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**RESOURCE COMPENDIUM OF PRTR RELEASE ESTIMATION TECHNIQUES
PART 2 : SUMMARY OF DIFFUSE SOURCE TECHNIQUES**

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Series on Pollutant Release and Transfer Registers

No. 6

**RESOURCE COMPENDIUM OF
PRTR RELEASE ESTIMATION TECHNIQUES**

Part 2 : Summary of Diffuse Source Techniques

IOMC



INTER-ORGANIZATION PROGRAMME FOR THE SOUND MANAGEMENT OF CHEMICALS

A cooperative agreement among **UNEP, ILO, FAO, WHO, UNIDO, UNITAR and OECD**

**Environment Directorate
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT
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PRTR Series No. 1: Proceedings of the OECD International Conference on Pollutant Release and Transfer Registers (PRTRs). PRTRs: National and Global Responsibility. Tokyo, 9-11 September 1998. Part 1 (1999).

PRTR Series No. 2: Proceedings of the OECD International Conference on Pollutant Release and Transfer Registers (PRTRs). PRTRs: National and Global Responsibility. Tokyo, 9-11 September 1998. Part 2 (1999).

PRTR Series No. 3: Presentation and Dissemination of PRTR Data: Practices and Experiences, Getting the Word and Numbers Out (2000).

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The Organisation for Economic Co-operation and Development (OECD) is an intergovernmental organisation in which representatives of 30 industrialised countries in North America, Europe and the Pacific, as well as the European Commission, meet to co-ordinate and harmonise policies, discuss issues of mutual concern, and work together to respond to international problems. Most of the OECD's work is carried out by more than 200 specialised Committees and subsidiary groups made up of Member country delegates. Observers from several countries with special status at the OECD, and from interested international organisations, attend many of the OECD's Workshops and other meetings. Committees and subsidiary groups are served by the OECD Secretariat, located in Paris, France, which is organised into Directorates and Divisions.

The OECD began work on Pollutant Release and Transfer Registers (PRTRs) in 1993 as a follow-up to the United Nations Conference on Environment and Development. In co-operation with UN organisations and representatives of OECD Member governments, industry and the public, it prepared a Guidance Manual for governments considering the establishment of PRTRs. The Guidance Manual was published in 1996; the OECD Council adopted a Recommendation on Implementing Pollutant Release and Transfer Registers in the same year.

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This publication was produced within the framework of the Inter-Organisation Programme for the Sound Management of Chemicals (IOMC).

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The Inter-Organisation Programme for the Sound Management of Chemicals (IOMC) was established in 1995 by UNEP, ILO, FAO, WHO, UNIDO, UNITAR and the OECD (the Participating Organisations), following recommendations made by the 1992 UN Conference on Environment and Development to strengthen co-operation and increase international co-ordination in the field of chemical safety. The purpose of the IOMC is to promote co-ordination of the policies and activities pursued by the Participating Organisations, jointly or separately, to achieve the sound management of chemicals in relation to human health and the environment.

FOREWORD

OECD began work on the PRTR Release Estimation Techniques project in 1999. That same year, an expert workshop was held in Australia to (1) identify what information is readily available on release estimation techniques for point and diffuse sources, and (2) recommend what can be done to improve the use and availability of such techniques. One of the recommendations from the workshop was to establish a Task Force to manage OECD work in this area. The Task Force on PRTR Release Estimation Techniques was established in February 2000 under the auspices of the Joint Meeting of the Chemicals Committee and the Working Party on Chemicals, Pesticides and Biotechnology.

The work programme of the Task Force calls for the development of several technical documents to provide governments and industry - as well as others who are interested in this issue - with information and practical guidance for identifying, selecting and applying different techniques for estimating pollutant releases from point and diffuse sources and from transfers. The *Resource Compendium of PRTR Release Estimation Techniques* is the first in a series of documents created to help accomplish this goal. The intent of the *Resource Compendium* is to provide OECD countries with a basic information resource on estimation techniques typically used to quantify releases from point and diffuse sources and from transfers for a PRTR. It consists of three separate volumes: Part 1 summarises techniques used for point sources; Part 2 provides information about techniques used to quantify releases from diffuse sources; and Part 3 summarises information about techniques used to calculate the amounts of chemicals found in transfers. ***This document is Part 2 of the Compendium.***

The *Compendium* was prepared under the auspices of the OECD Task Force on PRTR Release Estimation Techniques, recently renamed the Task Force on PRTRs. Ms. Rhonda Boyle of the Environment Protection Authority, Victoria, Australia prepared Part 2 of the Compendium. It is published on the responsibility of the Secretary-General of the OECD.

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EXECUTIVE SUMMARY

Background

A key aspect of any Pollutant Release and Transfer Register (PRTR) programme is the estimation techniques used to generate data on releases from point and diffuse sources, and on transfers to off-site treatment. Companies that report data to a national PRTR generally estimate releases with, for example, emission factors or mass balance calculations, rather than submitting specific monitoring data. As different industrial processes and activities involve different throughputs, equipment and operating conditions, different methods for estimating releases and transfers are required. However, the development of new release estimation techniques can be extremely resource intensive, as can the identification and collection of techniques from other countries. To help reduce costs to Member countries, the OECD was asked to undertake work on release estimation techniques (RETs) and transfer estimation techniques, to collate information on techniques used and make them widely available.

The first step in this work was to survey OECD countries to identify available techniques. The second step was to hold an expert workshop to review the techniques identified and to recommend what can be done to improve the use and availability of such techniques. At the 1999 Canberra Workshop on Release Estimation Techniques for Point and Diffuse Sources (OECD, 200a), the difficulty and cost in locating estimation techniques for quantifying releases and transfers was raised as a key issue facing decision makers. While the information presented in the workshop background documents provided a good start, the workshop recommended that further work was needed and that this work should be managed and overseen by a Task Force on PRTR Release Estimation Techniques.

In February 2000, the Joint Meeting of the Management Committee and Working Party on Chemicals, Pesticides and Biotechnology established a Task Force on PRTR Release Estimation Techniques. In November 2002 the Joint Meeting expanded the work area of the Task Force and renamed it the Task Force on PRTRs. The work programme for this Task Force calls for, among other things, the development of a resource compendium containing information about techniques used in OECD countries to quantify releases and transfers for point and diffuse sources, as recommended by the Canberra Workshop.

Context

Historically, pollutant emission inventories have been developed as tools to assist governments to tackle environmental problems, particularly air pollution, global warming, pollution of inland and marine waters and contaminated soils. The scope of many inventories includes not only 'point' (or industrial) sources, but also diffuse sources. Point sources are considered to be stationary industrial facilities that generate emissions. Diffuse sources can be defined as: area sources, mobile sources, biogenic sources and geogenic sources. In many situations, diffuse sources can be a major source of emissions. For example, in many urban areas, the primary source of oxides of nitrogen is motor vehicle emissions rather than industrial facilities.

The primary difference between emission inventories and PRTRs is that PRTRs are intended to cover all environmental media, whereas the more *traditional* emission inventories are media-specific (*i.e.* air or water). In addition, the scope of *traditional* emission inventories tends to cover a more limited set of

pollutant species than PRTRs. Finally, there has often been little attention given to make emissions data contained in traditional inventories, particularly data from individual facilities, accessible to the public. While PRTRs are national systems, emission inventories vary and can be national or limited in scope to a defined geographic region or to a specific catchment area or airshed. When incorporated into a PRTR, the aggregated data from diffuse sources complement point source data by providing context, including information about the relative contributions of various sources and broad spatial patterns.

The development of new release estimation techniques, or the identification of techniques from other countries, can be extremely resource intensive. However, as noted at the Canberra Workshop, there are many available techniques that could be shared between countries. This Compendium summarises those release estimation techniques used for many of the diffuse sources that are typically included in a PRTR or for a specific emission inventory. Specific attention is paid to the manner in which *traditional* emission inventories overlap with PRTRs, including consideration of the following issues: how the design of a PRTR affects the data that are available for use in a diffuse source emission inventory, the release estimation techniques that can be used and the accuracy of the data reported in a diffuse source inventory.

Description of the Resource Compendium

The Resource Compendium of PRTR Release Estimation Techniques is divided into three parts. Part 1 focuses on point sources, Part 2 covers estimation techniques to quantify releases from diffuse sources and Part 3 will provide some basic information about techniques used to quantify amounts of chemicals in transfers, i.e. in wastes transferred off-site for treatment. As the documentation and details associated with a specific estimation technique can be lengthy (hundreds of pages for some techniques), the Resource Compendium simply gives information about a technique and the location where more documentation can be found. (It is anticipated that further information about techniques used to quantify releases and transfers from sources covered by a PRTR, and their documentation, will be made accessible through an Internet-based Resource Centre of RETs which the OECD Task Force on PRTRs is presently developing).

This Compendium is intended to assist those involved with PRTRs and emission inventories to make decisions and obtain more detailed guidance information. This Compendium is not intended as a stand-alone guide on release estimations, but rather as a roadmap to help users identify what techniques are being used and where more detailed guidance can be found.

Summary of contents

This is Part 2 of the Resource Compendium of PRTR Release Estimation Techniques. It defines diffuse sources and discusses how diffuse source data are collected, describes the different types of techniques available for various diffuse sources and discusses how to identify or calculate the input data for the techniques. One final point raised in this document is that there are release data available in various emission inventories. However, most PRTR programmes have yet to integrate such data. (While a PRTR is not an emission inventory *per se*, these inventories provide examples on how releases from diffuse sources are included and calculated). In the future, countries may wish to look at the data sources available to determine whether such data can be integrated into annual PRTR reports.

Part 2 of the Resource Compendium specifically addresses estimation techniques for releases from diffuse sources, provides guidance and information on what techniques are available and notes the locations of where this information might be found. While this document is not a comprehensive guide of all techniques available and all source categories, it does provide a wide range of information about techniques currently used in a large number of OECD countries.

LIST OF ACRONYMS

BOD	Biological oxygen demand
CARB	California Air Resources Board
CITEPA	Centre Interprofessionnel Technique d'Etudes de la Pollution Atmospherique (France)
CO	Carbon monoxide
CO ₂	Carbon dioxide
CH ₄	Methane
CLRTAP	Convention on Long Range Transboundary Air Pollution
COD	Chemical oxygen demand
CORINAIR	European programme to establish coordinated inventory of atmospheric emissions
CRTK	Community right-to-know
DETR	Department for the Environment, Transport and Regions
DEFRA	Department for the Environment, Food and Rural Affairs
EA	Environment Australia
EEA	European Environment Agency
EC	European Commission
EIIP	Emissions Inventory Improvement Programme (US)
EMEP	Co-operative Programme for Monitoring and Evaluation of the Long Range Transmissions of Air Pollutants in Europe
EPAV	Environment Protection Authority, Victoria, Australia
EPER	European Pollutant Emission Register
EU	European Union
ETC	European Topic Centre
GIS	Geographic information system
HAP	Hazardous air pollutant
HARP	Harmonisation of reporting procedures
HELCOM	Helsinki Convention
HFC	Hydrofluorocarbon
IEA	International Energy Agency
IFEN	Institut Francais de l'Environnement (France)
IFCS	Intergovernmental Forum on Chemical Safety
IOMC	Inter-Organisation Programme for the Sound Management of Chemicals
IPCC	Intergovernmental Panel on Climate Change
IPPC	Integrated Pollution Prevention and Control
LPG	Liquified petroleum gas
LTO	Landing and take-off cycle (for aircraft)
MEDPOL	Convention on Protection of the Mediterranean Sea
N	Nitrogen
NAAQ	National ambient air quality standard (US)
NGGIC	National Greenhouse Gas Inventory Committee (Australia)
NH ₃	Ammonia
N ₂ O	Nitrous oxide

NO _x	Oxides of nitrogen
NO	Nitric oxide
NO ₂	Nitrogen dioxide
NMVOOC	Non-methane volatile organic compounds
NPI	National Pollutant Inventory (Australia)
NPRI	National Pollutant Release Inventory (Canada)
NSW EPA	New South Wales Environment Protection Authority, Australia
NTI	National Toxics Inventory (US)
O ₃	Ozone
OECD	Organisation for Economic Co-operation and Development
OSPARCOM	Oslo and Paris Commission
P	Phosphorous
PAH	Polycyclic aromatic hydrocarbon
PFC	Perfluorocarbon
POP	Persistent organic pollutant
PRTR	Pollutant Release and Transfer Register
QA	Quality assurance
QC	Quality control
RET	Release estimation technique
RVP	Reid vapour pressure
SIP	State Implementation Plan (US)
SF ₆	Sulphur hexafluoride
SO ₂	Sulphur dioxide
SNAP	Selected Nomenclature for Sources of Air Pollution (Europe)
TIM	Time in mode (for aircraft)
TFEI	Task Force on Emissions Inventories
TRI	Toxics Release Inventory (US)
UNCED	United Conference on Environment and Development
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNITAR	United Nations Institute for Training and Research
US EPA	United States Environmental Protection Agency
VKT	Vehicle kilometres travelled
VMT	Vehicle miles travelled
VOC	Volatile organic compound

CHAPTER 1: INTRODUCTION

1.1 Background and context

A key aspect of any Pollutant Release and Transfer Register (PRTR) programme is the release or transfer estimation techniques used to generate release and transfer data from point and diffuse sources. For point sources, companies that report data to a national PRTR may use estimation techniques (*e.g.* emission factors, mass balance calculations) to characterise pollutant releases and transfers, rather than submitting specific monitoring data. As different industrial processes and activities involve different throughputs, equipment and operating conditions, different methods for estimating releases and transfers are required. Different types of techniques are also used to calculate releases from diffuse sources.

In 1998, the Environment Agency of Japan hosted an OECD PRTR conference to take stock of the progress and status of PRTRs around the world and defining future directions (OECD, 1999). One of the recommendations was that the OECD should provide guidance on sharing techniques for estimating pollutant releases from point and diffuse sources.

In December 1999, a workshop was held in Canberra, specifically to discuss release estimation techniques (RETs) for point and diffuse sources. One recommendation from this workshop (OECD, 2000a) was to provide additional information on techniques used to estimate releases from diffuse sources. Another recommendation was to develop a clearing-house on the Internet to keep the compendium of methods and other information about RETs up-to-date. Based on these recommendations, this report presents a summary of the major RETs used to estimate diffuse emissions to air and water, an overview of OECD country programmes and information on relevant contacts and documentation.

Increasingly, OECD countries are including release data from diffuse sources in their PRTRs. This is to provide a broader picture of the sources of pollutants. PRTR managers wanting to incorporate diffuse sources will often be able to incorporate existing inventory data. For example, diffuse source components of a greenhouse gas inventory could be incorporated directly, although further work may be needed to disaggregate such data spatially. Other emissions inventory data may need to be supplemented, for example, expanding traditional air inventory data to incorporate 'hazardous air pollutants' as well as criteria air pollutants. When incorporated into a PRTR, the aggregated data from diffuse sources complement point source data by providing context, including information about the relative contributions of various sources and broad spatial patterns.

1.2 Study methodology

This study involved a review of existing information available from key contacts, publications and information on the Internet. Details of the key reference sources are provided in relevant sections of the report and in the bibliography. Key contact organisations for diffuse source inventories are listed in Annex 1. Lists of different diffuse sources and major groupings in USA, the Netherlands and elsewhere in Europe are provided in Annex 2.

Interviews were held with the European Commission and country representatives in selected European countries. A series of on-site interviews were conducted in Europe as many European countries have diffuse source inventories. A list of interviewees and a summary of the main information obtained from these interviews is provided in Annex 3.

1.3 Structure of the report

This report is divided into six chapters and three annexes. Chapter 2 describes the characteristics of traditional emission inventories that incorporate diffuse sources. Chapter 3 provides an overview of release estimation techniques for diffuse sources. Chapter 4 addresses alternative approaches for selected sources and Chapter 5 contains an overview of country approaches to specific emissions inventories.

The first two annexes contain information on how to locate RETs for diffuse sources. The third annex summarises the information collected in the various interviews that were conducted.

CHAPTER 2: CHARACTERISTICS OF INVENTORIES THAT INCLUDE DIFFUSE SOURCES

2.1 Introduction

Before considering specific release estimation techniques to quantify releases from diffuse sources, it is important to understand the aims and uses of *traditional* emission inventories, the types of pollutants considered in such inventories and the relationships between point and diffuse sources. These factors define the general methodological approaches and RETs used for different source categories in diffuse source inventories.

The remainder of this chapter will focus on diffuse sources data in emission inventories and provide working definitions of pollutant sources.

2.2 Aims and uses of emission inventories

An emission inventory is a comprehensive listing, by source, of the emissions of specified pollutants to air, water or land, covering a specific geographic area and for a particular time period. Inventories vary greatly depending on the purposes for which they are developed according to:

- the number and types of pollutants addressed;
- whether diffuse sources are included in addition to point sources;
- the spatial coverage and degree of detail including spatial and temporal resolution;
- the degree and style of transparency and public access to the inventory data; and
- their links with government regulatory processes.

PRTRs form one type of inventory. Their key distinguishing characteristics include: public access to data on releases from individual industrial facilities, site-specific reporting, periodic reporting (typically annually), a listing of pollutants, and coverage of all environmental media (air, water, land) and transfers.

Many other types of inventories exist in OECD countries. In general, those that include diffuse sources are not integrated across the environmental media but relate to a specific environmental medium (*i.e.* to air, water or land). While they may be nationally based, many apply to smaller geographic regions and are defined by jurisdictional or administrative boundaries, urban airsheds or catchments.

The driving forces for the development of an inventory that can influence whether or not diffuse sources might be included are:

- Regulatory: These inventories generally focus on point source emissions (to single or multiple environmental media depending on the inventory scope) and are frequently integrated with licensing and emissions monitoring systems.

- Community right-to-know: These tend to focus on point source emissions to all media and to have longer pollutant lists (*i.e.* cover a greater number of pollutants) than inventories developed solely for regulatory purposes. While some of these inventories include diffuse sources (*e.g.* the Netherlands Emissions Inventory, the Australian National Pollutant Inventory), the majority tend to focus on point source releases.
- Government planning, policy development and reporting tools: These generally include point and diffuse sources and may have more restricted pollutant lists than inventories developed for the purposes of community right-to-know. Their focus is generally on known environmental problems and the inventories are used as research tools for informing longer-term policy design, development and evaluation.

Diffuse source inventories for air and, to a lesser degree, water, are well established in virtually all OECD countries. In most cases, these inventories are medium-specific and generally attempt to include all significant point and diffuse sources. The typical uses of both air and water inventories include:

- monitoring trends in emissions (*e.g.* against emission reduction targets);
- characterising the nature of environmental burdens and their sources;
- assisting policy development;
- tracking progress of government policy (including regulatory) initiatives;
- as inputs to airshed and catchment modelling in order to assess current and potential future environmental quality;
- as inputs for risk assessment studies;
- assisting policy development, evaluation and reporting for national or international programmes;
- assisting environmental impact assessments in relation to proposed new sources of emissions;
- disseminating information so as to raise public awareness of environmental issues;
- broadening public involvement in environmental policy decision-making processes; and
- helping select sites for locating monitoring equipment.

For all of these applications, having a reasonably complete, technically defensible inventory, with no major sources missing, is paramount. Clearly, the level of detail and accuracy will vary, depending on the intended end uses of the inventory.

2.2.1 Air emission inventories

Air emission inventories have developed over several decades and methodologies for estimating emissions from diffuse sources are well established and documented. The spatial scale and the level of detail of such inventories range from national inventories down to those covering specific urban regions. National inventories (such as greenhouse gas inventories) tend to be used to monitor trends and progress towards emissions reduction strategies, to support national or state policy development, and may be used for broad scale modelling to assess transboundary impacts, such as acid rain.

Inventories established at a regional or local level are also used to assist policy development. However, they differ from national inventories in that they are generally used in combination with air quality modelling and possibly exposure modelling, under different meteorological conditions. These inventories

play an important role in the development of air quality management plans for urban regions. This usually involves the projection of emissions into the future and modelling of alternative scenarios to explore likely implications for future air quality. The model outputs can also be used as background concentrations when assessing the impact of proposed new industrial or road developments. Spatially disaggregated emissions data in the form of maps showing gridded emissions are often used to assist land use planning, indicating areas likely to be subject to high levels of pollution. Inventory data can also assist with the design of monitoring networks. When incorporated into a PRTR, the aggregated data from diffuse sources complement point source data by providing context, including information about the relative contributions of various sources and broad spatial patterns.

Traditionally, air emission inventories have focused on what are typically referred to as common or criteria pollutants – those for which air quality standards are defined and which are known to have significant health and environmental impacts. Increasingly, however, other pollutants are being included, particularly heavy metals and various organic chemicals. This is being driven by the increasing awareness of the potential adverse impacts of these substances and international reporting requirements. For example, greenhouse gas inventories have evolved in the last decade, closely linked to the requirements of UN Framework Convention on Climate Change (UNFCCC). These are generally prepared on a national or sector/activity basis. Often, data are not spatially disaggregated, as the location of emissions sources is not a relevant consideration for climate change impacts.

An important characteristic of air emission inventories is that they include extensive underlying data sets, including:

- spatially and temporally resolved data (*e.g.* emissions for every hour over a year, building in seasonal, weekly and diurnal variations, spatially resolved to varying grid squares *e.g.* 1 kilometre or 20 kilometres, and specific stack locations and heights);
- emission factors and activity data used to generate emissions estimates;
- source data collected from industry and other data providers, such as population, vehicle kilometres travelled (VKT), sales information;
- spreadsheets and databases representing various steps in the calculation procedures; and
- spatial data, often part of a computerised geographic information system (GIS).

The aggregated data on total emissions from sectors and individual point sources represent the ‘front-end’ of an inventory. It is often the case that this is the only information that is widely disseminated to stakeholders (*i.e.* the underlying datasets are frequently treated as confidential or are not readily available).

2.2.2 Water emission inventories

Diffuse water emission inventories typically involve the estimation of nutrient loads entering inland or marine waters. This reflects the longstanding concern with eutrophication in many parts of the world. The estimation of pollutant export rates (emissions) is often linked with overall attempts to model pollution impacts on receiving waters through the use of catchment runoff models. Other indicators are usually included in the model, that are not chemical species as such, for example, biological oxygen demand, suspended solids and bacteriological agents.

Runoff estimates are often based on generation rates for different land uses and the basic geographic unit (which is frequently the same as the geographic scope of the inventory) is the catchment area for the water body of interest. Nutrients are normally represented by estimates of total nitrogen and phosphorous loads. Increasingly other pollutants, such as heavy metals and organic chemicals, are being addressed, again

driven by growing awareness of their impacts and reporting requirements. The atmospheric contribution of some of these pollutants, most notably nitrogen, is often included in the catchment modelling, depending on the proximity of large urban areas or industry. This reflects an important link between air and water emission inventories.

Catchment models incorporating emission loads are important tools in the catchment area management plans, facilitating the understanding of the impacts of land use and management changes on waterways. Catchment models tend to be designed and calibrated for particular catchment areas or regions and, as a consequence, are less readily transferable than air RETs to other regions or countries. Compared with air emission inventories, the overall accuracy of such inventories tends to be low, reflecting the greater complexity of calculating pollutant export rates and the enormous variability under different climatic conditions and between different catchment areas.

2.3 Definitions

An integral part of any inventory is to establish terminology and associated definitions. There is some difference between the definitions that have been adopted for national PRTRs and other emission inventories. The following *working definitions* have been adopted to ensure consistency of OECD's work on RETs.

2.3.1 Point sources

Point sources range from large, stationary, identifiable sources of pollutant releases, such as manufacturing plants, mines, and electric utilities, to small point sources, such as gas stations and dry cleaners. Some countries may group small point sources into the area source category of diffuse sources. Within a given point source, there may be several point level releases or stack emissions, as well as fugitive releases (*e.g.* small leaks, valve releases) that make up the point source.

