general, or for point sources for which sufficient information is not available, an inventory should be made of relevant statistical data or marketing information that could be used to construct emission estimates. Emission factors suitable for calculating emissions should be derived either from the literature or through comparisons with situations elsewhere. A general approach for conducting such an inventory involves the following three steps:

1. First, a quick gathering of available information and data relevant to emissions estimation for each economic activity under consideration should be carried out, without trying to achieve optimal accuracy. This material should be evaluated in order to determine priority sectors as well as economic activities for which more detailed information will be needed in order to estimate emissions. Areas for which information is missing should also be clearly identified.

2. The next step is to generate emission estimates with the collected information for the priority sectors identified in the first step.

3. The third step is to verify the accuracy of these emission estimates through a verification programme involving the use of modelling approaches and/or drawing upon available measurements of environmental quality. An acceptable fit of the emission estimates with other external measurements indicates that indeed the available information is enough to provide suitable estimates.

For the sake of efficiency, is important to avoid spending a lot of effort in calculations for sources that may be irrelevant at a later stage.

Management of non-point source emissions data in the context of a PRTR

The estimation of emissions arising from non-point sources will generate a national data set for these sources. To assess total nationwide emissions, this non-point data set needs to be "layered" on top of the point source PRTR data. These two data sets are structurally different. The non-point data set consists of emission estimates associated with particular geographical areas, the size of which is usually determined by the particular source being examined, and in some cases which might correspond to particular landscape features such as roads, an inland shipping route, a city, a water body, etc. In comparison, the standard point source data set consists of PRTR emission data associated with single points in geographical space.

Because the two data sets are structurally different, software aids must be used that enable the layering of the non-point source emission estimates with the standard point source emission data by geographically referencing the two data sets and combining them in an appropriate "combined emissions" data set or "aggregate emissions map." The tools developed for geographical information systems (GIS), as described below, provide the user with instruments essential for an effective layering of these two data sets in order to arrive at an overall picture of national emissions.

Another important aspect for correctly incorporating the non-point source emission estimates into the larger national PRTR system, and in fact for the overall accuracy of the whole PRTR exercise, is a good organization of the data collection, handling and information flows between local, regional, and national levels. A precise definition of data estimation, collection, and management procedures at all levels is of utmost importance. Local and regional staff need to be adequately trained, inter alia, on how to perform the data aggregation that may be required at the local and/or regional level before relaying the data to the central database. A thorough agreement on definitions (i.e. measurement units, source and pollutant categories, etc.) and methods to be applied is essential both among government staff as well as towards other actors who may be involved in the system in various capacities (i.e. individuals supplying information or estimating emissions from their plants, consultants assisting with data collection and emissions estimation, etc.)

Additional analyses which can be performed on emission estimates

In general, for emissions arising from non-point sources, the estimation techniques described in Part B of this document are sufficient to construct an aggregate emissions estimate for each particular area in which emissions of this nature are taking place. This is often all that is required for inventory (i.e. PRTR) purposes. However, for further evaluation of these emission estimates, including for instance the diffusion of these emissions away from the area from which they originate, modelling of pollutant fate and transport becomes necessary. In cases where information is required on the ultimate fate of the inventoried emissions in the environment, the use of computer modelling techniques can provide insight into the transport, treatment, and transformations undergone by particular pollutants in their receiving media (i.e. air, water and soil). However, it should be kept in mind that such techniques are very intensive in terms of data, computer analysis and professional time.

Detailed analyses of fate and transport usually fall outside the scope of the basic inventory function of a PRTR. However, some countries have included in their PRTR systems additional levels of analytical capability. These analytical capabilities involve software aids that facilitate the analysis of the raw emission inventory data for a variety of environmental management and policy purposes. These components can be thought of as analytical modules appended to the basic PRTR emissions database and inventory system.

1.2 Useful Tools

In the context of estimating emissions from non-point sources within a national PRTR system the following tools are frequently used:

- Geographical information systems (GIS)

The economic activities considered as non-point sources of emissions in the context of a national PRTR are typically located within 'governmental' as well as 'technical' boundaries. The governmental boundaries refer to provinces, towns, water boards and other responsible authorities. The technical boundaries relate to those used in the context of modelling applications, spatial planning, etc. For example, in air pollution modelling a grid cell system is needed, whereas for water pollution modelling relevant watershed areas are defined.

The development of geographical information system (GIS) tools has solved the problems associated with identifying and referencing locations which are described under these different systems. There are several GIS software packages available which allow information layers to be combined and subdivisions made with the relevant non-point source data. Digitalization of line and area elements in the data of course must first be done. In practice the grid coordinates are the starting point based upon which other data can be incorporated. For example, some tools are available which enable the user to link addresses (e.g. of facilities) with grid coordinates or grid cells. If this is not the case, the economic activities acting as non-point sources first must be located on maps so that the coordinates of the activity can then be introduced into the system. The GIS tools can also add labelling and other additional information for the digitalized governmental or technical boundaries.