2.3.2 Diffuse sources

'Diffuse' emissions are assumed to cover all emissions other than those classified as 'point sources' for a particular inventory. As stated above, some countries often include small point sources within diffuse sources. In broad terms, diffuse sources may, in a specific inventory, cover some or all (depending on the specific scope of the inventory) of the emissions from area, mobile, biogenic and geogenic sources. Large point source emissions are normally, for the purposes of emission inventories and PRTRs, considered of sufficient importance to be surveyed individually.

In addition, the specific definition of a diffuse source will, to some extent, depend on the purpose of the inventory and the resulting degree of detail and spatial resolution. A detailed local-scale inventory may measure or estimate emissions from every small industrial plant, meaning that these plants are effectively treated as point sources. On a regional or national level, many of these would fall below any thresholds for point sources and be treated as area sources. However, collectively, the releases from all of these smaller facilities in the area may be significant and, therefore, these sources should be included in the PRTR. Some of the sources covered in Chapter 4 of this report (such as dry cleaners) are actually small point sources, but are normally dealt with collectively for practical reasons. In a local-scale inventory, however, these could be treated as individual point sources, using data from individual premises.

Thresholds for defining which industrial facilities are to be treated as individual point sources in an inventory may be based on:

- the size of a facility;
- the number of employees;
- quantities of listed substances handled or fuel used; and/or
- estimated emissions of listed pollutants.

The level at which thresholds are set will depend on the objectives, including accuracy and resolution, of the PRTR. In general, higher thresholds will minimise the number of point sources. However, the greater the proportion of industrial emissions dealt with in aggregate as diffuse sources, the greater will be the loss of accuracy. Spatial accuracy will also be lost if population density or other surrogates are used in place of locations of individual premises. Dealing with sub-threshold combustion emissions from industry, for example, will require assumptions about 'average' boilers and their emissions, and a spatial allocation based on population distribution, industrial employment or industrial land use. The greater the sub-threshold sector becomes in relation to total industry emissions, the more important it is to obtain accurate activity data (such as fuel use) for the study region as a whole.

For the purposes of this report, diffuse water inventories exclude consideration of releases from obvious point sources such as sewage treatment plants. A storm water outlet is also assumed to be a point source in relation to receiving waters, even though storm water may be generated from runoff (and is therefore captured in a catchment model) and the sources are usually non-industrial. Water inventories need to ensure that double counting does not occur, due to the potential multi-stage process between initial pollutant generation and final emissions to a water body.

For the purposes of the OECD work on RETs, the following categories of diffuse sources have been agreed to under the adopted *working definition* for "diffuse sources":

(a) *Area sources*

Area source releases include:

- Releases from small stationary point source facilities whose individual releases do not qualify them as point sources (*i.e.* do not exceed defined reporting thresholds). For example, as discussed above, a single dry cleaner within a PRTR area typically will not qualify as a point source.
- Releases which result from a large number of very small sources spread relatively uniformly over extensive areas. Examples include residential wood combustion, architectural surface coatings, pesticide use and solvent use.

Releases from area sources are not compiled using the same methods as emission inventories for point sources. The level of effort required to collect data and estimate emissions from the large number of individual facilities or activities would be very high and often impracticable, especially with respect to the relatively low levels of pollutants emitted by each. To estimate releases from area sources, the individual facilities or activities are grouped with like facilities or activities into broad source categories so that releases can be collectively estimated using one methodology.

(b) *Mobile sources*

Mobile sources include all non-stationary sources, such as automobiles, trucks, aircraft, trains, construction and farm equipment, and others. Generally, release estimates for individual vehicles are not prepared for

these sources. Mobile emissions are normally spatially allocated along linear transport routes but in some cases may be spatially allocated like areas sources, for example recreational boating.

(c) *Biogenic sources*

Biogenic emissions are defined as all pollutants emitted from non-anthropogenic, biological sources. Examples include trees, vegetation and microbial activity.

(d) *Geogenic sources*

Geogenic emissions are defined as emissions from natural occurrences, such as gas seep, soil erosion and volcanoes (*geogenic sources are also non-anthropogenic*).

2.4 Links between point and diffuse source air inventories

The nature of the data collected from point sources has important implications for the accuracy and completeness of diffuse source estimations. This is because contributions from smaller industrial premises and any sub-threshold emissions are generally calculated by a subtraction process using aggregated statistics for the industrial sector as a whole. The most important example of this relates to emissions from fuel combustion where the amount of fuel consumed by point sources is subtracted from the total fuel consumed in a region (normally available from statistical data) and the remaining fuel is then used to estimate emissions from small industrial premises.

The contribution of small and medium size enterprises (SMEs) to emissions from fuel combustion, surface coatings and other solvents can be significant, and the necessary subtractions cannot be performed if the point source survey only collects emissions data. Hence, it is important to ensure that data on fuel combustion and solvent use are obtained from the major reporting premises. As described above, the levels at which reporting thresholds are set will determine the importance of the sub-threshold area source contributions.

Inventories that are established primarily for community right-to-know purposes typically focus more on large industrial emitters. Therefore, a portion of industrial releases is not accounted for, as there are many facilities that fall below a threshold level (*e.g.* dry cleaners), and numerous other diffuse sources releasing pollutants of concern. If supplementary data are not obtained, it could be difficult to make reliable estimates of the remaining sub-threshold industrial emissions. Additionally, the collection of supplementary data greatly assists quality control checks of data submitted by industry. If the emissions inventory is to be used for airshed modelling (which is often the case), other information will be needed and, when possible, expert advice from air quality modellers should be sought when designing the survey.

In broad terms, surveys of emitters for point source inventories, or registers, tend to be carried out at three generic levels, with varying implications for diffuse source estimation and possible inventory end uses:

1. Total emissions data for each listed pollutant (plus supplementary details of industry contacts, source reduction, reduction targets, etc.). This type of inventory is most likely to be designed for community right-to-know purposes.
2. Other process information is included, such as details of fuel combustion, solvent use, and emissions control technology. This allows more scope for quality control checks and greatly assists the estimation of the diffuse emissions component of the inventory.

3. Detailed spatial and temporal data (such as stack heights, emission velocities, diurnal and seasonal patterns) are requested, in addition to the data from items 1 and 2 above. This is the most detailed type of inventory system and is designed to fulfil modelling requirements. It may also be integrated with a licensing system.

In situations where the first type of inventory exists, separate industry reporting processes will also need to be established in urban areas where comprehensive air inventories are required. One complication with including requests for additional information in point source surveys is the possible need to distinguish between mandatory and voluntary requirements. Emissions data are most likely to be mandatory (*e.g.* as part of a PRTR or licensing regulations) whereas some of the other data needed for inventory purposes may not be.

CHAPTER 3: RELEASE ESTIMATION TECHNIQUES FOR DIFFUSE SOURCES

3.1 Pollutants

As discussed in Chapter 2, the majority of the diffuse inventories that have been developed have focused on emissions to either air or to water. There are, however, some issues specific to air or to water emissions inventories that should be discussed as they could have implications for the use of diffuse source data in a PRTR. For example, air inventories designed for modelling and policy analysis generally include primary pollutants that are critical to the formation of secondary pollutants such as ozone. This means that mixtures such as VOCs and PM₁₀ are important to include. It is important to note that it is generally not feasible to estimate releases of these substances by simply adding together releases of individually listed organic pollutants or metals respectively. The following table summarises the main criteria air pollutants and their precursors.

Table 1. Summary of main criteria air pollutants and their precursors

Criteria Pollutant	Primary and/or Secondary	Secondary Pollutant Formation Process
Carbon monoxide (CO)	Primary	
Ozone (O ₃)	Secondary	O ₃ is formed as a result of the interaction of VOCs and NO _x (which comprises a mix of NO and NO ₂) in the presence of sunlight (<i>i.e.</i> photochemical reactions).
Particles	Primary and secondary	Secondary particles form as a result of photochemical reactions involving NO _x , SO ₂ and NH ₃ aerosols.
Nitrogen dioxide (NO ₂)	Primary and secondary	Oxidation and photochemical reactions convert NO to NO ₂ .
Sulphur Dioxide (SO ₂)	Primary	

Generally speaking, inventories incorporating diffuse sources are likely to have a more restricted list of pollutants than those that focus solely on point sources. The pollutants that may be included in air emissions inventories can be grouped as follows:

- criteria pollutants (*e.g.* NO_x, PM₁₀, SO₂, as listed in Table 1);
- greenhouse gases;
- organic chemicals (*e.g.* benzene, formaldehyde, dioxins), including a subset known as persistent organic pollutants (POPs);
- inorganic gases (*e.g.* chlorine), although these are less commonly associated with diffuse sources; and
- metals and their compounds (*e.g.* lead, nickel, chromium).

The types of pollutants that are included in water inventories can be grouped as follows:

- nutrients (total N and total P);
- other inorganic pollutants (*e.g.* heavy metals);
- organic pollutants (*e.g.* POPs);
- suspended particles; and
- indicators such as BOD, COD, salinity.

3.2 Sources

The diffuse sources included under PRTRs, and particularly in air inventories, are often grouped according to sectors:

- fuel combustion;
- fossil fuel distribution;
- solvents/product use;
- agriculture and forestry;
- biogenic/geogenic; and
- mobile sources.

Although different countries have adopted different ways of grouping sources, it is common to separate mobile sources, area sources and biogenic/geogenic sources. Annex 2 provides lists of the sources and major groupings that have been adopted in the US, the Netherlands, and elsewhere in Europe.

Diffuse water inventories may not incorporate distinct source categories in the same way as air inventories, although an alternative categorisation could be based on the different land use categories (*e.g.* agriculture, forest, urban) from which diffuse pollution is generated. Estimating pollutant loads in catchment areas may then require further detailed information about activities such as manure treatment.

3.3 Overview of approaches for air inventories

Diffuse source inventories rely on 'top-down' techniques rather than direct measurement of emissions from individual sources. Emission factors are likely to be based on measurement programmes conducted within the home country or elsewhere. The activity data used in such inventories are largely the data that are already available from government or other sources. In fact, the RETs used in diffuse source inventories evolved according to the types of statistical data normally available within a country. As discussed previously, special surveys can be designed to collect specific activity data. For guidance on survey methods, refer to the following documents:

- Australian NPI EET Handbooks, for example: *Aggregated Emissions from Domestic Lawn Mowing*, (Environment Australia, 1999), http://www.npi.gov.au/handbooks/approved_handbooks/. Appendix A discusses domestic surveys.

- US EPA EIIP documents, for example: *Guidance for Estimating Lawn and Garden Equipment, Emissions Inventory Improvement Programme, Volume IV, Chapter 3* (US EPA, 1997), <http://www.epa.gov/ttn/chief/eiip/techreport/volume04/index.html>.

In addition to the three basic types of data (emission factors, activity data, spatial surrogates), information about individual sources, such as fuel composition or density, may be required. Where emission controls are applied, decision makers may wish to consider the information found in the US EPA document, *Rule Effectiveness and Rule Penetration*¹. Rule effectiveness accounts for sources that do not achieve required emissions reductions for various reasons. Rule penetration relates to the proportion of the source category covered by a regulation. For example, vapour recovery for service stations may only apply to geographic sub-regions, stations above a certain size or those built after a certain date. Emissions from certain mobile sources that cross international boundaries (e.g. aircraft) may be excluded from inventories prepared for national reporting purposes but should be included for completeness when considering the total environmental impact within a country or region.

The most common generic approaches relevant to diffuse source air inventories are:

- emission factors (based on test data or surveys of manufacturers);
- materials balance (e.g. assumes that all solvent in a product evaporates);
- fuel analysis (e.g. assumes complete conversion of S to SO₂ during combustion); and
- emission estimation models (empirically derived sets of equations to estimate emissions, e.g. MOBILE6, COPERT).

In the absence of specific emission factors, speciation profiles may be needed to speciate VOCs into organic compounds and particles into metals and their compounds.

The following types of activity data are generally used for area sources:

- population data only (used with default per capita emission factors);
- extrapolated point source data (for SME's);
- sales, consumption and employment data. These may relate to the specific study area or may have to be scaled down from national or state data and are generally obtained from relevant government agencies or private sector organisations; and
- survey data (e.g. households, small businesses or local governments).

Mobile source emissions estimation generally requires more complex information about vehicle characteristics, fuels used and movements of the fleet of motor vehicles, aircraft or ships. Activity data should relate to the particular study region. Releases from less significant sources, such as construction machinery and household lawn mowers, are often estimated using simpler approaches based on statistical data and emission factors.

For estimating biogenic emissions, complex computer models are used such as the BEIS2 that require local data on vegetation types. Although biogenic sources are unlikely to be considered in emission reduction programmes, they are often a significant source of VOCs and so contribute to ozone formation. Airshed modelling needs to take these sources into account in order to simulate atmospheric processes. Geogenic sources, such as sea salt and windblown dust, are difficult to estimate and are often excluded from inventories.

1. Refer to Sections 3.10 and 3.11 of *Rule Effectiveness and Rule Penetration*, US EPA (1999)

3.4 Diffuse water inventories

RETs for diffuse emissions to water are generally incorporated into catchment models. One way of categorising these models (NSW, EPA 1999) is as follows:

- empirical;
- conceptual; and
- physics-based.

These groupings are discussed in more detail in Chapter 4. Most models require spatial data on land use coverage, as well as other data such as population density, amount of fertiliser used and livestock numbers. Emission factors should relate to specific activities, not just the land use category. Emission factors are applied to specific processes and the calculated emissions from these various sources are aggregated. There is little point in using complex physics-based models if the required input data are not available. The direct sampling of pollutants released from point sources such as storm-water drains may assist in the estimation of pollutant loads from various diffuse sources. In addition, validation of models through measurement of pollutant concentrations in water bodies is important.

3.5 Spatial and temporal allocation for diffuse source air inventories

The use of a PRTR will ultimately determine the spatial resolution. The spatial resolution for diffuse source air inventories ranges from 500 metres to around 20 kilometres, depending on the size of the country, population size and density, and the use of the inventory. Some inventories, like greenhouse gases, may not be spatially resolved below the national level. Airshed modelling normally requires gridded data across a rectangular domain.

Stationary (diffuse) sources in air inventories are usually spatially allocated according to population, but other approaches include:

- locating small 'point source' emissions, such as from service stations and dry cleaners, to grid squares according to the actual locations of these facilities (but emissions from each may be assumed to be identical);
- using employment data; and
- using other spatial surrogates (*e.g.* industrial zones for area-based industrial emissions, agricultural zones/areas).

Mobile sources are generally spatially allocated as line sources based on transport routes. In detailed inventories, this could involve spatially resolving motor vehicle emissions down to individual roads.

Temporal resolution, necessary for modelling purposes, may be defined on different time scales, for instance diurnal, weekly or seasonal. These profiles reflect daily patterns in motor vehicle traffic, fuel combustion *etc.*, weekday *versus* weekend differences and seasonal differences. In situations where special surveys are conducted, it is possible to collect relevant temporal data, for example times of the day and year when solid fuel combustion or lawn mowing occurs. In many cases, however, assumptions will have to be made to supplement survey and other data.²

2. Refer to the EMEP/CORINAIR Guidebook (EEA, 1999) Part B for a discussion of temporal variations.

3.6 Quality and uncertainty

There are many factors that influence the quality of an inventory. The main indicators of data quality are:

- accuracy (the measure of ‘truth’ of a measure or estimate);
- comparability (between different methods or datasets);
- completeness (the proportion of all emissions sources that are covered by the inventory); and
- representativeness (in relation to the study region and sources of emissions).

Key data features such as accuracy, confidence and reliability come into play when addressing issues associated with uncertainty in emission estimates. As indicated in CORINAIR, Part B (EEA, 1999), the term accuracy is often used to describe data quality objectives for inventory data. However, accuracy is difficult to establish in inventory development efforts, since the ‘truth’ for any specific emission rate or emissions magnitude is rarely known. This is the crux of the release estimation process.

Emissions can nevertheless be estimated with both confidence and reliability. Confidence can be defined as the term used to represent trust in a measurement or estimate (EEA, 1999). Having confidence in inventory estimates does not make those estimates accurate or precise, but will help to develop a consensus that the data can be incorporated into the inventory. Since reliability is defined as ‘trustworthiness, authenticity or consistency’, the use of reliable estimates in an inventory will provide confidence in the data and RETs used in the inventory.

Apart from calculation errors by the team preparing the inventory (which should be minimised by quality control (QC), sources of error or uncertainty often cannot be quantified. The sources of error or uncertainty include:

- Emission factors that do not reflect real life conditions. The use of emissions factors generally cannot be avoided for practical reasons. Those developed from rigorous local testing are likely to be superior to international ‘default’ emission factors. However, the latter may be acceptable if the source characteristics and operating conditions are much the same as in the country where the tests were done. The accuracy of emission factors is also strongly influenced by the number of tests carried out. Rating systems to reflect the accuracy of emission factors have been developed by the US EPA and also applied in Europe. Factors are rated from *A* to *E*, where *A* is the highest and *E* the lowest. *A* describes an emissions factor based on a large number of measurements at a large number of facilities that fully represent the sector.
- Activity data that do not adequately reflect the study region. Scaling down national or state activity data to smaller regions according to population or other indicators will always result in decreased accuracy. The errors are likely to be greatest if the study region is relatively small and has distinctly different characteristics compared with the region to which the data applies.
- Spatial and temporal disaggregation introduces errors in these dimensions that are difficult to quantify. These errors, however, will depend on the nature of the source and activity data used. For example, while spatial disaggregation based on population may be very acceptable for consumer use of paints, use of sales data may lead to large errors if sales information is not correlated with usage within the study region.

- Sample surveys will be subject to sampling error (which can be quantified) but also to other unknown errors resulting from the accuracy of the reported information and non-responses.

Despite these uncertainties and limitations on accuracy, inventories can be useful tools, provided that they are used for the purposes for which they are designed. Users need to ensure that inventory data are not used for other purposes, such as trying to draw precise conclusions about exposure to pollutants at the local level. Inventories are often of greater value in determining trends rather than absolute values, providing that methodologies are consistent over time or that past inventories are recalculated or updated as necessary to account for changes in inventory methodology.

In general terms, inventories of criteria and greenhouse gas pollutants (excluding biogenic sources) are likely to be the most accurate. The reason is that these pollutants have been studied in the greatest detail and have been the subject of extensive regulatory attention, at both the domestic and international levels. The following inventory types or segments are generally less accurate:

- particles in air inventories from non-combustion sources;
- HAPs based on speciation profiles;
- most biogenic sources; and
- diffuse water inventories.

3.7 Quality control and quality assurance

Quality control (QC) involves routine technical procedures adopted within the inventory team to measure and control inventory quality. Possible QC procedures include:

- technical reviews of sources of data;
- accuracy checks of data entry and calculations by other team members;
- reality checks against previous inventories or those from other regions;
- computerised checks for data entry errors and reality checks;
- designing and implementing standardised procedures to facilitate checking and tracking of errors;
- statistical checks (*e.g.* using descriptive statistics, identifying outliers, comparability checks);
- visualisation checks for spatial data (*e.g.* ensuring land-based sources are not located off-shore); and
- using an alternative method to estimate releases, if data are available and resources permit it.

Quality assurance (QA) involves external review and audit procedures conducted by people outside the inventory team. These are usually performed by technical experts in the relevant fields.

The inventory project team will need to develop QA/QC procedures early in the inventory process. The importance of proper documentation needs to be stressed. This greatly assists QA/QC by making it easier to find errors and identify any assumptions. Documentation also ensures reproducibility, transparency to stakeholders (including technical reviewers and other users of the inventory) and assists future inventory updates. Documentation should include all raw data used, assumptions, and all steps in calculations; and communications with data providers and QA/QC processes. Important missing data (*e.g.* missing pollutants

due to a lack of emission factors, missing source types) need to be acknowledged and documented. Sensitivity analyses can also provide a useful insight into inventory quality.

If an inventory is being used for catchment or airshed modelling, a valuable reality check on the inventory as a whole (including point sources) can be made through comparing model outputs with monitoring data. This is the only way of actually knowing whether the inventory (in combination with the model) reasonably reflects the real world situation. In a similar way, measurements of pollutant concentrations in water bodies will indicate the extent to which a water inventory/catchment model system reflects actual emissions or *the real world*.³

3.8 Inventory project management

Depending on the size and extent of the inventory, its preparation will require a team of experts. At least some team members should have inventory experience or, as a minimum, easy access to those experts who would have the time to provide assistance. All team members should have good computer (particularly spreadsheet and GIS) skills, be able to handle large volumes of data easily and be reasonably accurate with good attention to detail. Also helpful would be a basic knowledge of chemistry.

The project manager needs to be a good organiser, have a flexible approach, be a strategic and lateral thinker and have good personal skills. The latter may be needed when dealing with data providers, and is essential in building and managing a successful team. Inventory planning is critical. In particular, relevant reports documenting RETs must be reviewed and sources of activity and spatial data must be identified. Scheduling needs to ensure all data collection commences early in the process and to ensure that sufficient time is allowed for these data to be received. Requests to one agency for different data sets need to be co-ordinated. In many countries, statistical agencies may keep data disaggregated data confidential so as not to compromise their sources. This means time may be needed to establish working relationships and mutual trust. Time should be allocated for staff training, particularly if specialised computer packages are being used.

For further information about inventory project management, refer to the US EPA (1999) Inventory Handbook. This is designed for state and local agency personnel undertaking air inventories for criteria pollutants from stationary sources. Also refer to EIIP documents (which can be found at <http://www.epa.gov/ttn/chief/index.html>), and the EMEP/CORINAIR guidebook (EEA, 1999) which also has a useful introduction.

3. Additional guidance and information on QA and QC can be found in Chapter 4 of the US EPA Inventory Handbook (US EPA, 1999), the EIIP report: *Quality Assurance Procedures* (US EPA, 1996 and 1997) and Part B of the EMEP/CORINAIR Guidebook (EEA, 1999).

CHAPTER 4: APPROACHES FOR SELECTED DIFFUSE SOURCES

4.1 Introduction

This chapter presents a selection of techniques for estimating releases from those diffuse source categories that are likely to be among the most significant sources of pollutants in OECD countries. The list of categories is by no means intended to be complete; (other sources are documented in the various emission inventory guidebooks listed in the bibliography and, in some countries or regions, there are bound to be other sources as well). The sources covered here do, however, illustrate the generic estimation approaches in common use. The selection of sources and emission estimation techniques will, of course, depend on the objectives of the inventory, its resolution, the nature of the study area and the pollutants to be included. These characteristics would generally be resolved early in the process (see Chapter 3), prior to finalising estimation methodology.

While this chapter presents a selection of RETs for particular diffuse sources, Annex 2 lists all diffuse source categories covered in the main guidebooks available from the US EPA and the EEA (US EPA, 1995; US EPA, 1985; EEA, 1999) for air inventories as well as in the Dutch Emissions Inventory and the Australian NPI. Depending on the degree of detail required in the inventory and reporting thresholds set for point sources, additional sources not discussed here (but covered in the available guidebooks) may need to be inventoried as diffuse sources.

Methodologies for estimating greenhouse gas releases are not specifically included, although greenhouse gas sources frequently coincide with urban air pollutant sources. Greenhouse inventory techniques are well documented by the Inter-governmental Panel on Climate Change (IPCC, 1997). The release estimation techniques considered in this report are generally consistent with or are more detailed than the IPCC default methods. The EMEP/CORINAIR Guidebook has been specifically designed to suit all European reporting requirements, including those of UNFCCC, to encourage consistency in approaches and input data. That is, if greenhouse gases are included in a PRTR, data acquisition processes should be minimised and consistency maximised.

A number of fugitive sources of emissions of particles (*e.g.* re-entrained road dust, construction and demolition) may be significant. However, the RETs available for these sources are crude and, as a result, they are often excluded from inventories. These sources are not discussed here, but methods and emission factors are provided in AP-42 (US EPA, 1995) and elsewhere. Biogenic and geogenic sources are also not covered.

The first 13 source categories relate to emissions to air. Diffuse emissions to water are dealt with in a single section at the end, as methodologies are less distinctive for specific sources. The specific source categories considered here are as follows:

Fuel combustion (see Section 4.2)

- gas combustion
- domestic solid fuel combustion

Fossil fuel distribution (see Section 4.3)

- gasoline distribution
- natural gas distribution

Solvents/product use (see Section 4.4)

- industrial solvents
- architectural surface coatings
- domestic and commercial solvents

Agriculture and forestry (see Section 4.5)

- wildfires, prescribed and agricultural burning
- manure

Mobile sources (see Section 4.6)

- road traffic
- aircraft
- ships
- garden maintenance

Diffuse emissions to water (see Section 4.7)

- catchment runoff

Table 2 summarises source categories, techniques and indicates the specific information source on the technique.

4.2 Fuel combustion

Two specific categories of fuel combustion, gas and domestic solid fuel, have been selected as they are the more common sources under fuel combustion.

4.2.1 Gas combustion

(a) Nature of the source and relevant pollutants

The pollutants emitted from gas combustion include CO, CO₂, NO_x, particles, SO₂, CH₄, N₂O, plus various organic HAPs and metals and their compounds. Gas and other fuels, such as LPG, are potentially used in several sectors, in particular the residential, commercial and industrial sectors.

Table 2: Summary of categories, techniques and information sources

Source category	Estimation method	Sources of information on techniques
Gas combustion	Use of local fuel consumption data	USEPA – EIIP; Australia – NPI EET manuals; EEA – EMEP/Corinair
	Scaling down national or state fuel consumption data	USEPA – EIIP; Australia – NPI EET manuals; EEA – EMEP/Corinair
Domestic solid fuel combustion	Survey to obtain local fuel consumption data	Australia – NPI EET manual; USEPA – EIIP;
	Scaling down national or state fuel consumption data	USEPA – EIIP; EEA – EMEP/Corinair
Gasoline distribution	Use of gasoline sales information for the region	USEPA – EIIP; Australia – NPI EET manual; EEA – EMEP/Corinair
	Scaling down national or state fuel sales data	USEPA – EIIP; EEA – EMEP/Corinair
Natural gas distribution	Dividing pipelines into sub-categories	IPCC; EEA – EMEP/Corinair; USEPA - EIIP
	Using total gas sales and average emission factors	IPCC; EEA – EMEP/Corinair; USEPA – EIIP
Industrial solvents	Survey of solvent users	USEPA – EIIP
	Use of sales data from suppliers	Australia – NPI EET manual; EEA – EMEP/Corinair
	Use of default emission factors	USEPA – EIIP; Australia – NPI EET manual; EEA – EMEP/Corinair
Architectural surface coatings	Survey of distributors/manufacturers	USEPA – EIIP
	Scaling down national or state consumption data	USEPA – EIIP; Australia – NPI EET manual; EEA – EMEP/Corinair
	Use of default per capita emission factors	USEPA – AP-42
Domestic and commercial solvents	Survey of distributors/retailers or use of consumption data	<i>method is not normally used and mption data is rarely available – ception is The Netherlands.</i>
	Use of default per capita emission factors	USEPA – EIIP; EEA – EMEP/Corinair, Australia – NPI EET manual
Wildfires, prescribed and agricultural burning	Categorisation of farmland according to crop types and use of specific emission factors	EEA – EMEP/Corinair; Australia – NPI EET manual; IPCC; USEPA – EIIP; USEPA

		– AP-42
	Use of local data to calculate mass of carbon emitted from forest burning	EEA – EMEP/Corinair; IPCC
	Use of default emission factors (eg. amount of waste/fuel per hectare of farmland or forest burnt)	EEA – EMEP/Corinair; Australia – NPI EET manual;
Manure management	Process-based model of nitrogen flows	EEA – EMEP/Corinair; USA-EIIP
	Use of default emission factors for each animal type	EEA – EMEP/Corinair; IPCC
Road traffic	Spatially disaggregated VKT/VMT-based methods, often involving the use of specialised software (MOBILE5, COPERT)	USEPA – AP-42; USEPA - Procedures for Emission Inventory Preparation, volume IV; EEA – EMEP/Corinair
	‘Top down’ approach based on aggregated fuel consumption data, often used for greenhouse gases	IPCC; EEA – EMEP/Corinair; Australia – NPI EET manual
	Direct on-road sampling of emissions (rarely used in inventories)	EPA Victoria (1999); NERI (2000)
Aircraft	Spatially disaggregated approach based on LTO cycles for each aircraft type and different operating modes	EEA – EMEP/Corinair; USEPA – Procedures for Emission Inventory preparation, volume IV; Australia – NPI EET manual
	Use of default emission factors for different types of aircraft based on national statistics	EEA – EMEP/Corinair; USEPA – Procedures for Emission Inventory preparation, volume IV; Australia – NPI EET manual
	Use of default emission factors for an average aircraft, total LTOs and fuel data (CO ₂ only)	EEA – EMEP/Corinair
Ships	Spatially disaggregated approach based on times in berth and channels for ships of different sizes	Australia – NEP EET manual
	Use fuel consumption data for different ship categories	EEA – EMEP/Corinair
	Use of default emission factors and fuel consumption data (CO ₂ only)	EEA – EMEP/Corinair
Garden maintenance	Survey to obtain local data	USEPA – EIIP; Australia – NPI EET manual
	Scaling down national or state fuel consumption data	USEPA – EIIP; Australia – NPI EET manual; EEA – EMEP/Corinair

(b) *Factors affecting emissions*

The specific emissions are strongly dependent on the type of fuel burnt and on the nature of the combustion device. The temperature and the efficiency of combustion are also important, and are implicitly accounted for in emission factors for different units.

Gas combustion, particularly in larger industrial and commercial boilers, may be subject to emission controls. The most common controls are flue gas recirculation and low NO_x burners. Depending on the specific source, emission factors may be defined separately according to the control technology in use.

(c) *Description of release estimation techniques*

Sources of emission factors

US emission factors for a range of boilers of different sizes and with different control technologies are provided in AP-42 Volume I. These are expressed in terms of mass per unit of volume (pounds per standard cubic feet). European emission factors are also available in the section on 'Combustion Plants as Area Sources' in Chapter 1 of the EMEP/CORINAIR Guidebook. These are expressed in terms of mass per unit of energy (g/PJ). Additional speciation data for some pollutants are available from CARB (1991a, 1991b).

Activity data

Activity data used must match the chosen emission factors. In some cases, additional fuel data are needed to apply the emission factor (*e.g.* to convert mass to volume or to energy output). The two general approaches for compiling activity data are (a) using local data specific to the region, and (b) scaling down data from a larger region.

The preferred approach is to obtain data on the consumption of the relevant fuel types for each sector (domestic, commercial, and industrial) for the specific geographic region of interest. These data should be obtained from all relevant distributors. Accuracy may be reduced if all fuel sold is not consumed in the region or if all distributors are not identified and covered. If data cannot be obtained from a particular distributor, then data from others may need to be averaged and factored up based on population or some other indicator. It should be noted that data on fuel used by individual consumers will normally be confidential and, hence, unavailable from distributors.

To estimate emissions from the industrial sector, additional information should be obtained through any surveys being conducted of major industrial (point) sources. It is important that a survey of these individual facilities obtains information on fuel consumption so that the total fuel consumed by these facilities can be subtracted from the total consumed by industry overall. The remainder will represent fuel consumed by small industry below any reporting threshold for point sources. If this subtraction is not done, double counting will occur.

If local consumption data cannot be obtained, a less accurate method involves scaling down national or state data. Inaccuracies may be introduced depending on differences between the study region and the larger region to which the data apply. Consumption data would normally be available for residential, commercial and industrial sectors. If the gas network is spread across a state or country however, the scaling down approach may be quite acceptable. The approach used in The Netherlands is to use GIS data to distinguish between areas where there are higher proportions of detached dwellings compared with apartments,

When scaling down industrial fuel consumption data, it is generally preferable to use employment rather than population data.

(d) Spatial allocation

Domestic and commercial emissions from gas combustion would normally be allocated by assuming that fuel consumption is directly related to population distribution. If the activity data are available in smaller geographic units (*e.g.* by postal code), then the emissions could be allocated accordingly. The availability of reticulated gas across the study region should be considered, so that spatial allocation of emissions is restricted to relevant areas.

For industrial emissions dealt with as an area-based source (*i.e.* excluding individual point sources), emissions could be spatially allocated within industrial zones or according to industrial employment data.

(e) Summary of steps in the process

1. Identify the relevant fuels for the study region and possible boundaries for gas reticulation.
2. Ensure that a complementary point source survey of individual sites requests the necessary information on fuel combustion.
3. Review and select the most appropriate emission factors, locate and check availability of activity data and obtain any additional fuel parameters that may be needed.
4. Scale down any activity data (as described in method C above) if necessary.
5. Calculate total emissions for each type of fuel (if more than one) and for each sector. Obtain the industrial contribution by subtracting the total fuel burnt combusted by major point sources from the total fuel used by industry as a whole.
6. Spatially and temporally disaggregate as required.

(f) Comments on reliability

Consumption data provided by distributors should be reliable, particularly if overall consumption rates relate closely to those in the defined study region. Scaling down from a larger area will reduce accuracy.

Using emission factors from other countries may be less accurate than in the home country, depending on the characteristics of boilers, appliances and fuels. Speciation profiles are relatively less reliable than emission factors.

If fuel consumption data are not collected as part of a survey of major industrial facilities (*i.e.* those that are treated as point sources in the inventory), and/or total consumption data for industry as a whole are not available, then estimates of emissions from smaller industry are likely to be highly inaccurate. Combustion emissions depend very much on the size and nature of the manufacturing process, types of boilers and control technology. Without data on individual sites, it would be necessary to make gross assumptions for larger industrial facilities as a whole across a study region.

(g) *Sources of further information*

Australia

Environment Australia (1999), Emissions Estimation Technique Manual for Aggregated Emissions from Fuel Combustion (Sub-threshold) (Environment Australia, Canberra, Australia).

http://www.npi.gov.au/handbooks/aedmanuals/subcombustion_ff.html.

Environment Australia (1999), Emissions Estimation Technique Manual for Aggregated Emissions from Domestic Gaseous Fuel Burning (Environment Australia, Canberra, Australia).

http://www.npi.gov.au/handbooks/aedmanuals/gasburning_ff.html.

Europe

EEA (1999), EMEP/CORINAIR Atmospheric Emission Inventory Guidebook (EEA, Copenhagen, Denmark), 2nd Edition. <http://reports.eea.eu.int/EMEPCORINAIR/en/page002.html>.

US

US EPA (1995), *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, AP-42* (United States Environmental Protection Agency, North Carolina, US), 5th edition. <http://www.epa.gov/ttn/chief/ap42/index.html>.

US EPA (1999), *Residential and Commercial/Institutional Natural Gas and LPG Combustion, Area Source Method Abstract from Volume III of EIIP Document Series, US* (United States Environmental Protection Agency, North Carolina, US). <http://www.epa.gov/ttn/chief/eiip/techreport/volume03/ng.pdf>.

4.2.2 Domestic solid fuel combustion

(a) *Nature of the source and relevant pollutants*

In some countries, the emissions resulting from residential solid fuel (most commonly, wood and coal) burning are a major source of air pollution. A range of combustion devices may be used, including open fireplaces (either masonry or factory-built metal units), conventional wood stoves with no emissions control technology, and stoves incorporating emission controls. Wood stoves may also include catalysts to enhance the combustion process. The pollutants emitted from solid fuel combustion include particulate matter, CO, CO₂, NO_x, VOCs, SO_x, N₂O, CH₄, PAHs and various metallic compounds and organic HAPs.

(b) *Factors affecting emissions*

The quantity and type of emissions from solid fuel combustion vary greatly, depending on the nature of the device used, the control technology, the type and moisture content of the fuel, the mode of operation by the user and the degradation of the stove. Emissions also vary with the stage of the combustion cycle. In general, higher emissions are associated with slow burn rates and low flame intensity.

Open fireplaces are a particularly inefficient form of heating, with a high proportion of combustion heat being lost.

*(c) Description of release estimation techniques*Sources of emission factors

US emission factors, expressed in pounds per tonne, are available in AP-42 Volume I for the criteria pollutants, a number of individual PAHs, plus a range of organic HAPs and metals. It also includes an N₂O emission factor for fireplaces. The relevant sections are 1.9 (Residential Fireplaces), 1.10 (Residential Wood Stoves) for wood combustion, and 1.1 (Bituminous and Sub-bituminous Coal Combustion), 1.2 (Anthracite Coal Combustion) and 1.7 (Lignite Combustion) for other forms of solid fuel.

Some European emission factors for wood, briquettes and lignite are also available in the section on 'Combustion Plants as Area Sources' in Chapter 1 of the EMEP/CORINAIR Guidebook. These are expressed in terms of mass per unit of energy (g/GJ) and apply to CO, CH₄, VOC and NO_x. Additional emission factors apply to heavy metals from coal combustion.

The Canadian manual provides emission factors for the criteria pollutants, some of which are locally derived. The Australian NPI handbook on domestic solid fuel burning uses a combination of US EPA, CARB and local emission factors applicable to domestic wood and coal combustion.

Activity data

Carrying out a survey to obtain local data on fuel consumption and combustion devices. The preferred approach, particularly for wood combustion, is to conduct a sample survey of domestic premises. This is particularly the case in areas where a significant proportion of households are likely to collect their own wood (hence sales data would provide an underestimate) and data on the relative proportions of different combustion devices is required. The survey approach is most likely to be cost-effective if wood combustion is a significant source of emissions and/or a survey can be justified to gather data on other emission sources as well. The survey needs to collect data on the amount and type of fuel burnt (hardwood or softwood), the type of combustion device used and control technology applied. Respondents may be unaware of emission controls, so it can be more useful to ask when the appliance was purchased, assuming emission control regulations were introduced at certain dates. Seasonal and diurnal variability data should also be sought, particularly if the inventory is to be used for modelling.

Data from sampled households are scaled up according to total study region household numbers. If significant differences in usage within a study region are expected, partitioning the survey into separate sub-regions may be justified. If the extent of wood consumption is strongly related to other factors, such as the age of residence, then these could be incorporated in the survey design. For further information on conducting surveys, refer to the EIIP report on residential wood combustion. A survey could be carried out either by mail or by telephone.

A mail survey approach to conducting household surveys was developed and refined during trials of Australia's NPI. This generated response rates of 50-55% in a number of different study regions. Guidelines for conducting domestic surveys are included in Appendix A of the relevant NPI Manual.

Expert statistical and survey design advice should always be sought prior to conducting surveys. The following issues must be considered in order ensure an adequate response rate and to ensure that reliable data are obtained:

- careful design of the layout and wording of questionnaires to facilitate data entry and avoid ambiguity; ask questions that people can reasonably be expected to answer, and formulate them so as to obtain only data that will be used;

- wording used in cover letters, introductory comments and general manner for telephone or door-to-door surveys;
- sample size;
- pilot surveys;
- follow-up approaches to increase response rates; and
- quality control procedures.

Scaling down national or state consumption data. A simpler approach is to scale down available statistics on the amount of wood and other forms of solid fuel consumed. If the study region is representative of the region to which the data apply, and the self-collection of firewood is insignificant, then aggregated consumption data based on sales may be quite accurate. Data would also be required on the different types of heating devices used. If data are not available, assumptions on the proportions of sales of heating devices would have to be made.

Whichever approach is used to collect activity data, if solid fuel is reported in terms of volume, then additional information will be needed to convert this to weight or energy units, depending on the emission factors chosen.

A top-down approach for coal or lignite combustion is likely to be acceptable providing consumption data are available from government or local distributors. It may be necessary to exclude coal used in commercial and small industrial premises (which could be inventoried as a separate source category) and to subtract the contribution from point sources if activity data cover all users. Note also that household consumption data may include fuel used in barbecues. This may also be significant enough to consider as a separate source.

(d) *Spatial allocation*

Emissions would normally be spatially allocated according to household or population distribution. If the survey has been partitioned into sub-regions, then survey data will need to be scaled up and spatially allocated in each sub-region separately. If other spatial factors are defined through a survey process, such as age of residence, then these could be used.

(e) *Summary of steps in the process*

1. In the study region, establish the significance (or otherwise) of domestic solid fuel combustion as a source of emissions and indicate the relevant fuels.
2. Identify the availability of existing activity data on solid fuel consumption and review available emission factors.
3. Depending on the importance of the source and the quality of available statistics, decide whether to conduct a household survey.
4. If needed, design and carry out the survey, and collect any other fuel data that may be necessary.
5. Scale activity data up (if derived from a survey) and/or down (if a top-down approach is used).

6. Calculate total emissions for each type of combustion device, combining emission factors, activity data and any other data required. Allow for any regulations that may restrict burning on certain days.
7. Aggregate emissions across equipment types for each pollutant.
8. Spatially and temporally disaggregate as required.

(f) *Comments on reliability*

Household surveys should yield reasonably reliable results, providing the surveys are carefully designed and executed. Top-down approaches (*e.g.* using national fuel consumption data) will generally be inferior, as they assume uniform activity rates and do not generally account for wood collected by individual households from forests. The smaller the study region is in relation to the region for which general activity data apply and the greater the differences (*e.g.* climate, housing type) between the study region and the larger region, the less accurate this approach will be.

In addition, using fuel consumption statistics also means that supplementary data are required on the share of fuel used by different types of combustion devices. This may be another significant source of error. A decision to use this approach must take into account the overall likely significance of this source to total emissions of the pollutants being considered in the inventory.

Emission factors based on local testing will generally be superior to those developed in other countries. In particular, emission factors for HAPs based on standard speciation profiles will generally be of low reliability.

(g) *Sources of further information*

Australia

Environment Australia (1999), Emissions Estimation Technique Manual for Aggregated Emissions from Domestic Solid Fuel Burning (Environment Australia, Canberra, Australia).
http://www.npi.gov.au/handbooks/aedmanuals/servstatns_rev4.html

Canada

Environment Canada (1991), Methods Manual for Estimating Emissions of Common Air Contaminants from Canadian Sources (Environment Canada, Ottawa, Canada).
<http://www.ec.gc.ca/pdb/cac/inventorycompilation.html>.

Europe

EEA (1999), EMEP/CORINAIR Atmospheric Emission Inventory Guidebook (EEA, Copenhagen, Denmark), 2nd Edition. <http://reports.eea.eu.int/EMEPCORINAIR/en/page002.html>.

US

US EPA (1995), *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, AP-42* (United States Environmental Protection Agency, North Carolina, US), 5th Edition. <http://www.epa.gov/ttn/chief/ap42/index.html>.

US EPA (1997), *Residential Wood Combustion*, Chapter 2 from Volume III of EIIP Document Series, Prepared by Radian Corporation, US (United States Environmental Protection Agency, North Carolina, US). <http://www.epa.gov/ttn/chief/eiip/techreport/volume03/iii02.pdf>.

US EPA (1999), *Residential and Commercial/Institutional Coal Combustion*, Area Source Method Abstract from Volume III of EIIP Document Series (United States Environmental Protection Agency, North Carolina, US). <http://www.epa.gov/ttn/chief/eiip/techreport/volume03/coal.pdf>.

4.3 Fossil fuel distribution

4.3.1 Gasoline distribution

(a) Nature of the source and relevant pollutants

Evaporative emissions of VOCs occur at different stages along the gasoline distribution system. This starts at petroleum refineries or tanker ships and includes various storage, transfer and retail facilities (for further information on the gas distribution system, refer to Figure 5.2.1 in AP-42)⁴. Emissions from the refining process and major storage terminals are normally dealt with as point sources. Within the remaining parts of the supply chain, emissions from service stations and associated activities are likely to be the most significant. Emissions generated from the following activities (note that all except the first occur at service stations) are dealt with here:

- gasoline trucks in transit;
- unloading of fuel from tankers to underground storage tanks;
- underground tank breathing/emptying;
- vehicle refuelling; and
- spillage.

Note that AP-42 also deals with losses from the loading of rail, ships and trucks, as well as ballasting losses and cargo transit losses.

The specific VOCs that may be relevant to a particular inventory include benzene, toluene, styrene and xylenes.

4 . US EPA (1995), *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, AP-42* (United States Environmental Protection Agency, North Carolina, US), 5th Edition. <http://www.epa.gov/ttn/chief/ap42/index.html>.

(b) *Factors affecting emissions*

Emissions of VOCs will depend on Reid vapour pressure (RVP) and the nature of vapour recovery systems in place. Stage I vapour recovery applies during the transfer of gasoline from tank trucks to storage tanks at service stations, while Stage II vapour recovery applies during the transfer of fuel to motor vehicle tanks. The stage I technology for loading tanks (splash loading, submerged loading or vapour balance) has a major impact on the release of displacement emissions. Stage I controls are more widely implemented than Stage II. Note that while this section discusses gasoline, evaporative emissions from other fuels, such as diesel and LPG, can also be estimated (*e.g.* see Australia's NPI manual on emissions from service stations). However, the emissions from other fuels tend to be relatively small due to their low volatility.

(c) *Description of release estimation techniques*

The basic method used to estimate emissions from gasoline distribution involves the use of published emission factors together with information on the volume of gasoline distributed. Hence, the appropriate activity data needed is total fuel sold within the inventory region. Fuel sales data (which are normally obtainable from either government or industry sources) may have to be scaled down from a larger area. This scaling could be based on relative VKT or population.

The EIIP report describes methodologies and provides emission factors (from AP-42) for the first three of the five activities listed above. To estimate emissions from the unloading of fuel from trucks to underground tanks, information on the amounts of fuel delivered according to each method (submerged, splash, vapour balancing) is required. If this information is not readily available, a survey of service stations representative of the study region (this should include both large and small service stations) could be carried out.

EIIP recommends that the model MOBILE 5A be used to generate Stage II emission factors for vehicle refuelling activities including spillage. MOBILE 5A allows for corrections for RVP and temperature. It should be noted that these corrections are not yet incorporated into the published AP-42 emission factors (expressed in pounds per gallon throughput) for motor vehicle refuelling. However, equation (6) in AP-42, includes temperature and RVP factors as incorporated into MOBILE 5A, so this equation could be used in place of the model itself to improve local accuracy for uncontrolled displacement losses.

The EMEP/CORINAIR Guidebook (Section 5) covers emissions from underground tanks at service stations and from motor vehicle refuelling. It contains emission factors (expressed in grams per megagram) designed for a simpler approach, applicable to three broad components of gasoline distribution (*i.e.* refinery dispatch, transport and service stations) that could be used across a whole country or large region. Emission factors provided for more detailed sub-categories (as in EIIP) are also provided for more precise estimations.

The same activity data (*i.e.* fuel consumption within the inventory region) should also be used to estimate emissions from storage tank breathing and vehicle refuelling. If these data are unavailable, relative VKT or population could be used to scale down national or state data.

EIIP describes a method for estimating emissions from gasoline trucks in transit. This involves averaging loaded and unloaded components and making an adjustment for gasoline transported twice within the region.

Tables 11.3-2 and 11.3-3 in the EIIP report summarise all preferred and alternative methods applicable in the US. The emission factors do not vary, only the nature of the activity data.

If total VOCs are to be speciated into organic compounds such as benzene, local data on liquid and vapour composition of gasoline should ideally be obtained. If vapour composition is not available, this can be calculated from liquid composition data which are, generally, more readily available (refer to Australia's NPI manual on service stations for the algorithm).

(d) *Spatial allocation*

The spatial allocation of emissions from service stations could be based on employment data, population density, actual facility locations, zoning or business district locations. The use of employment data or exact facility locations is superior to population density as the latter may not accurately reflect service station locations. If exact facility locations are identified for the purposes of spatial allocation, then an even higher level of accuracy would involve varying emissions within relevant grid squares according to throughput of each outlet (*i.e.* effectively treating service stations as point sources). If the applicability of Stage I or II controls varies across the inventory region according to spatial criteria, then the spatial allocation of emissions should, if possible, reflect this variation.

(e) *Summary of steps in the process*

1. Determine the availability of activity and other data (*e.g.* gasoline consumption, extent and nature of Stage I and II vapour recovery technologies, fuel composition, RVP and temperature).
2. Collect data and conduct additional surveys of service stations if necessary.
3. Calculate emissions for each sub-category, using emission factors and/or MOBILE 5A.
4. Aggregate emissions across different sub-categories.
5. Spatially and temporally disaggregate emissions as required.