Methods for estimating emissions at the source vs. emissions into the environment

It is important to distinguish between emissions localized at the source and emissions dispersing into the environment. For emissions into air, the source is usually also the place where the emission enters the environment. For emissions into water, and to a lesser extent for solid waste emissions, this is often not the case. In a PRTR, policy applications targeted at sources require information on the emissions at the source, e.g. for source monitoring. Policy applications focusing on environmental quality monitoring, on the other hand, require information on the emissions as they disperse into the environment. This often necessitates the development of a module describing the transport and treatment of the emissions, for example for wastewater, solid waste, or other specific emission flow under consideration. In many cases, associated emission flows will also need to be considered. For example, in the case of wastewater, some diffuse contribution is also provided by emissions from storm sewers, emergency outlets or low-quality sewer systems. In modelling emission flow and dispersion into the environment, care should be taken that the same emissions are not reported twice.

A related problem relates to the distinction between primary and secondary pollutants, which occurs for example in the deposition of air pollutants or leaching of polluted soil. In such cases, the same pollutant contributes twice to emissions into the environment, once when it is originally emitted and a second time through deposition or leaching after it has been released into an environmental compartment. The figures considered in these estimations are usually produced by models, and care should be taken to present the difference between the secondary pollutant flows and the primary emissions.

- Models for calculating the distribution of emissions over the different environmental compartments

For several economic activities which act as non-point sources, the environmental compartment to which the emissions should be attributed is not always clear. For instance, this is the case with several pesticide applications, as well as for lead from motorcar exhaust. There are several models available for making these calculations. However, these models usually use assumptions about particle size or application techniques which may be rather difficult to establish for a given situation. A very simple model which uses only the properties of the substance in question is the fugacity (or Mackay) model which is used to predict the migration of that chemicals diffuse or are transported in different media.

- Composition profiles for standard mixtures

Some of the emissions produced by an activity are in fact mixtures of individual chemical compounds. Some of these compounds may be individually relevant for policy makers. This is the case for hydrocarbons from motorcars, for example, or for PAHs which arise from several processes and activities. Incorporating the whole list of possibly interesting substances in the database is not very efficient but composition or speciation profiles can be used to desegregate an estimate for a pollutant category into its individual components by chemical species. In this way, separate modules containing process-related profiles of the pollutant mixtures can be developed and used whenever individual chemical species have to be reported.

• Methods for estimating the accuracy of emission factors and emission estimations

In order to compare the quality of the different data to be used for emission estimation, it is important to clearly define the quality criteria. A simple classification that works in practice is applied in the EMEP/UNECE *Air Pollutant Emission Inventory Guidebook*[22]. This classification uses the following definitions.

Rating	Definition	Typical Error Range
A	An estimate based on a large number of measurements made at a large number of facilities that fully represent the sector	10 to 30 %
B	An estimate based on a large number of measurements made at a large number of facilities that fully represent the sector	20 to 60 %
C	An estimate based on a number of measurements made at a small number of representative facilities, or an engineering judgement based on a number of relevant facts	50 to 200 %
D	An estimate based on single measurements, or an engineering calculation derived from a number of relevant facts	100 to 300 %
E	An estimate based on an engineering calculation derived from assumptions only	Order of magnitude

It is important to document the data sources and expected level of accuracy that enters into the construction of any emissions estimate. In this way a measure of the uncertainty associated with each estimate can also be reported, along with the estimate, to give the user a more objective picture.

2 Some Practical Experiences On The Incorporation Of Non-Point Sources In A National PRTR:

THE NETHERLANDS EMISSION INVENTORY SYSTEM

2.1 Development of the Netherlands PRTR System

In the Netherlands, the first steps for the establishment of an integrated PRTR were made as early as 1974. Over the years, the system has gradually developed into a tool which is used in direct support of national policy. In 1989, the National Environmental Policy Plan made an important contribution to this development, defining groups of priority emission sources and emission goals or targets to be reached for each of the groups. The plan also defined a series of environmental themes reflecting various policy priorities as well as indicators for each of those themes. The

[5] https://www.eea.europa.eu/publications/emep-eea-guidebook-2016

[6] www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?doclanguage=en&cote=env/jm/mono(2003)14

PRTR system was adapted to reflect and support this overall policy approach. Other adaptations or additions to the PRTR occurred as new data analysis tools became available or in response to new requests from international, national and regional authorities. This process of adapting and improving the PRTR system is ongoing.