(f) *Comments on reliability*

The nature of the activity data used will influence accuracy. If activity data apply precisely to the study region and reliable data on vapour recovery technologies are available, the accuracy should be reasonably good. The use of international emission factors could reduce accuracy, as local gasoline formulations and

temperatures may be different. Speciating VOCs into organic HAPs is likely to be inaccurate if local data on fuel composition are not used. Spatial accuracy will vary according to the method used, as described in Section 3.6.

(g) *Sources of further information*

Australia

Environment Australia (1999), Emissions Estimation Technique Manual for Aggregated Emissions from Service Stations (Environment Australia, Canberra, Australia)
http://www.npi.gov.au/handbooks/aedmanuals/servstatns_rev4.html.

Europe

EEA (1999), *EMEP/CORINAIR Atmospheric Emission Inventory Guidebook* (UNECE/EMEP Task Force on Emission Inventories, European Environment Agency, Copenhagen, Denmark). <http://reports.eea.eu.int/EMEPCORINAIR/en/page002.html>.

US

US EPA (1995), *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, AP-42* (United States Environmental Protection Agency, North Carolina, US), 5th Edition.
<http://www.epa.gov/ttn/chief/ap42/index.html>.

US EPA (1997), *Gasoline Marketing (Stage I and Stage II)*, Chapter 11 from Volume III of EIIP Document Series, Prepared by TRC Environmental Services, US 42 (United States Environmental Protection Agency, North Carolina, US). <http://www.epa.gov/ttn/chief/eiip/techreport/volume03/iii11.pdf>.

4.3.2 *Natural gas distribution*

(a) *Nature of the source and relevant pollutants*

Fugitive emissions occur along various parts of the transmission and distribution system that brings gas from a terminal to consumers via pipelines, compressor stations and storages. Gas distribution networks consist of a national or state transmission system using large diameter high-pressure pipelines, and regional supply systems with smaller, low pressure pipelines. Emissions occur as a result of various types of small leaks and losses. These include leaks through joints and cracks, and losses from excavator damage, purging of new mains, gas lost on start-up and shut-down of compressors. At the consumer end, losses occur from leaking lines at fittings and leaking appliance valves.

The most important pollutant emitted from gas distribution sources is methane (CH₄), a greenhouse gas. VOCs should also be considered in an air emissions inventory, although natural gas distribution is generally a relatively minor source of VOCs.

(b) *Factors affecting emissions*

Important determinants of emissions include the types of materials used in networks, the number and condition of joints in pipes, operating pressures, maintenance, leak detection and repair programmes, and measures in place to collect gas during commissioning, decommissioning, *etc.*

(c) *Description of release estimation techniques*

A detailed method presented in the EMEP/CORINAIR Guidebook (Section 5) involves dividing the pipeline into categories, each with common emissions characteristics. The data required are: length (kilometres) and pressure (mbar) for each category, and the number of point sources (gas holders, compressor stations) installed. The Guidebook provides an example of pipeline categories (Table 5.1), plus default emission factors for these categories. Storage facilities and processing plants are normally treated as point sources; compressor stations may also be considered as point sources if appropriate data are available.

A simpler method involves using a single emission factor and total sales of gas in a region. An estimate of unaccounted-for gas and gas composition data is required from the relevant distributors. The emission factors can be expressed in terms of proportion of total gas sales or in tonnes per PJ of energy. In the latter case, gas calorific value data (MJ per cubic metre) is also needed in order to calculate emissions. Default emission factors for CH₄ and VOCs in different countries (tonnes per PJ) are provided in the EMEP/CORINAIR Guidebook. These are derived from the IPPC workbook.

In Australia, leakage from the high-pressure transmission is very small, as it is relatively new and built to high standards. Most leaks are from the low-pressure distribution network and, therefore, only these losses have been considered in the release estimation process.

(d) *Spatial allocation*

Any emissions from a high-pressure transmission network should be spatially allocated as line sources according to the location of pipelines. Emissions from a regional low-pressure distribution network would normally be based on population density. If a detailed methodology is followed, major installations (terminals, storage, processing plants and large compressor stations) could be spatially located as point sources.

(e) *Summary of steps in the process*

1. Identify relevant parts of the gas distribution network within the study region and the sections which need to be dealt with according to likely losses.
2. Determine what data are available on gas consumption, estimated losses and gas composition, plus spatial data for different elements of the network.
3. Decide whether to use the detailed or simple method according to the data available, the objectives of the inventory and the significance of the source.
4. Collect the required data and estimate emissions.
5. Spatially and temporally disaggregate as required.

(f) Comments on reliability

The nature of the activity data and emission factors used (*i.e.* to what extent they reflect the actual situation) will determine the accuracy of estimated emissions. The detailed method will be superior to the simple method. However, if greenhouse gases are not included in the inventory, the simple method may be adequate, as VOCs from this source are, generally, relatively minor.

*(g) Sources of further information*Australia

NGGIC (1996), Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks, Workbook 2.1 (revision 1) (Department of the Environment, Sport and Territories, Canberra, Australia).

Europe

EEA (1999), *EMEP/CORINAIR Atmospheric Emission Inventory Guidebook* (UNECE/EMEP Task Force on Emission Inventories, European Environment Agency, Copenhagen, Denmark). <http://reports.eea.eu.int/EMEPCORINAIR/en/page002.html>.

International

IPCC/OECD/IEA (1997), Revised 1996 Guidelines for National Greenhouse Gas Inventories (OECD, Paris, France).

US

US EPA (1999), *Methods for Estimating Methane Emissions from Natural Gas and Oil Systems*, Chapter 3 from Volume VIII of EIIP Document Series, prepared by ICF Consulting, US (United States Environmental Protection Agency, North Carolina, US), <http://www.epa.gov/ttn/chief/eiip/techreport/volume08/viii03.pdf>.

4.4 Solvents and product use

Three categories are considered here: industrial solvents, architectural surface coatings and domestic/commercial solvents. Other categories commonly included in inventories are: dry cleaning, printing and graphic arts, industrial surface coatings, motor vehicle refinishing and cutback bitumen. Methodologies are very similar across this group of sources.

4.4.1 Industrial solvents*(a) Nature of the source and relevant pollutants*

Solvents are used extensively by industry for solvent degreasing and surface cleaning (*i.e.* essentially to remove unwanted materials from hard surfaces). This is often done to prepare surfaces for painting, electroplating, galvanising, tin plating or varnishing. This category excludes other solvents used for architectural surface coatings (see Section 4.4.2), motor vehicle refinishing and printing and graphic arts, which are normally estimated separately.

The solvents used by industry may contain one or more of a range of VOCs, such as trichloroethylene, tetrachloroethylene, carbon tetrachloride, chloroform and methyl ethyl ketone. The types of solvents used vary from country to country. In Australia, for example, industrial solvents are predominantly trichloroethylene; this simplifies the inventory process.

Industrial cleaning activities can be categorised as follows:

1. Batch cold cleaning machines. These use liquid solvents at room temperature and are generally represented by a large number of small sources.
2. Batch vapour-cleaning machines. These use solvent vapours from halogenated compounds.
3. In-line cleaning machines. These are larger machines with automated continuous loading and emissions are generally included with point source estimates. Solvents may be used in vapour or liquid modes.
4. Clean-up solvent use. This is often done by wiping.

(b) *Factors affecting emissions*

Many control processes can reduce emissions from solvents. These may include the use of covers, measures to prevent emissions during malfunctions, distillation of vapours, low pressure spraying, and product reformulation to reduce volatility.

(c) *Description of release estimation techniques*

Emissions from industrial solvents are normally estimated as an area source with adjustment made for contributions reported by point sources. Emissions estimation is based on a mass balance approach, assuming that all VOCs in the solvents used across the airshed evaporate to the atmosphere. The following general approaches may be used to collecting activity data:

1. Conduct detailed surveys of solvent users. This requires identifying facilities to be surveyed which adequately represent the total industrial sector and gathering data on the types and amounts of solvent used for the different cleaning activities, level of emissions control applied and any recycling or disposal of solvents off-site. This method is the most accurate but also the most resource intensive. Refer to the EIP report (Section 3.1.2) for guidance on surveys of users and suppliers.
2. Obtain sales data from suppliers. This may be sufficiently accurate if all substances used can be easily identified and sales data are readily obtained from suppliers (*e.g.* as is the case in Australia). Control technologies will not normally be accounted for (unless they are subject to regulation or other information is available) and it may be necessary to scale down sales data from a larger area using employment or population data. It is also necessary to adjust emissions downward to allow for the point source component.

3. Use published emission factors (in per capita, per employee, or per equipment unit in use terms). This is the least accurate of the three methods. See EIIP on Solvent Cleaning (Table 6.5-2) for per capita and per employee emission factors and AP-42 on solvent degreasing (Table 4.6-2) for per unit emission factors (kg/yr/unit). The latter factors are reproduced in the EMEP/CORINAIR Guidebook (Table 8.1).

If the HAPs contained in any of the solvents are included separately in the inventory, data on the composition of these solvents should also be obtained from suppliers.

(d) Spatial allocation

Emissions could be spatially allocated according to industrial zones or according to industry employment data. A less accurate approach would be to use population density.

(e) Summary of steps in the process

1. Review the types of solvents used by industry in the region, identify distributors and the availability of sales data.
2. Review the likely significance of the source and determine whether a detailed survey approach is necessary or whether a top-down approach (using sales data obtained from distributors) or default emission factors would be sufficient.
3. Collect activity data (either by survey or from distributors) or emission factors.
4. Estimate emissions and adjust by subtracting any point source contributions.
5. Spatially and temporally disaggregate as required.

(f) Comments on reliability

The nature of the activity data will influence the resulting accuracy of emissions estimates. Using a top-down approach (assuming all solvents are used for cleaning and degreasing) may overestimate or double-count emissions with other source categories, as solvents may be used for other purposes. If no allowance is made for solvents that may be recycled, reclaimed or disposed of off-site, emissions may also be over-estimated. If activity data are scaled down from a larger region, the extent to which the study region is representative of the larger region, (in terms of industrial activity), will also be important.

Using default emission factors from other countries may be quite inaccurate.

(g) Sources of further information

Australia

Environment Australia (1999), Emissions Estimation Technique Manual for Aggregated Emissions from Use of Industrial Solvents (Sub-threshold) (Environment Australia, Canberra, Australia). http://www.npi.gov.au/handbooks/aedmanuals/subsolvent_rev2.html.

Europe

EEA (1999), *EMEP/CORINAIR Atmospheric Emission Inventory Guidebook* (UNECE/EMEP Task Force on Emission Inventories, European Environment Agency, Copenhagen, Denmark). <http://reports.eea.eu.int/EMEP/CORINAIR/en/page002.html>.

US

US EPA (1995), *Compilation of Air Pollutant Emission Factors, Volume I, Stationary Point and Area Sources, AP-42* (United States Environmental Protection Agency, North Carolina, US), 5th Edition. <http://www.epa.gov/ttn/chief/ap42/index.html>.

US EPA (1997), *Solvent Cleaning*, Chapter 6 from Volume III of EIIIP Document Series, prepared by Eastern Research Group, US (United States Environmental Protection Agency, North Carolina, US). <http://www.epa.gov/ttn/chief/eiip/techreport/volume03/iii06fin.pdf>.

4.4.2 Architectural surface coatings

(a) Nature of the source and relevant pollutants

Architectural coatings involve the application of a thin layer of coating (paints, primers, varnish or lacquer) to buildings, furniture *etc.*, as well as the use of solvents as thinners and for clean-up. Architectural coatings are used for domestic, commercial, government and industrial structures. The VOCs used as solvents in the coatings are emitted during application and as the coating dries. VOCs may include specific HAPs of interest for a particular inventory, such as benzene, methyl ethyl ketone and toluene.

Surface coatings include other categories not discussed here, such as those used for industrial purposes, traffic markings, graphic arts and automobile refinishing.

(b) Factors affecting emissions

The amount of coating used and its VOC content determine the emissions from architectural coatings. The relative weight fractions of any HAPs will determine their emissions. The amount of paint actually used can be reduced by increasing the solids content, decreasing the thickness of the coat, and increasing transfer efficiency (*i.e.* reducing wastage). Adding thinners to paints increases the solvent content and hence increases emissions.

Architectural coatings are normally known as solvent-based or water-based. Solvent-based coatings contain between 30 % and 70% VOCs by weight and water-based contain about 6%. Powder paints contain no solvents. Regulations exist in some countries or states limiting the VOC content of coatings.

(c) Description of release estimation techniques

Estimating emissions from architectural surface coatings requires data on the total volume of the various products used according to their VOC content and composition (*i.e.* speciation profiles). Architectural coatings and thinners can only be treated as an area source.

The three main approaches to gathering activity and product data are as follows:

1. The survey approach involves contacting paint distributors and/or manufacturers and seeking data on product types, content, and amounts distributed within the study region. This approach may also involve determining the amounts recycled or sent to landfill by surveying recycling facilities. (Refer to the EIIP report on architectural surface coatings). Emissions for each class of product identified would be estimated separately and then summed, and VOC content and composition data would determine the relevant emission factors. This approach is the most detailed and resource intensive.
2. The top-down approach involves scaling down national or state consumption data, usually according to population. This requires consumption data for the particular state or country, population data, as well as VOC content and composition data. Note that VOC content should automatically reflect any controls in place. Consumption data needs to be split into water and solvent-based paints with separate emission factors applied according to the average VOC content for each. Depending on the level of disaggregation of the consumption data, emissions could be estimated for various subgroups based on the VOC content for each, and then the emissions could be summed. The EIIP report provides default emission factors for the VOC content of solvent and water based paints (lb/gal) plus speciation profiles from CARB. The EMEP/CORINAIR Guidebook also provides emission factors for the VOC content (g/kg) and a speciation profile from the UK.
3. A simple, but potentially inaccurate, method involves the use of default per capita emission factors, such as those provided in AP-42.

(d) Spatial allocation

The most accurate approach possible would be to spatially allocate emissions according to a measure of building coverage. The most common approach is to use population distribution to disaggregate emissions spatially.

(e) Summary of steps in the process

1. Review the nature and sources of activity data.
2. Decide on the most appropriate methodology, depending on the quality of available data, nature of the inventory and resources available.
3. Carry out a survey or gather consumption and other required data, or select default emission factors to be used.
4. Estimate emissions for all classes of coatings separately (unless default factors are used) and sum these to obtain total emissions.
5. Spatially and temporally disaggregate as required.

(f) Comments on reliability

It is important to have reliable activity data that accurately reflect the different types of coatings and thinners used and their VOC content. The increasing use of water-based paints in many countries has a significant impact on emissions. Using default values (*e.g.* from another country) for VOC content and speciation profiles may be quite inaccurate, unless the coatings used are known to be very similar.

Scaling down national or state data may reduce accuracy if the study area has different characteristics that could influence the use of surface coatings (*e.g.* types of buildings, climate, proximity to the sea).

Using default per capita emission factors may be quite inaccurate.

(g) *Sources of further information*

Australia

Environment Australia (1999), Emissions Estimation Technique Manual for Aggregated Emissions from Architectural Surface Coatings (Environment Australia, Canberra, Australia). <http://www.npi.gov.au/handbooks/aedmanuals/archcoat1-1.html>.

Europe

EEA (1999), *EMEP/CORINAIR Atmospheric Emission Inventory Guidebook* (UNECE/EMEP Task Force on Emission Inventories, European Environment Agency, Copenhagen), 2nd Edition. <http://reports.eea.eu.int/EMEPCORINAIR/en/page002.html>.

US

US EPA (1995), *Compilation of Air Pollutant Emission Factors, Volume I, Stationary Point and Area Sources, AP-42* (United States Environmental Protection Agency, North Carolina, US), 5th Edition. <http://www.epa.gov/ttn/chief/ap42/index.html>.

US EPA (1995), *Architectural Surface Coating*, Chapter 3 from Volume III of EIIP Document Series, prepared by Radian Corporation, US (United States Environmental Protection Agency, North Carolina, US). <http://www.epa.gov/ttn/chief/eiip/techreport/volume03/archsfc.pdf>.

4.4.3 Domestic and commercial solvents

(a) *Nature of the source and relevant pollutants*

The VOCs released from consumer and commercial products result from the evaporation of solvents when these products are used. An extensive range of products is solvent-based and can be considered in the following categories:

- personal care products;

- household cleaning products;
- motor vehicle after-market products;
- adhesives and sealants;
- pesticides and herbicides;
- coatings and related products; and
- miscellaneous products.

VOCs are primarily released by immediate evaporation (aerosol spray), evaporation after application (product drying) and direct release in the gaseous phase. Specific organic HAPs may also be of interest for a particular inventory.

Releases from architectural surface coatings are covered in the previous section of this report (as the estimation of releases for coating are normally based on specific activity data). Releases associated with motor vehicle refinishing and broad-acre agricultural use of pesticides and herbicides are also not included here.

(b) Factors affecting emissions

Emissions from a particular product will depend on the amount and composition of the VOCs contained in the product, any controls on product formulation and the way in which the product is used.

(c) Description of release estimation techniques

The normal method for estimating emissions from this source involves the use of per capita emission factors for the various sub-categories. Those derived in the US, which are based on extensive surveys of product manufacturers and industry associations, are widely used. Table 5.4-2 in the EIIP report on consumer and commercial solvent use contains per capita emissions factors for total VOCs as well as a range of HAPs (expressed in pounds per person per year). Note that these emission factors include only reactive VOCs – total VOCs are obtained by multiplying reactive VOCs by a factor of 1.45. Refer to the Australian NPI manual for US emission factors adjusted to include all VOCs and converted to kilogrammes per person per year. These emission factors are simply combined with population data to give total emissions. If any specific controls on product content are in place, then the emission factors can be adjusted accordingly.

The EMEP/CORINAIR Guidebook provides alternative per capita emission factors for domestic solvents derived in the UK. These cover cosmetics and toiletries, household products, construction/DIY and car care products.

An alternative method would involve conducting a survey of distributors and/or retailers on types and quantities of products sold within the region. Information on VOC content would also be needed from manufacturers and/or distributors. In some countries (*e.g.* the Netherlands), these types of statistics are collected and provided to government, allowing more accurate estimation of emissions. In most countries, however, the amount of effort required to compile the necessary data would make this approach impractical due to resource needs.

(d) Spatial allocation

Emissions from domestic and commercial solvents would normally be spatially distributed according to population density.

(e) *Summary of steps in the process*

1. Obtain population data (or carry out detailed surveys to produce specific emission factors if desired).
2. Identify relevant emission factors, taking care not to duplicate other sections of the inventory (e.g. surface coatings) and adjust for any regulations if necessary.
3. Multiply per capita emission factors for VOCs and other HAPs by population.
4. Spatially and temporally disaggregate emissions as required.

(f) *Comments on reliability*

Reliability will depend on the emission factors used and on how much the range, availability and consumption of products reflects those of the US or UK. Emission factors for HAPs would be less reliable in another country, as the speciation profile of products may vary significantly according to product formulation. Product use may of course vary spatially within a study region, but may also differ from a national average.

(g) *Sources of further information*

Australia

Environment Australia (1999), Emissions Estimation Technique Manual for Aggregated Emissions from Domestic/Commercial Solvent and Aerosol Use (Environment Australia, Canberra, Australia). http://www.npi.gov.au/handbooks/aedmanuals/domcomsolvents_rev.html.

Europe

EEA (1999), *EMEP/CORINAIR Atmospheric Emission Inventory Guidebook* (UNECE/EMEP Task Force on Emission Inventories, European Environment Agency, Copenhagen). <http://reports.eea.eu.int/EMEPCORINAIR/en/page002.html>.

US

US EPA (1995), *Compilation of Air Pollutant Emission Factors, Volume I, Stationary Point and Area Sources, AP-42* (United States Environmental Protection Agency, North Carolina, US), 5th edition. <http://www.epa.gov/ttn/chief/ap42/index.html>.

US EPA (1996), *Consumer and Commercial Solvent Use*, Chapter 5 from Volume III of EIIP Document Series, prepared by Eastern Research Group, US (United States Environmental Protection Agency, North Carolina, US). <http://www.epa.gov/ttn/chief/eiip/techreport/volume03/iii05.pdf>.

4.5 Agriculture and forestry

Two source categories are presented: wildfires (both prescribed and agricultural burning) and manure management. Both source categories are important sources of greenhouse gases. In addition, fires contribute to criteria air pollutants and HAPs, while manure is an important source of ammonia.

4.5.1 *Wildfires, prescribed and agricultural burning*

(a) *Nature of the source and relevant pollutants*

In agricultural areas, stubble, crop residues and other waste are often burnt. Forest burning includes prescribed burns for various purposes such as fuel reduction and ecosystem management, plus wildfires that are the result of arson or occur naturally. A wide range of pollutants are emitted from burning of agricultural areas and forests, including particles, CO, VOCs, SO₂, NH₃, various HAPs such as dioxins, PAHs and heavy metals. The inefficient form of combustion from fires means that there is relatively little NO_x produced. Fires are also a significant source of greenhouse gases, particularly CO₂, but also CH₄ and N₂O.

The open burning of household and garden wastes and land cleaning debris is not considered here.

(b) *Factors affecting emissions*

Emissions from the burning of agricultural waste depend very much on the type of crop burnt, the size of harvest and farming practices. It is not practicable to use abatement methods to control emissions from open burning. The only way of reducing emissions is to reduce the activity. The impacts on adjoining areas may be minimised, however, by avoiding burning on days of adverse meteorology.

Emissions from prescribed burning and wildfires are also highly variable, depending on the type of fuel and loading. Emissions are also likely to vary greatly from one year to the next according to variations in the amount of fuel, the areas burnt and the prevailing climatic conditions.

Other factors influencing emissions from agricultural and forest burning (but which are not generally factored into release calculation processes) include the stage of burn, fuel loading geography, moisture content and topography.

(c) *Description of release estimation techniques*

Agricultural waste

In the EMEP/CORINAIR Guidebook, Section 9 (relating to the open burning of agricultural wastes) excludes stubble burning but includes other crop residues, timber, leaves, animal carcasses, *etc.* The simplest approach is to use a single emission factor for each pollutant representing emission per mass of waste burned. This requires input data on the amount of waste per hectare of farmland and the total area. The Guidebook includes a default value for the amount of waste per hectare of arable farmland, and some typical emission factors for dioxins, PAHs, VOCs and NH₃/NH₄. Section 10 of the Guidebook includes a brief section on stubble burning which includes an emission factor for NH₃.

A more detailed approach involves estimating the weight of waste per hectare for different types of farming and crops. This requires a more detailed breakdown of crop yields, the residue/crop ratio and the proportion of harvest subject to burning. AP-42 provides emission factors (kg/Mg) and fuel loading factors (Mg/ha) for various types of crops for emissions of particles, CO, CH₄ and VOCs. The Australian NPI manual on prescribed burning and wildfires includes a table of emission factors (g/kg) for agricultural burning for a range of crops. The emission factors provided are derived from both local and US (mostly CARB) sources.

Methods for estimating emissions of greenhouse gases (CH₄, CO₂ and N₂O) from agricultural waste are documented by IPCC. The EIIP report contains a worked example following several steps: the amount of dry matter burnt is first calculated. This calculation requires data on crop production rates, residue/crop ratios, the proportion of harvest subject to burning, the dry matter content of residue, burning efficiency and combustion efficiency. Then the total amount of carbon released is estimated and the CH₄ and N₂O emissions can also be estimated following the calculation of total nitrogen content.

Forest burning

Section 11 of the EMEP/CORINAIR Guidebook includes a chapter on forests and other vegetation fires. A simple method for estimating emissions for five vegetation types involves multiplying the area burnt by emission factors (such as a default factor), which are expressed in kilogrammes/hectare (kg/ha). A more detailed method involves first estimating emissions of carbon, then estimating emissions of other gases using emission ratios with respect to carbon. An algorithm is provided to estimate the mass of carbon emitted (which depends on the area burnt), average biomass of fuel per unit area, fraction of above ground biomass, and the burning efficiency of above ground biomass. Some default values for the last three variables are given, based on European results. Input data on the area burnt must be used; other data should preferably also be derived from local information.

The Australian NPI Handbook provides some local fuel loading values for forest wildfires, forest prescribed burning and grassland burning. This relatively simple method requires data on area burnt (ha), fuel loading (kg/ha) and emission factors (expressed in g/kg). Fuel loading and emission factors are provided for three types of fires, namely forest wildfires, prescribed forest burning and grassland.

The US EPA AP-42 provides fuel loading factors for different vegetation types and emission factors (kg/ha) for wildfires in the US. Prescribed burning emission factors (g/kg) are also provided for different vegetation types. These emission factors need to be used in conjunction with local fuel loading values.

(d) Spatial allocation

Spatial allocation should be according to the areas of farms and forests burnt in a given year. If a more detailed method is used, involving the breakdown of emissions into farm/crop types, then spatial allocation could reflect this if the corresponding spatial data are available.

(e) Summary of steps in the process

1. Determine which forms of forest and agricultural burning are relevant to the study region and the extent of available activity data and local fuel loading values, emission factors and other data.
2. Decide which estimation methods to use and collect the data needed.

3. Calculate emissions for each sub-category, then aggregate as required.
4. Spatially and temporally disaggregate as required.

(f) *Comments on reliability*

Activity data on the areas of farmland and crop harvests may be quite good in many countries, but estimates of waste (residue/crop ratios) from crops are often unreliable. Some emission factors (*e.g.* dioxins, PAHs in particular) may have a high degree of uncertainty.

Emission factors for forest burning are associated with a high degree of uncertainty – even more for trace gases than for CO₂ and the common pollutants. Data on areas burnt and timing are likely to be reliable. The quality of fuel load data will depend on the source and how the data have been derived.

(g) *Sources of further information*

Australia

Environment Australia (1999), *Emissions Estimation Technique Manual for Aggregated Emissions from Prescribed Burning and Wildfires* (Environment Australia, Canberra, Australia).
http://www.npi.gov.au/handbooks/aedmanuals/burning_ff.html.

Europe

EEA (1999), *EMEP/CORINAIR Atmospheric Emission Inventory Guidebook* (UNECE/EMEP Task Force on Emission Inventories, European Environment Agency, Copenhagen, Denmark).
<http://reports.eea.eu.int/EMEPCORINAIR/en/page002.html>.

International

IPCC/OECD/IEA (1997), *Revised 1996 Guidelines for National Greenhouse Gas Inventories* (OECD, Paris, France).

US

US EPA (1995), *Compilation of Air Pollutant Emission Factors, Volume I, Stationary Point and Area Sources*, AP-42 (United States Environmental Protection Agency, North Carolina, US).
<http://www.epa.gov/ttn/chief/ap42/index.html>.

US EPA (1999), *Methods for Estimating Greenhouse Gas Emissions from Burning of Agricultural Crop Wastes*, Chapter 11 from Volume VIII of EIIP Document Series, prepared by ICF Consulting, US (United States Environmental Protection Agency, North Carolina, US).
<http://www.epa.gov/ttn/chief/eiip/techreport/volume08/viii11.pdf>.

4.5.2 *Manure management*

(a) *Nature of the source and relevant pollutants*

Agriculture is the major source of ammonia in many countries. In Europe, animal excreta contributes over 80% of ammonia (NH₃). It is also a significant source of nitrous oxide (N₂O), both directly from manure and also following the input of nitrogen from manure to the soil. Methane (CH₄) emissions from manure are less significant than from enteric fermentation in livestock, and NMVOC emissions are relatively minor compared with other sources.

This section deals with animal excreta deposited in buildings and collected as liquid slurry or solid manure. The EMEP/CORINAIR manual deals with emissions from manure in open paddocks in separate sections (Cultures with Fertilisers and Cultures without Fertilisers). This is because it is difficult to distinguish emissions from urine and manure from those associated with fertilisers and soils only.

(b) *Factors affecting emissions*

For housed animals, emissions are divided into those directly from animal houses and those associated with subsequent storage and the spreading of wastes. Emissions of NH₃ depend on the types, age and weight of animals, and also on the nitrogen content of feed, housing system, waste storage system, climatic conditions and the amount of time animals spend indoors *versus* outdoors. Emissions of NH₃ after spreading depend on properties of the waste, soil properties, method and rate of application, height of crop, and meteorology.

Emissions of CH₄ depend on the manure management system and contact with oxygen, moisture level and temperature. Emissions of N₂O depend on the composition of the manure and can be also be influenced by manure storage and management, including moisture level and oxygen content. It is difficult to influence emissions from soils following nitrogen input.

(c) *Description of release estimation techniques*

In most cases, quantitative data on all of the factors mentioned above will not be available. The simplest method for estimating NH₃ emissions is to use default emission factors, such as those in the EMEP/CORINAIR Guidebook for each animal type, inside housing, outside storage and surface spreading (expressed in kg of NH₃ per animal). Then total emissions are scaled up according to the total number of animals in each class. A more detailed approach would be based on nitrogen flows within a process-based model. For this, country specific information on manure management and animal husbandry would be required. A spreadsheet can be obtained (refer to the Guidebook for details) for calculations, with one table for each animal type, and default values included on volatilisation rates, abatement measure efficiency, nitrogen excretion rates and manure management systems.

The IPCC guidelines provide default N₂O emission factors (expressed in kg of N₂O per kg of N excreted) for different types of animal waste management systems. Data are required on animal types and weights, the fraction of manure produced in waste management systems for each animal type, N excretion for each animal type (default values for the latter are in the EMEP/CORINAIR Guidebook). The Guidebook also has default emission factors for N₂O emissions from soil due to manure input. For these emissions, data on total N excretion by animals are also needed, or default values can be used. No more detailed methods are provided, although country specific data can be used in place of default IPCC values.

Estimating CH₄ releases from manure requires data on animal populations and manure management practices. Note that the EMEP/CORINAIR Guidebook includes CH₄ emissions with the section on Enteric Fermentation. IPCC default emission factors (expressed in kg per animal) for each type of animal are reproduced in the EMEP/CORINAIR Guidebook. A more detailed approach would involve using country specific information on feed intake and waste management systems to derive local emission factors, and would also include more animal sub-categories.

(d) *Spatial allocation*

The spatial allocation of any emissions from manure management should be based on the spatial distribution of animal numbers and types as much as geographic data will allow, in particular for NH₃ which may be important in airshed modelling programmes.

(e) *Summary of steps in the process*

1. Determine whether housed livestock in the study region may be an important source of emissions, assuming ammonia and/or greenhouse gases are included in the inventory.
2. Determine the availability of activity data including livestock numbers for different classes of animals, geographic distribution, and other information about waste management practices, feed intake, *etc.*
3. According to data available, resources and inventory objectives, decide on the most suitable methodology.
4. Collect the necessary data and estimate emissions for each animal type then sum for each pollutant.
5. Spatially and temporally disaggregate as required.

(f) *Comments on reliability*

The use of a simple methodology involving default emission factors for NH₃ for each class of animal will be less accurate than a country specific approach that takes account of different farming situations. There is a high level of uncertainty regarding agricultural emissions of N₂O in general, including emission factors and N excretion. The available emission factors do not account for the effects of soil type, crops or climate on N₂O formation. For NMVOC emissions from manure, the lack of measurement data means there is a significant uncertainty in relation to emissions estimates.

(g) *Sources of further information*

Europe

EEA (1999), *EMEP/CORINAIR Atmospheric Emission Inventory Guidebook* (UNECE/EMEP Task Force on Emission Inventories, European Environment Agency, Copenhagen, Denmark), 2nd Edition. <http://reports.eea.eu.int/EMEPCORINAIR/en/page002.html>.

International

IPCC/OECD/IEA (1997), Revised 1996 Guidelines for National Greenhouse Gas Inventories (OECD, Paris, France).

US

US EPA (1999), *Methods for Estimating Greenhouse Gas Emissions from Manure Management*, Chapter 7 from Volume VIII of the EIIP Document Series, prepared by ICF Consulting, US (United States Environmental Protection Agency, North Carolina, US). <http://www.epa.gov/ttn/chief/eiip/techreport/volume08/viii07.pdf>.

4.6 Mobile sources

Road traffic is generally the most significant source of many common pollutants and HAPs in urban areas, and the estimation methods are among the most complex of those used in air emissions inventories. The other mobile sources covered (aircraft, ships and garden maintenance) are among the next most significant in this group.

4.6.1 Road traffic

(a) Nature of the source and relevant pollutants

The road traffic sector includes different types of vehicles: passenger cars, commercial vehicles, trucks, buses and motor bicycles. Off-road vehicles such as trail bikes and snowmobiles are normally considered separately in inventories. Exhaust pollutants from on-road vehicles result from the burning of fossil fuels in the engine. Various pollutants are produced as by-products of the combustion process, including a range of VOCs, NO_x, CO, SO₂, particles, lead and other heavy metals.

VOC emissions also result from the evaporation of volatile substances, mainly from gasoline (diesel fuel has a much lower vapour pressure). These emissions occur in several ways:

- diurnal losses: as air temperature rises during the day, the temperature of the fuel increases leading to increased vapour loss;
- running losses: heat from the engine and exhaust system vaporises gasoline during vehicle operation;
- hot soak losses: evaporation continues after the engine is turned off; and
- resting losses: vapour is lost through various leaks and permeation through rubber components.

Particles are also emitted from brake and tyre wear.

(b) Factors affecting emissions

The main factors affecting vehicle emissions are:

- vehicle type;
- type and composition of fuel used;
- vehicle age; and
- types of roads where vehicles travel.

Emission controls in force at the time a vehicle is manufactured will have a major impact on emissions. Hence, it is necessary to break vehicle fleet data down into age classes and relate these to periods when different levels of controls were in force. (For example, exhausts from the latest gasoline vehicles are controlled by catalytic converters and necessitate the use of unleaded petrol.) For in-service vehicles, the emissions control technology, condition of emission control equipment and state of maintenance are generally reflected in emission factors for different age classes of vehicles.

Emissions also vary significantly with the mode of operation, involving factors such as traffic flow and vehicle speeds. These variables are usually reflected in emission factors for different road types. 'Cold starts' (that is, the first few minutes of operation of gasoline vehicles when the catalyst does not function properly) also produce significantly higher emissions and should be accounted for in inventories. Factors affecting evaporative emissions are Reid Vapour Pressure (RVP), temperature and number of trips per day. Other relevant factors, but which are generally only considered in detailed local studies, include road conditions and grade.

(c) *Description of release estimation techniques*

If extensive local vehicle test data (for both new and in-service vehicles) are available, then emission factors for those vehicle types can be developed from first principles. In the absence of any local data, the best approach would be to use one of the existing software packages (*e.g.* MOBILE6 or COPERT). A wide range of published emission factors are available, expressed in grams per kilometre and/or grams per megajoule. US EPA emission factors from AP-42 apply to criteria air pollutants whereas the EMEP/CORINAIR Guidebook includes all pollutants required for international reporting purposes.

Conventional inventory methods

Release estimation involves multiplying VKT (vehicle kilometres travelled) figures by emission factors (grams per kilometre travelled). Emission factors need to be weighted according to the structure and composition of the vehicle fleet. The US EPA has a well-known software package called MOBILE6, used to calculate exhaust and evaporative CO, NO_x and VOC emissions for the US passenger and commercial fleet. The following data are required as inputs to the model:

- relative vehicle miles travelled (VMT) by vehicle/fuel type (where necessary this will need to be converted from VKT);
- VMT in the airshed by vehicle/fuel type and age;
- number of vehicles by vehicle/fuel type and age;
- percent of VMT in cold-start and hot-start operating modes for gasoline vehicles; and
- RVP, average temperature and average daily maximum and minimum temperatures.

Adjustments can also be made according to inspection and maintenance programmes in force, air-conditioning and vehicle speed. Countries where emissions standards are behind those of the US will tend to under-estimate emissions unless an appropriate time lag is built in.

MOBILE6 is developed by the US EPA and was released in 2001. The California Air Resources Board has its own motor vehicle emissions model.

Spatial VKT data are usually available from transport authorities using transport model results. If necessary, traffic count data may be used instead, although it will be more time consuming to derive gridded VKT. The general method for deriving gridded VKT data and relative VKT according to vehicle, fuel and road types is described in Australia's NPI Manual relating to motor vehicles.

In Australia, passenger (gasoline) vehicle emission factors for NO_x, CO and VOCs have been calculated from local vehicle test data. Only one drive cycle has been used for vehicle testing in Australia (rather than separate drive cycles applicable to different road types). Because of this, a method has been developed in Australia involving the division of the test cycle into segments and, from the sampled emissions during each segment, estimating emissions for different road types according to 'splitting factors' (EPAV, 1991; EPAV 1996).

In Europe, the COPERT model has been developed by EEA and is made available through the CORINAIR programme. This model is used by many countries in Europe. The COPERT model takes into account the composition of the vehicle fleet, the annual kilometres driven, and specific emission factors per kilometre driven in urban, rural and highway traffic. Vehicles are divided by size, fuel type and emissions legislation level. Hot and cold-start emissions are estimated separately, as well as evaporative emissions. The model requires data on the number of trips (so that cold starts are accounted for explicitly) as well as total VKT. COPERT creates a fuel balance whereby fuel consumption is calculated and compared with statistical fuel data. The difference between these numbers must be less than a certain amount, so the number of annual kilometres travelled is adjusted across vehicle classes and the emissions are calculated repeatedly in an iterative way. Emissions of particles can be estimated using US EPA software PART5 or the COPERT model.

Emission factors for lead and SO₂ are estimated from fuel sulphur content and fuel consumption rates for the various vehicle types. (Refer to Australia's NPI Manual for a description of methodology). Note that unleaded gasoline contains small quantities of lead, so data on the proportion of leaded *versus* unleaded fuels sold will be required. Emissions of CO₂ can also be calculated from fuel consumption data according to IPCC methodology. The EMEP/CORINAIR Guidebook (Section 7, Tables 5.3 and 5.4) summarises four different approaches used for various pollutants. These categories range from most complex (*e.g.* NO_x, VOC and CO from gasoline passenger cars) where both speed dependent hot emissions and cold starts, road types, trip lengths and temperatures are taken into account, to the simplest (*e.g.* SO₂) based on fuel consumption only. The EMEP/CORINAIR methodology also includes greenhouse gases.

On-road measurements

There are several approaches to developing emission factors from on-road measurements, for example through sampling emissions from tunnel vent stacks. Generally, it is only possible to obtain a 'fleet average' emission factor for the particular road sampled. Measurements from any one road or tunnel may not be representative of different road types and fleet mixes. Another disadvantage is that average emission factors do not allow the relative contributions from different vehicle types to be determined, so an inventory that is based on such emission factors will have limited value as a policy analysis tool. The main value of these sorts of approaches is to monitor trends over time and to compare the results with emission factors derived from normal inventory methods and then averaged across the fleet.

One approach to on-road measurement has been developed by CSIRO and EPAV in Australia (EPAV, 1999). This determines emission factors for CO₂, CO, NO_x and VOC (as well as VOC speciation data) by sampling air above moving traffic on a roadway, capturing emissions from many vehicles and determining

an unknown emissions rate by 'ratio-ing' it to a known emissions rate (CO₂) from the vehicle. CO₂ emissions, directly related to fuel consumption, are well known.

Another approach used in Denmark involves using a dispersion model 'backwards' to calculate emissions from measured concentrations at kerbsides (NERI 2000).

(d) *Spatial allocation*

Road traffic emissions are normally spatially allocated in a linear fashion reflecting some or all traffic routes. The spatial resolution will depend on the scale and purpose of the inventory. Very detailed inventories (*e.g.* as carried out in London) represent every roadway with VKT based on accurate traffic count data. Most inventories, however, will only identify major traffic routes, with minor roads being spatially allocated according to another indicator such as population density.

(e) *Summary of steps in the process*

The general steps in compiling estimates of road traffic emissions can be summarised as follows:

1. Review all relevant sources of vehicle, fuel, emissions and meteorological data.
2. Select the most appropriate emission factors/models and activity data to be used and obtain relevant data.
3. Calculate relative VKT by road type, vehicle and fuel type, and vehicle age.
4. Derive exhaust and evaporative emission factors using selected methods for different pollutants.
5. Speciate VOCs and particles into individual pollutants.
6. Calculate total emissions in each grid cell by combining activity and emissions data.
7. Incorporate temporal variations if required.

(f) *Comments on reliability*

In general, vehicle registration data and fuel data available from government and industry sources should be quite reliable. The accuracy of VKT data will depend on the reliability of the particular transport model used and/or traffic count data, including spatial coverage and resolution.

The accuracy of emission factors will depend on the extent to which they accurately represent the local fleet. This will depend on the number and nature of the vehicles tested. If international emission factors/models are used, then accuracy may be low if the vehicle fleet is significantly different from the fleet reflected in the model. Emission factors based on fuel consumption will generally be reliable. Speciation factors are likely to be of low reliability, unless they are based on extensive local testing. Another less obvious reason for reduced accuracy of emission factors includes the nature of the drive cycle on which vehicle testing is based, and whether or not it represents real world conditions.

(g) *Sources of further information*

Australia

EPAV (1991), *Air Emissions Inventory Port Phillip Control Region: Planning for the Future*, SRS 91/001 (EPA, Victoria, Australia).

EPAV (1996), *National Pollutant Inventory: Technical Report on the Air Emissions Trials for the NPI, Volume 2* (Commonwealth of Australia, Canberra, Australia).

EPAV (1999), *Measurements of Motor Vehicle Pollutants and Fleet Average Emission Factors in Melbourne*, Publication No. 652 (EPA, Victoria, Australia).

Europe

EEA (1999), *EMEP/CORINAIR Atmospheric Emission Inventory Guidebook* (UNECE/EMEP Task Force on Emission Inventories, European Environment Agency, Copenhagen, Denmark).
<http://reports.eea.eu.int/EMEP/CORINAIR/en/page002.html>.

COPERT model <http://vergina.eng.auth.gr/mech/lat/copert/copert.htm>

NERI (2000), *Benzene from Traffic* (Ministry of Environment and Energy, National Environmental Research Institute, Roskilde, Denmark).

International

IPCC/OECD/IEA (1997) *Revised 1996 Guidelines for National Greenhouse Gas Inventories* (OECD, Paris, France).

US

US EPA (1992), *Procedures for Emission Inventory Preparation, volume IV: Mobile Sources*, Office of Mobile Sources (United States Environmental Protection Agency, Washington, D.C., US).
<http://www.epa.gov/oms/models.htm#inventory>

US EPA (1985), *Compilation of Air Pollutant Emission Factors, volume II, Mobile Sources, AP-42* (United States Environmental Protection Agency, North Carolina, US), 5th edition.

Other US EPA sources

MOBILE6 <http://www.epa.gov/orcdizux/m6.htm>

PART5 <http://www.epa.gov/oms/part5.htm>

CARB model <http://www.arb.ca.gov/msei/msei.htm>.

4.6.1 Aircrafts

(a) Nature of the source and relevant pollutants

There are two main types of aircraft, which use different fuels and have different emission characteristics – gas turbine and reciprocating piston (propeller) planes. Both civilian and military aircraft may need to be considered in inventories. Exhaust emissions resulting from the combustion process include NO_x, SO₂, particles, CO, CO₂, VOCs, organic pollutants and metals. Although there are also evaporative emissions from aircraft operations, no emission factors are presently available.

Ground and maintenance operations at airports are not included here; if significant, these should be treated as point sources. In terms of urban air quality impacts and airshed modelling, emissions only need to be considered close to the ground within the mixing zone. For greenhouse gases (CO₂) it is necessary to also consider cruising above 1000m. For some reporting purposes (e.g. IPCC), domestic and international flights must be considered separately.

(b) Factors affecting emissions

Exhaust emissions from aircraft depend on the type of aircraft, type of engines and fuel used, and altitude of operation. The landing and takeoff (LTO) cycle incorporates all flight and ground level modes below a reference height above ground level, including descent/approach, touchdown, landing run, taxi in, idle and shutdown, start-up and idle, checkout, taxi out, takeoff and climb-out. Mixing height can be determined from detailed meteorological data (or a default height of 1000m is frequently chosen). Time in mode (TIM) provides estimates of the time each aircraft spends in each operational mode at a given airport. All operations within the LTO are grouped into four standard modes for which emission data are readily available:

- approach: from 1 000m above ground to ground level;
- taxi/idle: applicable to incoming and outgoing aircraft;
- takeoff: from commencement of acceleration to 200m above ground level, during which aircraft operates at full throttle; and
- climb-out: from 200m to 1000m above ground level.

For greenhouse gases, the cruise mode above 1000m must also be considered.

International emission controls regulate hydrocarbons, NO_x, CO and smoke emissions. CO and HC emissions are highest during idling and taxiing, NO_x during takeoff and climb-out.

(c) Description of release estimation techniques

A reasonably detailed approach to estimating emissions during the LTO cycle is described in Australia's NPI Manual. 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
- time spent operating auxiliary power units at the airport.

These data are normally available from airport authorities, airline companies and other government bodies. If possible, data should be collected for commercial (passenger, freight) flights, business aircraft, general aviation (private, recreation) and military planes. Some information may have to be obtained from individual airports. Emission factors (kg/hr) apply to each engine type of a particular aircraft type for each mode. These emission factors are available from the International Civil Aviation Organisation. It is also necessary to calculate emissions from auxiliary power units (APUs), requiring data on types of APUs and their operational time. If cruise emissions are to be included (for CO₂), the method will need to be varied and fuel consumption data will also be required. Refer to the 'detailed' methodology in the EMEP/CORINAIR Guidebook, plus a variation involving the use of fuel data for general aviation and military aircraft for which LTO data are often not available. AP-42 includes default times in mode that could be used for general aviation activity.

It will be necessary to speciate VOCs and particles into HAPs, depending on the pollutants listed in the inventory. Some speciation data are available from CARB and US EPA. For heavy metals except lead, emission factors from the stationary combustion of kerosene (similar to jet fuel) and gasoline (similar to avgas) could be used. The lead content of avgas (which is much higher than for gasoline) should be obtained from oil companies or a default value should be used.

A somewhat simpler method is based on the use of emission factors developed from national statistics on LTO and aircraft/engine types; this assumes all airports in a country are uniform. Default emission factors (expressed in kg of pollutant per LTO cycle) are included in the Australian NPI Handbook and in the US EPA procedures report on mobile sources. This method is not applicable to military aircraft and auxiliary power units. If cruise emissions are to be included and there are no data on cruise distances, it will be necessary to follow an amended approach using total fuel consumption data, as described under 'simple methodology' in the EMEP/CORINAIR Guidebook.

An even simpler method, most suited for estimating CO₂ emissions only, requires no data on the number of LTOs on an aircraft type basis. The only data required are the total number of LTOs and total fuel used with default emission factors per LTO cycle and cruise emission factors applicable to an average fleet. Refer to the 'very simple' methodology in the EMEP/CORINAIR Guidebook.

In the US, the Federal Aviation Administration has developed a computerised calculation tool to streamline the calculation of emissions. This tool includes a database with emission factors for different engine types. Refer to US EPA (1992) report (p.143) for details. The US EPA uses its NONROAD emissions model to estimate emissions from all non-road mobile sources.

(d) *Spatial allocation*

Aircraft emissions for the various modes should be spatially allocated to the grid cells in which the flight paths and ground movements occur. Emissions along flight paths should be divided into the four modes and distributed in grid cells in their correct proportions. APU emissions should be assigned to the grid cells where the airport is located.

(e) Summary of steps in the process

1. Identify civilian and military airports located within study region and sources of activity data.
2. Obtain activity data and assemble relevant emission factors.
3. Calculate emissions for each airport, using the best methodology according to data availability and resources for as many aircraft types as possible.
4. Spatially and temporally disaggregate as required.

(f) Comments on reliability

Activity data obtained from airports and airline authorities are generally highly reliable. Emission factors for criteria pollutants (CO, hydrocarbons, NO_x) have been derived from manufacturers' test data and should be reasonably reliable. Data on emissions of particulate matter are not always available, hence emission factors may not be based on direct measurements. Speciation profiles have a relatively low reliability. Using simpler methods involves making broad assumptions about the aircraft fleet and times in mode, so accuracy will be reduced. There is a high uncertainty associated with cruise emission factors.