In 1992 the three ministries concerned with environmental problems decided that the Emission Inventory Database should become the national database from which all information about emissions should be provided to the users. Based on this decision, a structure was developed in which the three ministries (Housing, Spatial Planning and the Environment, Traffic and Public Works, and Agriculture) and their supporting institutes, work together with the National Institute for Public Health and the Environment, Statistics Netherlands and the organization TNO which has been providing technical support during the whole PRTR development process. These activities are coordinated by the Environmental Inspection who is responsible for the final products. Every year a national report is produced by several expert teams in which the partners are represented. The teams report to a central committee chaired by the Environmental Inspection. The data accepted by the partners are used for actualization of the database and are available to the public.

2.2 Key Features of the Netherlands PRTR System

2.2.1 Inclusion of point source and non-point source data

The Netherlands PRTR is operated as a single system incorporating various tools for different applications and categories of sources. The distinction between “Individual registration” for point sources and “Collective registration” for non-point and diffuse sources is only related to the organization of the data collection process. In general, the point sources have a more accurate indication of location and the emissions data are directly derived from measurements. For non-point sources, various kinds of data are used to estimate emissions depending on the particular type of source in question. Aside from this there in not a sharp borderline between the data input systems for point and non-point sources.

2.2.2 Target groups and environmental themes

In the National Environmental Policy Plan the different emission sources were aggregated in so-called target groups, each comprising a different source category. With representatives from these target groups (i.e. industry representatives, etc.) agreements were established in which the reduction goals for the coming years were defined. Environmental themes reflecting environmental policy priorities in The Netherlands were also defined, and an indicator system developed to enable the policy makers to monitor progress towards these policy goals.

The ultimate goal of any environmental policy should be to improve the quality of the environment. The environmental themes provide a tool for monitoring these improvements. The only way to achieve results, however, is to direct efforts at the source of the pollution, i.e. the target groups.

The PRTR system can be used to link or relate the target group emissions with improvements/ deterioration of the indicators for various environmental policy themes. In this way, the PRTR is used as an environmental management tool in The Netherlands.

Target Groups (Source Categories)

Refineries

All refineries in The Netherlands are treated as point sources. The main emissions are determined at the plant itself. The information is introduced into the general system using tools like the hydrocarbon profiles or the metal content of crude oil.

Power plants

All power plants are treated as point sources. The emissions are based on measurements at the stacks and are supplemented by emission factors or profiles for individual hydrocarbons.

Waste disposal

The waste burning plants are treated as point sources. The emissions are measured at the stack. The landfills are individually located in the system on a 500 x 500 meter grid basis but their emissions to air and water are calculated from a model using yearly statistical information about the amount and type of wastes and emission abatement measures taken.

Industry

The 700 biggest companies are treated as point sources. They are present in the system with individual emissions which are either measured or calculated with emission factors. The data may be provided by the companies themselves or measured by TNO who gathers the information on contract from the Ministry. For emissions into water, the majority of the information comes from the responsible authorities who have extensive measuring programs. In the near future only the 300 biggest companies will be obliged to provide data in a standardized format. A verification program is being developed.

For profiles and external wastewater treatment, the tools from the general system are used. The other 40,000 industrial companies are identified by name and address, activity code and number of employees, and the emissions are generally calculated by the task groups mentioned above in terms of their contribution to nationwide production. The grid location is derived from an available address/grid tool. The facilities are also connected to the wastewater transport and treatment module (by hand so far). The total database contains about 400,000 companies, but the greater part is in the trade sectors. A discussion about their contribution to pollution is still going on.

For practical reasons, the emissions from a small fraction of the industrial activities are calculated in relation to population density. Examples include bakeries, garages and small dry-cleaning facilities. At the time when the general industrial address database was not yet available, more industrial activities were linked to population density, or for activities located in certain regions, industrial areas or town centres. The emissions for the smaller companies are at the moment extrapolated from the point sources in the same sector nationwide by their contribution to total production and localized by assuming a linear relationship with the number of employees. This approach, however, needs to be improved for some industrial branches. A project has been initiated by Tebodin, TNO and Statistics Netherlands in which analyses of the different industrial branches will be made to determine the representativeness of the larger companies as compared to the SMEs and to assess the contribution of the SMEs to total emissions. A possible outcome of this work may be the development of emission factors which are related to company size.

Agriculture

Agriculture is treated as a non-point source. The main pollution sources in The Netherlands are pesticide use and excess manure production, with minor sources like harvesting machines and tractors. All activities are attributed to a 500 x 500 meter grid. Information comes from a number of sources which in some cases are not fully consistent. Pesticide use comes from a combination of sales figures through two enquiries using different selections. The relation with the individual crops is provided by agricultural consultants, the distribution over the different compartments is provided by a model from an institute related to the agricultural university. The location is mainly based on remote sensing information and topographical maps. The task group mentioned above reaches consensus about the optimal figures for a given year. Figures about the number of cattle come from the same statistics mentioned above but discussions about the penetration of abatement techniques and their effectiveness still need some expert judgement.

Traffic and Transport

Traffic is treated partly as a line source and partly as a non-point source. For the main roads, traffic intensities for different types of cars are measured on a regular basis. The locations of these roads are included in the system in digitalized form and emissions are calculated by using emissions factors per car/km for the relevant driving mode. The rest of the emissions from road traffic is calculated top-down by Statistics Netherlands using fuel statistics and some enquiries about car use by consumers. These emissions are located by relating them to the population density.

Emissions from sea-going and inland shipping are calculated from data from bridges and locks or harbour information. Recreational shipping is still mainly estimated by expert judgement. The railway company has an excellent database which provides all relevant information. Calculations for airports are based on information from the individual airports and international emission factors.

Consumers

Data on the location of different types of houses on a 500 x 500 meter grid are provided by a joint project from the Postal Service, Statistics Netherlands and the National Planning Office. They locate addresses with an indication about the sort of activity belonging to the address. A simple adding program provides the number of houses. The number of inhabitants is related annually to the number of houses from information about the number of inhabitants per town. In an earlier stage the total number of inhabitants per town was distributed over the relevant areas using assumptions about population density in certain types of areas (town-centre, nineteenth century area, suburb, etc.). A great number of household and consumer-related activities are related to the population density. Some give only minor contributions, while others like solvent use or paint application are relevant on a national level.

Transport and Treatment of Wastewater

Data for this target group, which includes emissions from storm sewers, rainwater outlets and effluents from wastewater treatment plants, are in a separate module in the PRTR database.

Production of drinking water

This is a target group of minor importance. Discussions about the aspects to be monitored are ongoing.

Trade, services, government and research organisations

This is a target group that is mainly linked with other activities. Special monitoring targets are not yet defined.

Nature

While this is not an official target group, definition and incorporation into the database is necessary for achieving the complete picture. Data about natural areas are derived from topographic maps combined with satellite information. Emission factors for hydrocarbons from trees require a breakdown among the different types of trees. At the moment this is provided by a combination of a rather old statistics from 1982 and satellite data. Other interesting areas like wetlands are located from topographical maps. All data from these maps will be available shortly in a digitalized form from the Topographic Service.

Environmental Themes

As previously mentioned, the PRTR emissions data for the above target groups have to be interpreted in the light of indicators tracking the evolution or trends in policy targets defined for each environmental theme. The following environmental themes have been identified in The Netherlands:

Climate Change

The main substance is of course carbon dioxide emitted mainly by power plants, traffic, and spatial heating. Other contributions come from methane, sources of which include landfills, ruminants and anaerobic processes, and dinitrogen-oxide which arises from certain industrial processes, agriculture, and some natural processes.

Acidification

The primary substance of concern with regard to acidification has always been sulfur dioxide from combustion processes, with nitrogen oxides from traffic and industry in second place. In the Netherlands, ammonia from excess manure is an important source in particular because the cattle concentrations are located near the scarce woods.

Eutrophication

Eutrophication of lakes and rivers by excess phosphorus and nitrogen compounds is an especially important problem for The Netherlands. The cause is the great number of rather shallow lakes which are very vulnerable to this sort of pollution. Since the use of phosphorus compounds in detergents has been forbidden, agriculture has emerged as the main source, combined with remobilization of previously disposed sludges.

Waste Disposal

The problems around waste disposal are rather specific for The Netherlands, as the space available for landfills is very limited due to the high population density. Activities are directed at reducing the amount of solid waste by consumers and stimulating reuse.

Disturbance

Disturbance is a theme directed at reducing noise and odours. Noise abatement measures are directed at airports, main roads and sometimes at special industrial activities. Odour reductions are relevant near certain industrial activities as well as in areas where cattle raising with excess manure production is present. Criteria for the intensity of the problem are the number of people exposed to certain levels of noise and/or odours.

Dehydration

While the Netherlands is a rather wet country, there are still areas where the use of water for agriculture or industry has caused the lowering of the groundwater level below acceptable limits. The resulting degradation of natural areas has made this a relevant theme in certain areas.

Squandering

This is an environmental theme that has a lot to do with public awareness. There is a close relationship with life-cycle projects and efforts to stimulate reuse of wastes.

All of the above environmental themes are linked with indicators which are based on the contribution of individual substances to the general theme indicator. This provides the policy makers with a tool to monitor the effects of the environmental policy on the quality of the environment. A more in-depth discussion of the various policy applications that are possible by relating target groups of sources and the evolution of environmental theme indicators can be found in The Netherlands Emissions Inventory annual report.

Sources

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