*(g) Sources of further information*Australia

Environment Australia (2000), *Emissions Estimation Technique Manual for Aggregated Emissions from Aircraft*, Canberra, Australia, <http://www.npi.gov.au/handbooks/aedmanuals/aircraft2-2.html>

Europe

EEA (1999), *EMEP/CORINAIR Atmospheric Emission Inventory Guidebook* (UNECE/EMEP Task Force on Emission Inventories, European Environment Agency, Copenhagen, Denmark), 2nd Edition. <http://reports.eea.eu.int/EMEPCORINAIR/en/page002.html>.

International

ICAO (1995), *ICAO Engine Exhaust Emissions Data Bank*, International Civil Aviation Organisation, Montreal, Canada.

IPCC/OECD/IEA (1997), *Revised 1996 Guidelines for National Greenhouse Gas Inventories*, OECD, Paris, France.

US

CARB (1991b), *Identification of Particulate Matter Species Profiles*, ARB Speciation Manual Vol. 2, 2nd Edition, California Air Resources Board, US.

US EPA (1992), *Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources* (Office of Mobile Sources, US EPA, Washington D.C., US). <http://www.epa.gov/oms/models.htm#inventory>

US EPA (1985), *Compilation of Air Pollutant Emission Factors, Volume II: Mobile Sources, AP-42* (United States Environmental Protection Agency, North Carolina, US), 5th Edition.

NONROAD model. <http://www.epa.gov/otaq/nonrdmdl.htm>

4.6.2 Ships

(a) Nature of the source and relevant pollutants

This section covers cargo and passenger ships, tankers, colliers and naval ships. Smaller craft, such as tugs, fishing and recreational boats (less than 100 gross tonnes) should be considered separately. The normal combustion products – including CO, CO₂, VOCs, NO_x, SO₂, N₂O and HAPs are relevant. Most ships are powered by diesel engines, both for propulsion and auxiliary power. A small number are powered by steam turbine propulsion or gas turbines.

(b) Factors affecting emissions

Commercial ships emit pollutants under two main modes, while sailing and at berth under auxiliary power. At berth, diesel generators normally supply auxiliary power used for lighting, heating, pumps, refrigeration and ventilation. During the sailing mode, emissions come from both the exhaust and the auxiliary power systems. Exhaust emissions are influenced by many factors, including engine size, fuel used, operating speed and load.

In addition, there are fugitive emissions from the loading and ballasting of petroleum tankers in port as vapour is vented to the atmosphere. Ballasting emissions occur when vapour-laden air in the empty cargo tank is displaced to the atmosphere by ballast water being pumped into the tank. These emissions may occur at dock or some distance out to sea. Diesel loading is less significant as this fuel is relatively non-volatile. The loading and unloading of cargoes such as grain may release particles to the atmosphere, and incinerators on ships may be another source of emissions.

(c) Description of release estimation techniques

Australia's NPI Manual describes a relatively detailed methodology. The following data are required:

- location of ports;
- number of ships visiting in a year in various tonnage ranges;
- average number of hours at berth;
- average speed in shipping channels; and
- locations and lengths of shipping channels.

These data should be obtainable from port authorities and/or waterway/channel authorities. For major ports, Lloyd's Maritime Information Service has data on ship movements (for ships greater than 250 tonnes) world wide. Emission factors for main and auxiliary engines vary with tonnage ranges; these are available from Lloyd's Register (expressed in kg/hr). Emissions should be estimated by combining the number of hours at berth and in channels with the relevant time-based emission factors for each weight category. Speciation data can be obtained from CARB and Lloyds, although it is preferable to use local

diesel exhaust data if available. Note that many ships use light oil while in harbour then change to heavy oil (with high sulphur content) outside the harbour.

Another method, based on fuel consumption, is described in the EMEP/CORINAIR Guidebook. This involves less spatial resolution but may be suitable when statistics on fuel use for ship categories are available and emissions are more aggregated spatially (*e.g.* for national greenhouse inventories). Emission factors (expressed in kg/tonne) are available (*e.g.* from Lloyd's Register). There are single emission factors for pollutants other than NO_x, for which a speed based factor should be used. Fuel use data can be obtained from shipping companies or government sources.

A simple method described in the EMEP/CORINAIR Guidebook uses fuel sold and average emission factors (kg/tonne) according to fuels used. This method is appropriate for CO₂ emissions, even if the more detailed CORINAIR method described above is used for other pollutants.

To estimate emissions from loading and ballasting, data is required on the volume of petroleum liquid loaded at port, the number of tankers involved in loading and unloading, average deadweight tonnage of tankers, and the proportion of ballast emissions at berth. These data should be available from port and oil companies. Emission factors are provided in US EPA AP-42 (Volume I). Profiles for gasoline and crude oil evaporative emissions should be used for speciating VOCs.

International shipping needs to be taken into account for greenhouse gas inventories, but for urban air inventories only activity within the airshed needs to be considered.

The EMEP/CORINAIR Guidebook covers other in-port emissions from manoeuvring, and other vessels (*e.g.* tugs and dredgers).

The US EPA uses its NONROAD emissions model to estimate emissions from all non-road mobile sources.

(d) Spatial allocation

Emissions from ships in port (at berth, loading and ballasting) should be allocated to the port areas. Emissions from sailing should be distributed along the shipping channels.

(e) Summary of steps in the process

1. Identify relevant ports and availability of required data.
2. Decide on methodology according to inventory objectives, data available and resources.
3. Collect data and estimate emissions from ships in channels, at berth (and where relevant), loading and ballasting. If required for greenhouse gases also estimate emissions at sea also.
4. Spatially and temporally disaggregate as required.

(f) Comments on reliability

Shipping data obtained from port and marine authorities are generally reliable. Emission factors from Lloyd's Register are also considered to be reliable. Emissions associated with loading and ballasting are

likely to be less accurate. The use of speciation profiles for heavy metals and organic compounds will be of low reliability, particularly if not based on local fuel data. The detailed method will provide more accurate results than simpler approaches. NO_x emissions are highly dependent on engine type, so very simple approaches may result in a low level of accuracy for this pollutant.

(g) *Sources of further information*

Australia

Environment Australia (1999), Emissions Estimation Technique Manual for Aggregated Emissions from Commercial Ships/Boats and Recreational Boats (Environment Australia, Canberra, Australia). <http://www.npi.gov.au/handbooks/aedmanuals/shipping1-0.html>.

Europe

EEA (1999), *EMEP/CORINAIR Atmospheric Emission Inventory Guidebook* (UNECE/EMEP Task Force on Emission Inventories, European Environment Agency, Copenhagen, Denmark). <http://reports.eea.eu.int/EMEP/CORINAIR/en/page002.html>.

International

Lloyd's Register (1995), *Marine Exhaust Emissions Research Programme* (Lloyd's Register, Croydon, UK).

US

CARB (1991a), Identification of Volatile Organic Compound Species Profiles, ARB Speciation Manual: Volume 1 (California Air Resources Board, California, US) 2nd edition.

CARB (1991b), Identification of particulate matter species profiles, *ARB Speciation Manual: Volume 1* (California Air Resources Board, California, US) 2nd edition.

US EPA (1995), *Compilation of Air Pollutant Emission Factors, Volume I, Stationary Point and Area Sources, AP-42* (United States Environmental Protection Agency, Research Triangle Park, North Carolina, US) 5th edition. <http://www.epa.gov/ttn/chief/ap42/index.html>.

US EPA (1985), *Compilation of Air Pollutant Emission Factors, Volume II, Mobile Sources, AP-42*, 5th edition, (United States Environmental Protection Agency, Research Triangle Park, North Carolina, US).

4.6.4 Garden maintenance

(a) *Nature of the source and relevant pollutants*

The types of equipment that emit pollutants directly to the atmosphere include:

- two-stroke lawn mowers;

- four-stroke lawn mowers;
- tractors; and
- rotary tillers, chain saws, leaf blowers, snow blowers, shredders and other equipment.

The US EPA EIIP report lists 12 categories of equipment. The EMEP/CORINAIR Guidebook lists six categories. In the US, lawn mowers are the biggest contributor to emissions in this category.

Electric mowers and tools generate emissions indirectly through electricity generation. These emissions would be accounted for in a PRTR as point-source emissions from power stations and, therefore, are not considered here as a diffuse source.

All criteria pollutants are emitted from these types of equipment: CO, lead, NO_x, particles, SO₂, and total VOCs. HAPs emitted include PAHs, organic compounds such as benzene, 1,3-butadiene, toluene and xylenes, and metals and their compounds such as chromium, manganese and nickel. The relative quantities and proportions of these pollutants will depend very much on the type of equipment. For example, four-stroke mowers have lower emissions of VOCs, CO and particulate matter than traditional two-stroke mowers, but higher emissions of NO_x.

(b) *Factors affecting emissions*

The use of lawn mowers and other equipment will obviously vary significantly from one country or region to another. Usage rates can also vary within a study region. Important factors to consider when deciding how important this source of emissions might be include:

- climate, availability of water and nature of vegetation;
- residential land use patterns and to what extent suburban households have lawns; and
- non-domestic lawns and gardens, including consideration of the extent of public open space, golf courses, roadside verges, commercial and industrial lawns and open space.

As mentioned above, identifying the use pattern of each of the different equipment types is important. The fuel type (diesel, leaded or unleaded petrol) also influences emissions. Depending on the equipment type and emission factors being used, other information about the equipment (*e.g.* age, power rating) may also be relevant.

Usage is likely to vary significantly with season, day of week and time of day. If the emissions inventory is to be used for airshed modelling, then temporal activity data is required (or assumptions will need to be made based on data from elsewhere).

(c) *Description of release estimation techniques*

Sources of emission factors

Emission factors for two and four stroke small utility engines and agricultural equipment (including tractors) are provided in US EPA AP-42 Volume II. The emission factors do not account for evaporative losses.

Emission factors developed in Europe for different classes of engines and fuels are provided in the EMEP/CORINAIR Guidebook (Chapter 8). Some evaporative losses (diurnal) are incorporated in the emission factors. Deterioration rates (per year) are also provided.

Emission factors may be expressed in terms of:

- grams per kilowatt hour or horsepower hour;
- grams per litre or gallon of fuel used;
- grams per hour of use; or
- grams per unit-year (assuming a specified annual usage).

Activity data need to match the emission factors being used, so data collected through survey methods may need to be supplemented by additional data to complement the chosen emission factors. The different possibilities include:

- use emission factors based on fuel consumption and fuel consumption activity data;
- use emission factors based on power output, activity rates based on use per hour (or year) combined with power rating data for each type of equipment;
- use emission factors based on fuel consumption, activity rates based on use per hour combined with fuel efficiency (fuel use per hour) data; or
- use emission factors based on hours of use and activity rates based on use per hour.

Fuel composition, in terms of lead and sulphur content, should be compared with the default fuels on which the emission factors are based and the emission factors should be adjusted accordingly. Refer to the Australian NPI Manual for guidance on this. The emission factors that are currently available are not designed to be adjusted to account for fuel volatility.

Activity data

Using fuel consumption or general activity data. The simpler, but less accurate 'top-down' approach is to use nationally compiled statistics. The statistics most likely to be available would be on fuel consumption and obtainable from the relevant national government agency or industry association. These are unlikely to be disaggregated down to particular equipment types as the same fuels are normally used for other mobile sources (*e.g.* motor vehicles, small boats). Hence, general fuel consumption data must be combined with estimates of the numbers of two-stroke mowers, four-stroke mowers (and other equipment being considered) in use or the proportion of total fuel they consume.

In the US, national data on activity rates (hours of use per year) for different types of equipment are available, so these can be used in combination with time-based emission factors.

Fuel consumption or other national activity data will need to be scaled down (normally on the basis of relative population) to the study region.

Conducting surveys. A more accurate approach is to conduct a sample survey of domestic premises and any other significant users of mowers and garden equipment in non-domestic areas. If there are other domestic sources for which activity data are required and relevant information can be gathered at the same time, then a household survey is more likely to be cost-effective. A household survey should obtain data on amount of use (hours) over a year for each piece of equipment, type(s) of mowers and other garden equipment, fuel types, and if required for modelling, temporal variations in use. Although fuel use data

could be sought rather than hourly use data, this approach is less likely to produce accurate data from households. Depending on fuels available and whether deterioration is being taken into account, it may be desirable to include questions on the use of leaded *versus* unleaded fuel and on the age of equipment. The questions should cover use of mowers and equipment by commercial operators, unless a separate survey of commercial mowing/gardening services is planned (as suggested by US EPA in their EIIP report).

Data from the sampled households are scaled up according to total study region household numbers. If there are expected to be significant differences in use within a study region (for example, if there are differences in housing types and private gardens in different parts of the study region), partitioning of the survey into two or more sub-regions could be considered to improve spatial accuracy. However, this significantly increases costs as each sub-region must be considered separately and will require a similar level of sampling.

A detailed description of the major approaches to estimating activity data from surveys is provided in the US EPA EIIP report, which suggests telephone or door-to-door methods for surveying households.

A mail survey approach to conducting household surveys has been developed and refined during trials of Australia's NPI. This has been found to generate response rates of 50-55% in a number of different study regions. Guidelines for conducting domestic surveys are included in Appendix A of the NPI Manual on domestic lawn mowing.

In many study regions, emissions of some pollutants from mowing and garden/lawn maintenance in commercial and other non-domestic situations may be significant. For example, if there are extensive areas of open space and golf courses, then NO_x emissions are likely to be relatively high due to the greater use of four-stroke diesel-powered mowers. Emissions from these activities could be estimated by surveying the relevant authorities or clubs (*e.g.* local municipalities or parks authorities, private golf clubs, road maintenance agencies). It may be difficult to obtain hours of use data from these sources, but they would normally be able to supply fuel consumption statistics. In the situation of some agencies not responding, data provided by responding agencies could be used to scale up total emissions, using data on relative proportions and total open space and golf course coverage. This approach has been used in an air emissions inventory in Melbourne, Australia (EPAV, 1998).

As mentioned, the mowing of domestic lawns by commercial operators could be estimated either through a domestic survey (relying on householders' knowledge of mowing times, mower types, *etc*) or by a separate survey of the companies themselves. In the latter case, the household survey must be designed so that double counting does not occur by relating only to mowing done by the householders or others not connected with commercial companies.

Expert statistical and survey design advice should always be sought prior to conducting surveys. The following issues must be considered in order ensure an adequate response rate and to ensure that reliable data are obtained:

- careful design of the layout and wording of questionnaires to facilitate data entry and avoid ambiguity; ask questions that people can reasonably be expected to answer, and formulate them so as to obtain only data that will be used;
- wording used in cover letters, introductory comments and general manner for telephone or door-to-door surveys;
- sample size;
- pilot surveys;
- follow-up approaches to increase response rates; and

- quality control procedures.

(d) *Spatial allocation*

Domestic emissions would normally be spatially allocated according to household or population distribution. If the survey has been partitioned into sub-regions, then emissions will need to be scaled up and spatially allocated in each sub-region separately. Emissions from non-domestic sources could be allocated within specific open space areas, but this approach may not be warranted given the effort involved.

(e) *Summary of steps in the process*

1. Decide on the sectors of activity to be covered (*e.g.* domestic, park maintenance, commercial operations) and the types of equipment to be considered.
2. Review and select the most appropriate emission factors and activity data to be used, and the nature of surveys that may be conducted.
3. Design and carry out surveys. Obtain any other relevant data (*e.g.* fuel composition, fuel efficiency).
4. Scale activity data up (if based on a sample survey) or down (if a top-down approach is used).
5. Calculate total emissions for each type of equipment by combining activity data, emission factors (adjusted if necessary) and any other data required.
6. Aggregate emissions across equipment types for each pollutant.
7. Spatially and temporally disaggregate as required.

(f) *Comments on reliability*

Household and other surveys should yield reasonably reliable results, providing that the surveys are carefully designed and executed. Top-down approaches (*e.g.* using national fuel consumption data) will generally be significantly inferior, as they assume uniform activity rates. The smaller the study region is in relation to the region for which general activity data apply, and the greater the differences (*e.g.* climate, vegetation, housing type) between the study region and the larger region, the less accurate this approach will be. In addition, using fuel consumption statistics also means that supplementary data are required on the share of fuel used by different types of equipment. This may be another significant source of error.

Although surveys are preferable, a decision to use this approach must take into account the overall likely significance of these sources to total emissions of the pollutants being considered in the inventory.

Emission factors based on local testing will generally be superior to international default values. Emissions of HAPs based on standard speciation profiles will be of relatively low reliability.

(g) *Sources of further information*

Australia

Environment Australia (1999), Emissions Estimation Technique Manual for Aggregated Emissions from Domestic Lawn Mowing (Environment Australia, Canberra, Australia), http://www.npi.gov.au/handbooks/aedmanuals/lawnmowing_rev2.html.

EPAV (1998), *Port Phillip Air Emissions Inventory* (EPA, Victoria, Australia), http://www.epa.vic.gov.au/aq/air_emissions_inv/Default.htm. (Available from EPA Information Centre, GPO Box 4395QQ, Melbourne 3001, Victoria, Australia)

Europe

EEA (1999), *EMEP/CORINAIR Atmospheric Emission Inventory Guidebook* (UNECE/EMEP Task Force on Emission Inventories, European Environment Agency, Copenhagen, Denmark). <http://reports.eea.eu.int/EMEPCORINAIR/en/page002.html>.

US

US EPA (1985), *Compilation of Air Pollutant Emission Factors, Volume II, Mobile Sources, AP-42* (United States Environmental Protection Agency, North Carolina, US), 5th edition.

US EPA (1997), *Guidance for Estimating Lawn and Garden Equipment*, Chapter 3 from Volume IV of the EIIP Document Series, prepared by E.H. Pechan & Assoc., US (United States Environmental Protection Agency, North Carolina, US). <http://www.epa.gov/ttn/chief/eiip/techreport/volume04/iv03.pdf>.

US EPA (1992), *Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources* (Office of Mobile Sources, United States Environmental Protection Agency, Washington, D.C., US). <http://www.epa.gov/oms/>.

4.7 Diffuse emissions to water

4.7.1 Catchment runoff

(a) Nature of the source and relevant pollutants

Diffuse emissions to water result from pollutants contained in catchment runoff entering water bodies. These 'pollutants' can be defined as substances that are not released as part of natural processes but result from human activities and land management practices occurring in the catchment. Polluted runoff may pass through various stages before reaching the final receiving waters (*e.g.* it may be collected in pipes then transferred to rivers and finally to inland lakes or the marine environment). Hence, both inland and marine waters may be polluted and merit attention.

The pollutants most commonly estimated from diffuse sources are nutrients (total N and P) and sediments (suspended solids). However, the methods described here can be adapted to deal with other contaminants such as heavy metals and organic pollutants.

(b) Factors affecting emissions

Human influences on land use activities can drastically affect nutrient and other pollutant loads. These activities include vegetation removal, urban development and agricultural practices (*e.g.* through the use of fertilisers and pesticides). Nitrogen and phosphorous occur naturally in soils, so a certain amount is washed out naturally as part of the natural nutrient cycle. Human influences lead to additional inputs, often called 'surpluses' of N and P, when inputs exceed losses. Nutrient/pollutant generation rates depend on land use and management practices, soil type, topography and climate. These are factors that are likely to vary enormously between different catchment areas and regions or countries.

(c) *Description of release estimation techniques*

Much research has focused on the development of modelling techniques to predict water quality impacts from changes in land use and management activities. A wide variety of models and techniques exist to estimate the export of pollutants (*i.e.* pollutant loads) from catchment areas.

Load estimation

There are two main ways of estimating pollutant loads: using real data (*i.e.* from measurements) or modelling. Using real data involves applying various averaging, ratio and regression methods because loads are not measured directly but inferred from measurements of pollutant concentration and water discharge.

Modelling methods are used in the absence of observed data to predict pollutant loads according to relationships between nutrients/pollutants and other environmental attributes, such as population and land use established from other similar catchments. These methods can be used for N, P and other pollutants. Some methods use single predictors such as population density, quantity of fertiliser, or land use. For example, an estimate of nutrient load can be based simply on the area of each land use type within the catchment area and applying a pollutant generation rate. A review of different approaches and testing of their performance in a catchment area in Australia concluded that a multi-factor approach gave the best estimate of nutrient export rates, particularly in situations where no measured data exist (NSW EPA, 2000). A multi-factor approach uses a range of input data that are generally available (*e.g.* land use, agricultural practices, soil characteristics). These parameters are used to calculate the diffuse pollution load by means of coefficients that are calibrated with data from small homogenous catchment areas. Subtracting the known discharges from the measured transport in the river provides an estimate of the residual pollution load.

There is no single optimal load estimation technique. Selecting one that is appropriate depends on the availability of concentration and discharge data, the desired accuracy of estimates and preferred complexity of the technique. Simple empirical models are not sensitive to climate variability; hence they yield long-term averages only. However, such information is often sufficient for national pollutant inventories and national reporting purposes.

Catchment modelling

Computer models of sediment/nutrient transport (in which load estimation is a major part) fall into three broad categories:

- Empirical models: These are based on simple empirically determined relationships found between observed variables such as climate, land use and fertiliser input. They are the simplest of the three types of models, with a relatively small number of variables, but a high level of spatial and temporal disaggregation.

- Conceptual models: These are based on the conceptualisation of the catchment area as a configuration of internal storages and pathways through which pollutants pass. They usually incorporate the underlying physical mechanisms of sediment and runoff generation.
- Physics-based models: These are based on fundamental physical equations of flow and transport. They focus on the detailed modelling of processes, including hydrological factors such as rainfall and runoff. They normally require substantial measured input data (both spatial and temporal) and computing power. Physics-based models tend to be used by researchers involved in detailed studies on small spatial scales.

Each class of models has advantages and disadvantages. When selecting a model, the intended use of the model, data and computing resources available will need to be considered. Many models do not belong to one particular category, but have a combination of features from different classes. The categories listed above (adopted in the NSW EPA report referenced below) are not universally agreed by modelling professionals.

It is not necessarily the case that model accuracy increases with model complexity. Complex models suffer from problems such as error accumulation and unrealistic assumptions about the basic physics in the catchment system. Also, a lack of input data means that model parameters have to be determined through calibration. This leads to the problem of non-uniqueness and, therefore, the ultimate reliability of the predictions is questionable.

A common approach is to use empirical models (sometimes referred to as decision-support systems) to assist land use and land management planning. They do not give definitive solutions to problems but are a useful tool for identifying sources of pollutants, assessing management practices within a catchment area, and allowing relative assessments for different loads and catchments at an indicative level. Although not highly accurate, they are particularly useful when no measured data are available and only key nutrient sources and processes need to be characterised.

At the catchment scale, complex physics-based models are often not appropriate, nor can they be used in the absence of extensive input data.

(d) Comments on reliability

There are often large differences between measured and estimated loads computed using different methods. The reasons may include factors such as the lack of consideration of topography and soil erosion, climatic factors and the inaccurate interpretation/categorisation of land use classes. When data are poor or non-existent, it is preferable not to rely on a single estimation technique. If a catchment suffers from lack of data, it will be very difficult to prove that any particular method produces acceptable results. In such cases, all the assumptions and the uncertainty limits of the outcomes should be clearly specified.

(e) Sources of further information

Diffuse water inventory preparation is an inherent part of the catchment modelling process, and is also a complex area of scientific endeavour. A significant amount of this work occurs within research organisations, which often may not be directly connected with government activities. Preparing a diffuse water inventory also requires a greater depth of expert knowledge than in the diffuse air emissions inventory area, so inexperienced people attempting to apply the techniques would first need to identify research groups in their own country who can provide expert advice. More complex approaches will

normally need to be applied by expert researchers. Unlike the air emissions inventory area, there are no extensive guidance documents on water inventories provided by national governments and international agencies for countries to use.

Australia

NSW EPA (1999), *Review of Techniques to Estimate Catchment Exports* (New South Wales EPA, Sydney, NSW, Australia). <http://www.npi.gov.au/publications/nswreport.html>.

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US

US EPA: Basins 2.0 Model. <http://www.epa.gov/OST/BASINS/basinsv2.htm>

CHAPTER 5: EMISSIONS INVENTORIES THAT INCLUDE DIFFUSE SOURCES

5.1 Introduction

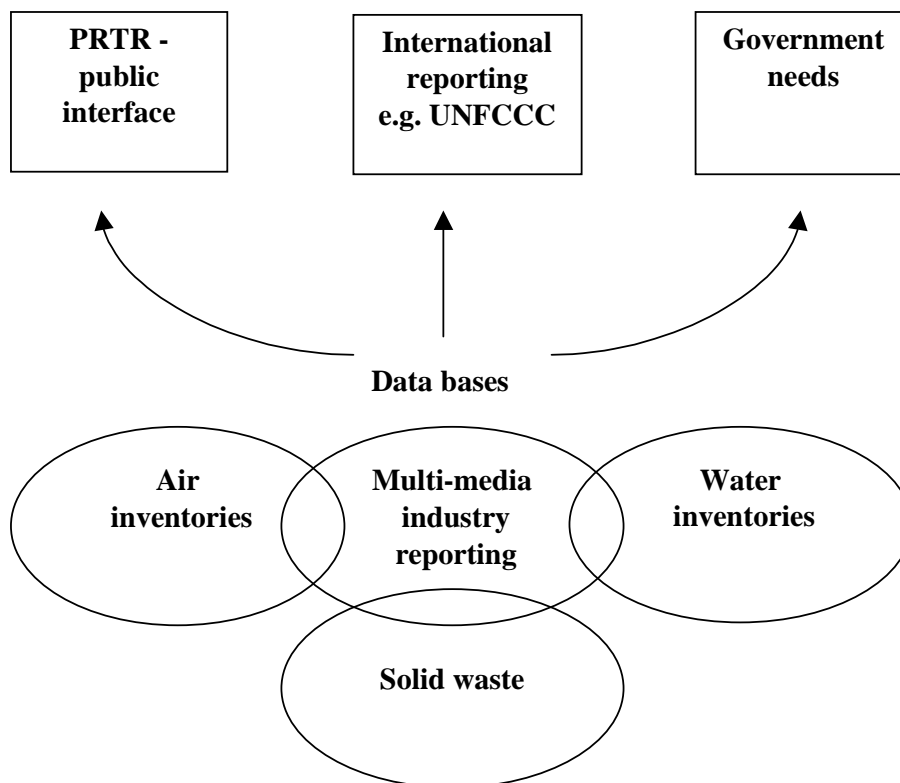
An important reason for the widespread development of air and water inventories has been the existence of various inter-country and international reporting requirements that have been set up to address transboundary and global environmental problems involving air and water pollution and public access to information. Many of these conventions recognise cross-media links, particularly the atmospheric deposition of nitrogen (via NO_x and NH_3) into waterbodies. The most important transboundary reporting obligations, current and future, are summarised in Section 5.2.

There are a variety of national and international emissions inventories that include data from diffuse sources. This chapter presents a brief description of some of the existing inventories under which estimation techniques for diffuse sources of pollution can be found. In most cases, these inventories are specific to a particular medium (*i.e.* air or water). They are considered 'comprehensive' in the sense that they attempt to include all significant point and diffuse sources.

Figure 1 illustrates how a PRTR programme could be used to interface with and integrate diffuse source data already collected by government bodies at the local, national and international level. That is, the PRTR could provide the "front end" for a range of inventories. Furthermore, the reporting processes, data acquisition measures and databases used for different inventories and for PRTRs overlap to a great extent, and this should be explicitly recognised by both the developers of PRTRs and by those conducting other inventory programmes. Recognising these overlaps and commonalities should enable consistency between the various inventory activities and minimise the time and resources required for the integration of diffuse sources into PRTRs. A complementary approach to the diffuse source specific techniques presented in Chapter 4 would be to consider other national and international inventory and reporting requirements that have to be met and to see if these requirements can be integrated into or otherwise combined with PRTR activities.

To date, very few diffuse source inventories have been incorporated into, or integrated with, national PRTR systems. The Netherlands Emissions Inventory is one of the few integrated systems in terms of media, as well as point and diffuse sources. This inventory was developed to serve government planning and policymaking, but is now evolving to make emissions data widely available, including emissions from individual industrial sources. The Australian NPI is developing along similar lines, although diffuse emissions are limited geographically (*i.e.* by airshed or by catchment area).

Figure 1
Relationship between inventories, reporting requirements and PRTRs



5.2 Transboundary reporting requirements

This section summarises international conventions that include diffuse release data.

5.2.1 *Convention on Long Range Transboundary Air Pollution (CLRTAP) 1979*

The CLRTAP was adopted in Geneva in 1979 by many European countries, Canada and the US. There are a series of Protocols under the Convention, which require emission abatement according to specified timetables. These Protocols are:

- Helsinki Sulphur Protocol (1985);
- Sofia NO_x Protocol (1988);
- Geneva VOC Protocol (1991);
- Oslo Sulphur Protocol (1994); and
- Aarhus Protocols on Heavy Metals and Persistent Organic Pollutants (POPs).

Under these Protocols, parties are required to submit inventories of annual national emissions of SO₂, NO_x, NMVOC, CH₄, CO and NH₃, plus various heavy metals and POPs using 11 main source categories (level 1

of SNAP, the Selected Nomenclature for Sources of Air Pollution) by 31 December following each reporting year. Parties are also invited to report emissions of more detailed sub-sectors (SNAP level 2) of source categories.

The following table summarises the environmental impacts addressed in the Convention and the relevant air pollutants causing these effects.

Environmental impact	Cause
Acidification	SO ₂ , NO _x , NH ₃
Eutrophication	NO _x , NH ₃
Ozone	VOCs, NO _x
Bioaccumulation of toxic substances	Heavy metals, POPs

Source: EEA, 1999.

The Co-operative Programme for Monitoring and Evaluation of the Long Range Transmission of Air Pollutants in Europe (EMEP) was formed by a Protocol under the CLRTAP, and a Task Force on Emission Inventories (TFEI) has been established to review current inventories and reporting procedures.

The TFEI objectives are to:

- provide a technical forum to discuss, exchange information and harmonise emission inventories;
- evaluate, in depth, existing emission factors and methodologies being used; and
- co-operate with other international organisations working on emissions inventories with the aim of harmonising methodologies and avoiding duplication.

The first edition of the combined EMEP/CORINAIR Emission Inventory Guidebook was finalised in 1996 and the second edition in 1999 (EEA, 1999). A third edition is due out in 2001. The CORINAIR programme is described below. Parties are also required to provide EMEP periodically with 50km gridded emissions *i.e.* 50km grids showing emissions of the pollutants listed above.

5.2.2 European Pollutant Emission Register (EPER)

The EC Directive on Integrated Pollution Prevention and Control (IPPC) was adopted in 1996.⁵ A committee was subsequently formed to establish the format and details of the European Pollutant Emission Register (EPER). EPER will cover major point source emissions to air and water.

The Swedish EPA undertook a study to provide the basis for developing the EPER which will apply to EU and, eventually, EU accession countries. Under the EPER, national data will be submitted to the European Commission by Member states, and must be facility-specific. Initial reporting will be every three years and will include 50 chemicals. Substances subject to international reporting requirements are included in the list of pollutants. In the longer term, reporting is expected to be more frequent. Emissions to land and solid wastes are not included at this stage. The main aims of the EPER are:

5. Official Journal of the European Communities (2000), Commission Decision 2000/479/EC on the Implementation of a European Pollutant Emission Register (EPER) According to Article 15 of Council Directive 96/61/EC Concerning Integrated Pollution Prevention and Control, OJ L 192, 28.7.2000.

- for governments to monitor progress towards meeting environmental targets in national or international agreements; and
- to raise public awareness of pollution and enable the public to compare emissions from individual facilities or industrial sectors.

5.2.3 *United Nations Framework Convention on Climate Change (1992)*

Using comparable agreed methodologies, parties to the UNFCCC must develop, periodically update and publish national inventories of anthropogenic emissions from sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol (on ozone depletion). Parties must report each year (by 15 April for the previous year) on CO₂, CH₄, N₂O, PFCs, HFCs and SF₆. Reports are made on a sector to sector basis and are not facility-specific. Parties should also provide information on emissions of CO, NO_x, and NMVOCs and are encouraged to include information on SO₂. The UNFCCC requires parties to use the Revised 1996 Guidelines for National Greenhouse Gas Inventories (IPCC, 1997). The first Guidelines for National Greenhouse Gas Inventories were finalised in 1995 through a co-operative programme by IPCC, OECD and IEA.

Parties may use different methods if they are considered to better reflect their national situation providing these methods are not inconsistent with IPCC Guidelines and are well documented. Continuing work is underway on a detailed common reporting format, guidance on good practices and managing uncertainties in inventories (IPCC, 2000).

5.2.4 *Agreement between the USA and Canada on Air Quality (1991)*

The general objective of this agreement is to control transboundary air pollution – directed specifically at reducing acid rain – between the two countries. This involves, *inter alia*, establishing objectives for limiting or reducing emissions of SO₂ and NO_x, exchanging information on emissions and producing regular progress reports.

5.2.5 *OSPARCOM (1992)*

The Oslo and Paris Commission applies to the Northeast Atlantic, including the North Sea, and integrates the Oslo Convention of 1972 and Paris Convention of 1974. The parties to the Commission are the EU, plus Norway, Iceland and Switzerland. The main goal is to protect the marine environment from pollution at sea and from land-based activities. The focus is on pollutant loads from major rivers, in particular nutrients but also heavy metals and POPs. Parties are required to produce national progress reports and develop a common basis for measurement.

5.2.6 *HELCOM (1988)*

The Helsinki Convention applies to the Baltic Sea. The parties to the Convention are the relevant EU countries, the Baltic countries, Poland and Russia. The Convention covers nutrients, heavy metals and POPs and aims to reduce the load of nutrients and other pollutants entering the Baltic Sea over a 10-year period.

5.2.7 *MEDPOL (1976)*

The Convention on Protection of the Mediterranean Sea includes recommendations on reducing nutrient inputs, monitoring programmes and an inventory of land-based sources. However, the Convention does not include specific reduction targets.

5.2.8 *Bucharest Convention (1996)*

This Strategic Action Plan for the Rehabilitation and Protection of the Black Sea also sets targets for reduction of nutrient loads.

5.2.9 *European Inland Waters*

Various inter-country agreements exist relating to pollution in major rivers and lakes. The most significant of these are:

- Rhine Action Programme;
- Elbe Action Programme;
- Strategic Action Plan for the Danube River Basin;
- Environmental Action Programme for Central and Eastern Europe; and
- UN Convention on the Protection and Use of Transboundary Watercourses and International Lakes (1992).

5.2.10 *North American Inland Waters*

Canada and the US have several treaties, conventions and agreements dealing with waters that flow along or across their boundaries, including:

- Boundary Waters Treaty (1909);
- Lake of the Woods Convention (1925);
- Rainy Lake Convention (1940);
- Columbia River Treaty (1961) and Protocol (1964);
- Skagit River Treaty (1984);
- St Lawrence Seaway Project (1952); and
- Great Lakes Water Quality Agreement (1972, 1978, 1987).

5.3 **Regional activities**

The various transboundary reporting requirements described above effectively require or strongly encourage estimates of pollutant loads or pollutant releases from point and diffuse sources. As a result, air emissions inventories exist in most European countries, Canada and the US, and water inventories exist or are under development for all seas of direct concern to Europe, as well as for some inland waters in North America and Europe. Most inventories were developed in response to a particular agreement or convention or in efforts to estimate pollution loads along shared borders. This section focuses on regional activities and inventory programmes.

5.3.1 *Air emissions*

(a) *North America*

US EPA compiles and publishes a national air emissions inventory annually. This includes the criteria air pollutants, greenhouse gases and some hazardous air pollutants (HAPs). As well as fulfilling reporting requirements for CLRTAP and UNFCCC, the inventory tracks changes following the Clean Air Act amendments of 1990. The annual report also documents trends in different sectors and in different states. The national inventory contains data submitted by several states. US EPA is currently developing a data management and reporting system to enable the extraction of the data from state inventories and the filling of gaps with EPA-generated inventory data. In recent years, the preparation of national emissions estimates has evolved towards meeting the need for more detailed and accurate inventories, resulting in the revision of many inventory methods. States do not estimate their own mobile source emissions. These estimates are prepared by EPA using their MOBILE and NONROAD models.

US EPA requires all states and territories to prepare State Implementation Plans (SIPs) in order to meet the National Ambient Air Quality Standards (NAAQS). Emissions inventories must be submitted periodically for areas not meeting these standards. In 1998, EPA issued a new regulation requiring 22 states and Washington DC to submit new SIPs aimed at reducing NO_x emissions.

The Emissions Inventory Improvement Programme (EIIP) is a joint programme of US EPA, state and local authorities. The programme promotes the development and use of standard procedures for collecting, calculating, storing, reporting and sharing air emissions data in the US. The EIIP has published inventory guidance documents in seven volumes, covering an introduction to the programme, point, area, mobile and biogenic sources, quality assurance and data management.

In 1993, US EPA began developing the National Toxics Inventory (NTI), covering 188 HAPs. The 1996 NTI has recently been completed. This national inventory utilises existing information, including some data from the Toxics Release Inventory (TRI) and AP-42. The NTI is an integral part of the Integrated Urban Air Toxics Strategy (finalised in 1999) and also supports other programmes, such as the Great Waters Programme, which requires the estimation of atmospheric deposition of HAPs to specified water bodies.

Canada also compiles and publishes a national emissions inventory at least every five years (the latest inventory was published in 1997). Environment Canada, in collaboration with provincial governments, prepares this inventory. It includes criteria pollutants as well as some heavy metals and POPs, consistent with CLRTAP reporting requirements. More detailed provincial data is available directly from the provinces. Environment Canada has compiled a *Methods Manual for Estimating Emissions of Common Air Contaminants from Canadian Sources* (Environment Canada, 1991). The objective of the Manual is to summarise, consolidate and describe best available inventory methods from the US and Canada. The US MOBILE6 model has been adapted for use in Canada. Local inventories also exist in parts of Canada. One example is the inventory developed for the Greater Vancouver Regional District.

In both Canada and the US, the PRTRs (TRI and NPRI) form quite separate systems to the national air emissions inventories, with separate data collection, management and dissemination processes. The TRI and NPRI do not include many of the national air inventory pollutants. Minor links between these systems include the use of some TRI data in the NTI, and the inclusion of some (mostly mobile) diffuse sources in NPRI.

(b) Europe

The CORINAIR programme (CORINE stands for CO-ordination d'INformation Environnementale) was established by the European Union (EU) in 1986, with the aim of compiling a co-ordinated inventory of atmospheric emissions from the original 12 member states for 1985. The main priority was acid deposition so the original inventory covered SO₂, NO_x and VOCs. In 1990, an update was prepared in co-operation with EMEP and IPCC-OECD to assist the preparation of inventories needed to meet CLRTAP and UNFCCC reporting requirements. The list of pollutants was extended to eight, with the addition of NH₃, CO, CH₄, N₂O and CO₂.

In 1994, five European Topic Centres were designated, one of these being devoted to air emissions (ETC/AE). The main work of ETC/AE is to set up an annual European air emissions inventory system, based on official national inventories. ETC/AE assists countries to report through the provision of software and by organising workshops. The European Commission is also a Party to UNECE/CLRTAP and UNFCCC, requiring it to report total emissions for the EU as a whole. Since 1994, the CORINAIR process has been run by the European Environment Agency (EEA). National estimates of 28 substances are now requested annually from 11 main sectors. Spatially resolved data (50 km x 50 km grid) and required every five years by EMEP for CLRTAP. In 1997, 35 countries reported, including many non-EU countries.

The EMEP/CORINAIR Atmospheric Emissions Inventory Guidebook (EEA, 1999) has been developed as a reference on good emission estimation practice and a checklist to ensure all major sources are covered. Parties are able to use other methodologies but must provide an explanation. There has been close co-operation between IPCC, OECD and IEA to ensure compatibility between the joint EMEP/CORINAIR and IPCC reporting formats. CORINAIR software tools are provided to assist in the preparation of estimates required under EU legislation and international conventions. The EEA requests countries to provide ETC/AE with more detailed data than the minimum specified where available.

The EEA has recognised the potential for extending the CORINAIR methodology to other media – air, water and land, as well as waste, with the purpose of developing integrated emissions inventories according to requirements of the *Fifth Environmental Action Programme: Towards Sustainability*. In the long term, an integrated inventory is envisaged to cover point and diffuse emissions from both anthropogenic and natural sources. This inventory would be updated annually, be accessible to policy makers, scientists and the public, and be co-ordinated by the EEA with the support of ETCs and national focal points.

As a result of the CORINAIR programme, most European countries broadly follow the methodology set out in the guidebook. Discussions on the implementation of the CORINAIR programme are summarised in Annex 3. Some interesting observations noted include:

- All of the countries contacted (UK, Denmark, Norway, France, Belgium and the Netherlands) use some of their own locally derived emission factors and/or computer models.
- France and the UK have carried out more detailed inventories for urban areas. The development of local inventories in the UK has been driven by the National Air Quality Strategy that sets mandatory objectives for local authorities. The Department for the Environment, Food and Rural Affairs (DEFRA) makes guidance notes and an emission factor database available for local authorities via its website. However, local and national inventories are beginning to converge in the UK, with the national inventory gradually becoming more detailed to serve local needs.

- The lack of integration between the UK's PRTR and the national air emissions inventory creates difficulties in terms of estimating emissions from small industrial sources not included in the PRTR (see Section 2.3).
- The manner in which information is made available to the public varies greatly. The EEA website contains air emissions data from point and diffuse sources from all European countries that report to CORINAIR. The website of the UK national inventory includes maps showing gridded emissions and allows users to search the database by postcode. The Netherlands is in the process of developing a website to present data from its emissions inventory. In other countries, public access to the data is generally through written summary information such as an annual report and through websites in the language of the home country. In some cases, point source emissions data from individual premises may be available on request.
- Technical reports on specific methodologies used are available to varying degrees. However, these are generally only available in the language of the home country.
- Norway has developed its own air emissions model known as *The Cube*, based on four axes: emission carriers (e.g. fuels), economic sectors, sources and pollutants.
- The Netherlands Emissions Inventory is currently the only example of a national inventory that is integrated across all media, point and diffuse sources, and includes all pollutants subject to international reporting requirements.

(c) *Australia and New Zealand*

Air emissions inventories have been compiled for most major urban areas in Australia and New Zealand over the last two decades. These have traditionally focused on the criteria air pollutants. In recent years, air inventories in Australia have started to be integrated with Australia's NPI, which includes both point and diffuse sources and covers criteria pollutants as well as HAPs. Inventory methods generally reflect those used around the world, perhaps with a greater reliance on household surveys for area sources. Some emission factors have been derived locally, although there has been a significant reliance on US EPA data. Current RETs for diffuse sources that are presented in handbooks and used for the NPI are available on Environment Australia's website. Greenhouse gas inventories are compiled independently by the Australian Greenhouse Office for the country and periodically for the states.

5.3.2 *Water*

In general, diffuse water inventories are much less centralised, far more heterogeneous and less well developed than air inventories. Pollutant load estimation and catchment modelling tend to be more catchment area-specific and considerable work is undertaken by research groups, not always closely connected with government programmes. The great variability in approaches reflects a wealth of scientific approaches.

(a) *North America*

The US Clean Water Action Plan, released in 1998, identifies watersheds with the most critical water quality problems and focuses resources by providing funds to states and territories for the implementation

of Watershed Restoration Action Strategies. To support these efforts, US EPA has developed a multi-purpose environmental analysis system, *BASINS 2.0* (Better Assessment Science Integrating Point and Non-point Sources), for use by state, regional and local agencies in watershed and water quality studies. This integrates a GIS, national watershed data, environmental assessment and modelling tools into one package. It supports the development of total maximum daily loads, integrating both point and diffuse sources across a watershed. A non-point source model component estimates land use-specific non-point source loadings for selected pollutants at a watershed or sub-watershed scale.

The US also has a programme to tackle non-point source pollution of coastal waters. Legislation requires 29 states and territories with approved Coastal Zone Management Programmes to develop Coastal Non-point Pollution Control Programmes.

(b) *Europe*

The EEA has initiated a programme to define a framework methodology for a European inventory of emissions to water. The aim is to establish a simplified, robust approach to provide inventory users with a set amount of data in a short period. The substances to be included will be determined by current legal reporting requirements, environmental priorities and feasibility. Initially, BOD, COD, total P, total N and NH₃ are recommended for inclusion with metals, PAHs and other substances to be added later. The basic spatial unit is the river or lake catchment, and CORINE Land Cover spatial data will be used. Annual reporting is seen as appropriate, but other temporal resolutions may be needed for different purposes.

Currently an EC working group known as EUROHARP (HARP – HARmonisation of Procedures) is assessing methods of estimating pollutant inputs, with the aim of harmonising techniques. Although there is substantial information on water emissions in Europe, it is not sufficiently consistent between countries. A generalised model, originally developed by the Institut Francais de l'Environnement (IFEN) in France, has been further developed by EEA and is being tested in various countries through EEA Topic Centres. This model is envisaged as a useful first step, with countries encouraged to adapt it to their own needs.

Emissions inventories are currently required under several EU Directives aimed at reducing pollution. For instance, the new Water Framework Directive embraces the concept of integrated catchment area and coastal zone management. Pollutants currently subject to reporting under EU Directives include various metals, total P and N, nitrate, nitrite, ammonia, a range of organic pollutants, as well as pathogens and other indicators such as suspended solids, COD, BOD, temperature and salinity.

Several European countries, such as Norway, have established national programmes of estimating and reporting diffuse source pollutants on a catchment area basis. The data are designed to suit the national reporting requirements and national environmental priorities. Eutrophication is seen as the main priority across Europe, hence the focus of most countries is on estimating total P and N.

(c) *Australia*

Australia's NPI incorporates estimates of diffuse emissions to water in selected catchment areas. A relatively simple model, WinCMSS (developed by CSIRO) is available as a default methodology. More complex models can be used where the necessary data are available. A recent report commissioned by Environment Australia (NSW EPA, 1999) identified 17 separate research groups involved in estimating nutrient emissions from diffuse sources in Australia. These include government departments, universities and other research organisations, and consulting groups.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

Part 2 of the Resource Compendium provides information about release estimation techniques used to quantify releases from diffuse sources. In addition, it gives an overview of inventories that include releases from diffuse sources across OECD countries and it summarises methods for estimating releases from selected sources. Through the collection and collation of information for this document, it was found that while inventories incorporating diffuse sources are widespread for air and water, these inventories are rarely integrated across all environmental media, or with national PRTRs. Decision makers, as they look to extend their PRTRs to include diffuse sources, may wish to (1) build on existing national and international inventory activities and (2) develop links and share information and knowledge.

Build on existing inventory activities

As described in Chapter 5, there is an extensive history of work in relation to inventories covering an entire country as well as for specific airsheds and water catchments. These have mostly been developed to serve government planning and policy-making purposes, as well as for international reporting requirements. Public access to these data varies significantly, and often data are not disseminated to the public. For instance, air and water inventories are normally prepared by quite separate arms of government, with water inventories often being created by research groups outside governments.

PRTR programmes need to build on the work already done rather than set up separate programmes for diffuse emissions estimation. There is scope to integrate existing inventories and add value to PRTRs by including existing data on diffuse emissions. A starting point for PRTR developers would be to:

- identify existing inventories;
- review these existing inventories to understand their scope and objectives, what data are collected, what sources are covered, spatial and temporal resolution, data reliability, *etc*; and
- consider how these existing inventories can be linked with the proposed (or existing) PRTR (*e.g.* common data sources, overlaps).

The methodologies and approaches described in Chapter 4 should enable PRTR developers to commence this process and ensure that the benefits of existing inventory programmes are obtained when incorporating diffuse sources into PRTRs.

Develop links and share knowledge

There is scope for OECD to develop links with key actors involved in diffuse source inventories, involving international bodies and task forces as well as separate countries. Building links could be carried out on two levels:

- encouraging the integration of inventories at the user interface; and
- facilitating the sharing of data among inventory practitioners.

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ANNEX 1: KEY CONTACT ORGANISATIONS

The following organisations have major responsibility for preparing diffuse source inventories for emissions to air and water.

COUNTRY	AIR INVENTORIES	WATER INVENTORIES	NATIONAL GOVERNMENT CO-ORDINATING AGENCY
Australia	State and Territory EPAs	State and Territory EPAs; Resource Management Agencies	Environment Australia
Austria	Federal Environment Agency Austria	Federal Environment Agency Austria	*
Belgium	Flemish Environment Agency	Flemish Environment Agency	-
Canada	Environment Canada	Environment Canada	Environment Canada
Denmark	National Environmental Research Institute; RISOE National Laboratory		
EU	EEA	EEA	EC
France	CITEPA	IFEN	Ministry of Ecology and Sustainable Development
Finland	Finnish Environment Institute	Finnish Environment Institute	
Germany	Umweltbundesamt	Umweltbundesamt	*
Greece	Ministry of the Environment	Ministry of the Environment	*
Ireland	Environmental Protection Agency	Environmental Protection Agency	*
Italy	National Environmental Protection Agency		
Japan	*	*	*
The Netherlands	Ministry VROM-Inspectorate	Ministry VROM-Inspectorate	Ministry VROM-Inspectorate
New Zealand	Local municipalities		
Norway	Norwegian Institute of Air Research; Statistics Norway	Norwegian Institute of Water Research; Norwegian Centre for Soil and Environmental Research	Norwegian Pollution Control Authority
Portugal	Instituto do Ambiente (Portuguese Environmental Institute)	Instituto da Água (Portuguese Water Institute)	Instituto do Ambiente (Portuguese Environmental Institute)
Spain	*	*	*
Sweden	Swedish EPA	Swedish EPA	Swedish EPA
Switzerland	*	*	
United Kingdom	AEA Technology	*	DEFRA
United States	US EPA	US EPA	US EPA

* Information not located

ANNEX 2: INVENTORY SOURCE CATEGORIES**EMEP/CORINAIR Atmospheric Emission Inventory Guidebook (EEA, 1999)**

Note: The following sectors often include source categories that involve both point source and diffuse (area and mobile) source air emissions estimation techniques. In some cases, particularly relating to industrial sources, a source category can be treated as a number of point sources or collectively as area sources, or as a combination of both. The first four sectors largely relate to point sources, but may have area source components. The source categories listed below under each sector are those most likely to be treated as diffuse sources.

1. Combustion energy (includes section on combustion as area sources)
2. Non-industrial combustion
3. Combustion in manufacturing industry
4. Production processes (some categories may be dealt with as area sources, including bread-making, asphalt roofing, road paving)
5. Extraction and distribution of fossil fuels
 - Gasoline distribution
 - Gas distribution networks
6. Solvent and other product use
 - Paints
 - Industrial degreasing
 - Dry cleaning
 - Graphic arts/printing
 - Household products/solvents
7. Road transport
 - Exhaust emissions
 - Evaporative emissions
 - Tyre and brake wear
8. Other mobile sources and machinery
 - Railways
 - Inland waters
 - Agriculture
 - Forestry
 - Industry
 - Households and gardening

- Shipping
 - Air traffic
9. Waste treatment and disposal
 - Incineration of domestic or municipal waste
 - Open burning of agricultural waste
 10. Agriculture
 - Cultures with fertilisers
 - Cultures without fertilisers
 - Stubble burning
 - Enteric fermentation
 - Manure management
 - Pesticides and limestone
 11. Other sources and sinks
 - Managed and non-managed forests
 - Soils
 - Forests and other fires
 - Grassland and other vegetation
 - Wetlands
 - Humans, wild animals
 - Volcanoes

Compilation of Air Pollutant Emission Factors, Volume I, Stationary Point and Area Sources, AP-42 (US EPA, 1995)

Note: Similar comments apply as for the EMEP/CORINAIR manual. Several of the following sectors largely relate to point sources. Source categories listed for each sector are those most likely to be treated as diffuse sources.

1. External combustion sources
 - Bituminous and sub-bituminous coal combustion
 - Anthracite coal combustion
 - Fuel oil combustion
 - Natural gas combustion
 - LPG combustion
 - Residential fireplaces
 - Residential wood stoves
2. Solid waste disposal
 - Refuse combustion
 - Landfills
 - Open burning

3. Stationary internal combustion sources
4. Evaporation source losses
 - Dry cleaning
 - Surface coating
 - Waste paper collection, treatment and storage
 - Asphalt paving operations
 - Solvent degreasing
 - Graphic arts
 - Commercial/consumer solvent use
5. Petroleum industry
 - Transportation and marketing of petroleum liquids
6. Organic chemical process industry
7. Liquid storage tanks
8. Inorganic chemical industry
9. Food and agricultural industries
 - Tilling operations
 - Growing operations (fertilisers, pesticides, *etc*)
 - Harvesting operations
 - Livestock and poultry feed operations
 - Agricultural wind erosion
10. Wood products industry
11. Mineral products industry
12. Metallurgical industry
13. Miscellaneous sources
 - Wildfires and prescribed burning
 - Fugitive dust sources
 - Explosives detonation
14. Greenhouse gas biogenic sources
 - Emissions from soils
 - Termites
 - Lightning emissions

Compilation of Air Pollutant Emission Factors, Volume II, Mobile Sources, AP-42 (US EPA, 1985)

1. Highway vehicles
2. Non-road sources
 - Lawn and garden equipment
 - Industrial equipment
 - Airport service equipment
 - Construction equipment
 - Recreational equipment
 - Agricultural equipment
 - Recreational marine equipment
 - Logging equipment
 - Light commercial equipment
 - Commercial marine vessels
3. Aircraft
4. Locomotives

US EPA EIIP Series

- Volume I: Introduction
- Volume II: Point sources
- Volume III: Area sources
- Introduction
 - Residential wood combustion
 - Architectural surface coating
 - Dry cleaning
 - Consumer and commercial solvent use
 - Solvent cleaning
 - Graphic arts
 - Industrial surface coatings
 - Pesticides – agricultural and non-agricultural
 - Agricultural operations (not yet available)
 - Gasoline marketing
 - Marine vessel loading, ballasting and transit
 - Autobody refinishing
 - Traffic markings
 - Municipal landfills

- Open burning
- Asphalt paving
- Structure fires

Method abstracts:

- Baked goods at commercial/retail bakeries
- Residential and commercial/institutional coal combustion
- Residential and commercial/institutional fuel oil and kerosene combustion
- Residential and commercial/institutional natural gas and LPG combustion
- Vehicle fires

Volume IV: Mobile sources

- Preferred and alternate methods for gathering and locating specific emissions inventory data
- Use of locality-specific transportation data for the development of mobile source emission inventories
- Guidance for estimating lawn and garden equipment activity levels

Volume V: Biogenic sources

- Biogenic sources preferred methods

Volume VI: Quality assurance procedures

Volume VII: Data management procedures

Volume VIII: Estimating greenhouse gas emissions

- Introduction
- Combustion of fossil fuels
- Industrial processes
- Natural gas and oil systems
- Coal mining
- Municipal waste disposal
- Domesticated animals
- Manure management
- Flooded rice fields
- Agricultural soils
- Forest management
- Burning of agricultural crop wastes
- Municipal waste water
- Mobile combustion (CH₄ and N₂O)
- Stationary combustion (CH₄ and N₂O)

Volume IX: Particulate emissions

- Getting started: planning for a PM_{2.5} inventory

Volume X: Emission projections

<p>The Netherlands Emissions Inventory (1999): Diffuse sources included for releases to air, water and soil</p>
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Note: Sources of emissions of ozone depleting substances are not included here.

1. Industry
 - Other process emissions:
 - Food, dairy and tobacco
 - Printing
 - Synthetic materials
 - Electroplating
 - Non-energy use of fossil fuels
 - Landfills
 - Bakeries
 - Fuel combustion (based on subtraction of point sources)

2. Non-industrial combustion
 - Heating of houses
 - Agricultural combustion (greenhouses)

3. Agriculture
 - Pesticides and herbicides
 - Animal manure
 - Fertilisers
 - Emissions of minerals to soil (heavy metals)
 - Enteric fermentation (methane from ruminants)
 - Use of wastewater treatment sludge
 - Biogenic VOCs
 - Degassing of ground water (methane)

4. Consumers and consumer related small companies
 - Auto refinishing
 - Service stations
 - Cleaning of new (imported) cars
 - Anti-corrosion treatment of cars
 - Cleaning of transport vehicles
 - Dry cleaning
 - Emissions from dental practices
 - Crematoria
 - Road painting
 - Miscellaneous car conservation products (home use)
 - Office utensils
 - Leather and furniture maintenance
 - Glues
 - Cosmetics and personal products
 - Household cleaning products
 - Use of paints by consumers

- Use of paints in construction
 - Fireworks
 - Household ammonia emissions (cleaners)
 - Ammonia emissions from humans and pets
 - Cigarette smoking
 - Meat preparation (barbecues)
 - Leaching of creosote treated wood in water and on land
 - Use of carbolinated wood and general carbolination applications
 - Recreational shooting (lead and zinc)
 - Recreational fishing (lead)
 - Corrosion of zinc roofs
 - Corrosion of greenhouses
 - Corrosion of road protection rails
 - Corrosion of lamp posts
 - Corrosion of zinc anodes in locks
 - Corrosion of lead slabs in houses
 - Corrosion of lead slabs in utility buildings
 - Corrosion of drinking waterlines
5. Miscellaneous water sources
- Effluents and sludge from wastewater treatment
 - Atmospheric deposition on water and soil
 - Leaching from soil to water
 - Pollution from foreign rivers
6. Natural sources
- Emissions from vegetation
 - Emissions from soil and water
7. Mobile sources
- Road traffic
 - Exhausts
 - Evaporatives
 - Tyre wear
 - Road wear
 - Oil leakage
 - Ships
 - Sea-going ships
 - Recreational boats
 - Bilge water (inland)
 - Anti-rust coatings
 - Corrosion of zinc anodes at locks
 - Oil leakage
 - Spillages
 - Coatings
 - Anti-fouling
 - Aircraft
 - Exhausts

- Evaporatives
- Railways
 - Exhausts
 - Corrosion of electric wires (copper)
- Other mobile sources

The Australian National Pollutant Inventory: Aggregated emissions sources
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Methodology handbooks have been prepared for the following source categories and are available on the NPI website:

- Aircraft
- Tropical aquaculture
- Architectural coatings
- Barbecues
- Cutback bitumen
- Prescribed burning and wildfires
- Domestic/commercial solvents and aerosols
- Dry cleaning
- Domestic gaseous fuel burning
- Domestic lawn mowing
- Motor vehicles
- Motor vehicle refinishing
- Paved and unpaved roads
- Printing and graphic arts
- Railways
- Service stations
- Commercial ships/boats and recreational boats
- Domestic solid fuel burning
- Fuel combustion (sub-threshold industry)
- Industrial solvents

ANNEX 3: SUMMARY OF DISCUSSIONS

UK: AEA Technology, National Environmental Technology Centre - Justin Goodwin and Mike Woodfield

- Data from UK Pollution Inventory (PRTR) feeds into the National Atmospheric Emissions Inventory. Note that PRTR only covers England and Wales, whereas National Inventory covers the UK.
- Difficulties with integrating policy and CRTK needs. Thresholds for PRTR reporting mean that the emissions inventory is incomplete. Difficult to estimate small industry emissions as pollutant inventory process does not gather the necessary data (*e.g.* fuel combustion) to allow subtraction of point source component. Modellers also have to collect additional industry data *e.g.* stacks, temporal variations).
- The UK Atmospheric Emissions Inventory is updated annually; summary information available on the web; used mainly for modelling and policy work, international reporting; 1 km emissions grid.
- Inventory methodology: some variations from EMEP/CORINAIR (*e.g.* local motor vehicle emission factors); some surveys done of small industry (*e.g.* dry cleaners, printers). Methodology documented in annual report.
- Pollutants: 3 (to fulfil reporting requirements), plus VOCs are speciated into 500 organic compounds and PAHs into 16 compounds.
- Priorities for further research: domestic wood combustion, POPs, PAHs, dioxins.
- Data presentation: maps of gridded emissions available on website, users can search by postcode; website designed to place emissions inventory data in context – links to air quality (concentration) data.

UK: Greater London Authority - Charles Buckingham
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- The London emissions inventory is an example of many local inventories. National Air Quality Strategy sets mandatory objectives for 8 pollutants for 400 local authorities. Where air quality fails to meet these standards, local air quality strategies and local inventories are required.
- Local scale inventories: high resolution (*e.g.* detailed road networks, use of traffic counts for individual roads). Data presented on 1 km grids. No household surveys carried out. Some local emission factors used.
- Smaller industries ('Part B processes') are regulated by local government, as distinct from Part A (large industries) which are regulated by the Environment Agency and are covered by the PRTR. Local government has some data on Part Bs and may do additional surveys.

- DETR has issued guidance notes for local authorities plus emission factor database – available on their website. Emissions from Part B industries can be made available to the public on request, but are not part of PRTR.
- Local and national inventories are now starting to converge. The aim is for the national inventory to be detailed enough to supersede local ones in the future.
- Inventories cannot satisfactorily account for particles. There is a need to focus on monitoring and modelling in order to track and characterise the range of anthropogenic and natural sources.

The Netherlands: Inspectorate for Environmental Protection – Pieter van der Most

- Emissions inventory has evolved since 1974. RETs selected by specialist task forces reporting to overall co-ordinating committee.
- Emissions inventory data to be made available through a website. Methodology is documented in Dutch reports (see bibliography). Emission factors are also expected to be put on the web. Currently these have not all been published. An annual summary report is available in English.
- Most emission factors are local (Dutch) or European. Inventory is spatially resolved down to 500 m grid squares, point sources to 10 m. Database is organised along three dimensions, namely by substance, activity and location.
- Industry reporting process has mandatory and voluntary components. Mandatory elements include total site emissions and combustion process details. Voluntary component includes other process and production data.
- Model used for estimating landfill emissions to air, water and land – described in report in Dutch (see bibliography).
- Yearly agricultural census provides data on agricultural machinery, livestock, manure treatment, fertilisers. Farmers may have to report pesticide use in the future. It is difficult to get good data on this, as the available data are very aggregated.
- Agricultural tilling: currently reviewing particle emissions estimation. Re-entrained road dust not included. Biogenic sources (crops, vegetation, *etc*) are included. One current priority is to improve ammonia emissions estimates from agriculture.
- Dry cleaning: an emission factor expressed in terms of quantity of clothes cleaned has been developed.
- Current weak point is in certain small industries: larger point sources are not representative of smaller facilities. An example is the electro-plating industry, for which a special project is underway.
- Household and commercial products: yearly survey of manufacturers and importers to get details of sales of car products, cleaners, cosmetics, *etc* and these data form the basis for estimating emissions from solvent-based products.
- Barbecues – meat preparation. Detailed study has been done of emissions of VOCs, organic HAPs, PAHs from fuel combustion and meat. Emissions depend on method of cooking and fuel used.

- Water inventory includes COD, N, P, Cl⁻, metals, benzene, toluene, ethylbenzene and xylenes. N and P estimated from runoff in rural areas through STONE model.
- Road traffic emissions studies undertaken by Statistics Netherlands. Emission factors are derived from compliance testing on three drive cycles, namely freeway, town and other (mainly rural). This is a continuing process and emission factors are revised yearly. The specific components estimated are exhausts, evaporative losses, tyre wear, road wear, oil leakage. VKT comes from transport model. A VKT-based approach is used for characterising emissions. COPERT model is not used.
- International traffic (roads, ships, aircraft) data are not required for CORINAIR reporting but are included in national inventory.

Belgium – Flanders : Flemish Environment Agency – Marie-Rose Van den Hende and other staff

- Flanders currently has separate inventories for air and water – to be linked later. Main purposes of air and water inventories are policy development, industry regulation and international reporting. Website is being developed to provide access to PRTR data on emissions.
- Industry reporting is mandatory. Facilities must provide detailed stack, process and fuel information. Small industry set up collectively like in the Netherlands. Data are suitable as input to airshed models.
- Air inventory resolved to 1 km grid, stacks down to 10 m. Approximately 60 pollutants are included in the air inventory.
- Methodology generally consistent with EMEP/CORINAIR Guidebook. Some specific emission factors (*e.g.* ammonia from livestock) have been developed in Belgium. Use COPERT for motor vehicles, but will be using a new, more detailed model shortly, based on local vehicle test data.
- Currently, University of Gent is carrying out detailed research on VOCs, and policy work is underway on reduction of solvents in household products. Other surveys underway (*e.g.* fuel combustion from commercial and government premises, and greenhouses).
- Reports on methodology only available in Dutch. Annual summary report in Dutch also. Methodology will be accessible on website later.
- Separate air inventories exist for the Brussels and Walloon regions. These largely follow CORINAIR methodology and reports are available in French only. There is currently no plan to combine the separate regional inventories into a national system, but aim is to work in a co-operative way.
- The Flanders water inventory mainly contains point source release data. Agricultural runoff – N and P only. SENTRWA model applied – System for Evaluation of Nutrient Transport to Water, developed by Institute for Chemical Research, Ministry of Agriculture – uses statistics on population, quantity of manure, *etc.* This model is also used in the Walloon region. Also the SEPTWA model is applied – System for Evaluation of Pesticide Transport to Surface Water – uses sales information on pesticides. Both models are calibrated against measurements. PEGASE model is used to translate emissions data into concentrations.
- Future research: improving links between ground water and surface water; water quality and flow rates.

- Belgium has agreements with the Netherlands and France to harmonise inventory methods in relation to two major rivers (the Muse and the Skelder).

<p>Norway: Norwegian Pollution Control Authority – Harald Sorby & Harold Leffertstra; Statistics Norway – Gisle Haakonsen; Norwegian Centre for Soil and Environmental Research – Nils Vagstad</p>

- Air and water inventories in Norway are not integrated with the national PRTR, which covers point sources only. No plans to incorporate diffuse emissions into PRTR, but websites are linked and form part of the overall package of information on air and water quality.
- Air emissions inventory covers whole country, with more detailed inventories for major urban areas. Used for national/international reporting (*e.g.* CORINAIR). Undertaken annually by Statistics Norway; road traffic emissions done by the Norwegian Institute for Air Research (NILU). NILU combines stationary source emissions with area and mobile sources into a single inventory used for airshed modelling.
- Methods mostly consistent with CORINAIR, but some Norwegian methods/emission factors are used. Fuel data are broken down into different uses/activities due to differing tax rates.
- Norwegian Pollution Control Authority (SFT) collects point source data for PRTR, including information on fuel combustion and production details. This is used in air emissions inventory and will be accessible to the public. Statistics Norway carries out additional survey to collect data needed for modelling.
- Spiked tyres cause problems by cutting up the roads (leading to emissions of particles, PAHs). Some research has been done on road dust in Norway.
- Road traffic: use local fuel-based model, mixture of local emission factors and those from other countries. Local emission factors developed for shipping in Norway – good agreement with Lloyd's Register.
- Priorities for research/surveys: better data on shipping, wood heater emissions, household survey of wood heater types and age.
- Norway has developed an emissions modelling system known as 'The Cube', based on four axes, namely emission carriers (*e.g.* fuels), economic sectors, sources and pollutants.
- Summary report on air inventory published annually as part of the *Natural Resources and the Environment* report in English. Inventory report (in English) published every five years – available on web. Reports on methodology generally only in Norwegian.
- International agreement relating to the North Sea (OSPARCOM) requires reduction of N and P inputs by 50%. Also agreement relating to the Baltic Sea (HELCOM) aims to reduce nutrient inputs. Main sources are agriculture, also aquaculture in coastal waters (west coast and fjords). Use of water is important as aquaculture requires clean water.
- Catchment model used to estimate N and P loads across whole country. Input data required includes agricultural information (fertiliser use, manure spread), soil erosion, point source inputs and land use data. Generalised meteorological data used, not specific to a given year. Measurement programmes also undertaken – used to develop emission factors and calibrate models. New research underway to develop a more advanced model.

- Current work in Europe to harmonise reporting procedures. Difficulties in that catchment estimates may not be comparable between countries. It is not possible to generalise approaches across very different catchments. Conditions may differ greatly (*e.g.* Norway has frozen soils in winter). Temporal variations, both long term and short term, differ greatly. Primary recipients may also be different (*e.g.* surface waters in Norway, ground water in the Netherlands).

Denmark: National Environmental Research Institute – Ruwim Berkowicz & Nicky Brown

- NERI is a research agency under the Ministry of Environment. Danish EPA is a separate body under the same Ministry. Air emissions inventory handled jointly by NERI and RISOE. RISOE is under the Ministry of Research.
- Air emissions inventory covers CORINAIR substances and is revised annually. Some local emission factors used, some from the Netherlands and some from the CORINAIR Guidebook.
- NERI has developed its own models for estimating emissions from aircraft and off-road machinery, according to CORINAIR guidelines. COPERT is used for road traffic.
- Point source emissions are reported to EPA. Fuel consumption data are also obtained to allow for subtraction of point source component to estimate aggregated industrial emissions.
- NERI has used dispersion models in reverse to estimate emissions based on concentration data – for benzene, CO and NO_x. Monitoring data used – background levels subtracted from kerbside levels. Reverse model calculates emissions for a specific road on an hourly basis and can be aggregated to annual emissions. Recently have used data on fleet composition to derive emission factors for different vehicle types – results have high degree of uncertainty. The main purpose of this research is to track changes in total emissions over time and derive average emission factors. These are not used in the emissions inventory but provide a useful comparison.

European Environment Agency: Niels Thyssen, Philippe Crouzet

- Main role of EEA is to co-ordinate and provide information for policy makers and the public. ETCs are established in seven countries. These are generally national research institutes with additional responsibilities to EEA.
- EU Water Framework Directive has been finalised but yet to come into force – based on catchment management approach.
- Water emissions need to be considered differently from air emissions: – water travels by specific vectors and there are different stages – runoff, pipe, river, sediment, sea. Both source and vector are important. Water inventories vary according to their need for input data.
- EEA is developing a generalised model for calculating non-point source emissions across Europe, which can be further adapted by countries to meet their own specific needs for particular catchments. This should be a useful first step. Comparisons of calculated fluxes with measurements – N within about 50%, P is not as good as more complicated. The model was developed by IFEN in France and applied there, and also in Germany and Czech Republic.
- Emission factors must relate to land use as well as specific activities – land use type alone is insufficient. In the same way, point source emission factors do not just relate to broad industry types

but specific processes. Data need to specify activities in terms of livestock numbers, fertiliser use, type of livestock food, *etc.*

- Major uncertainty with models of runoff is estimation of surplus N and P (*i.e.* loads that enter waterways). Input data are very important – there is no point using a complex model if there are little good data available.
- In general, less research has been done on lakes and groundwater than rivers.

France: CITEPA: Jean-Pierre Fontelle (by email)
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- The French atmospheric emissions inventory is based very much on CORINAIR. Currently, more than 30 pollutants are listed, including criteria pollutants, greenhouse gases, heavy metals, PMs and POPs. The inventory is revised annually. More detailed higher resolution inventories are prepared less frequently for particular regions.
- For road traffic, COPERT model is used. For aircraft, CITEPA's own model is used, which is based on local and international data.
- The model COBRA, developed by CITEPA, is used to estimate biogenic emissions. This calculates VOC emissions for crops and each species of tree on a monthly basis, taking into account meteorology and biomass. In the latest version also the land cover data and forest altitude are considered.
- Spatial allocation is largely according to CORINAIR guidelines. This is updated every five years for EMEP, or for special requests.
- A report on quality control issues is scheduled to be completed in 2003.
- Methodology is briefly documented in English and French. A guidebook is expected to be published by the end of 2003.