EUROPEAN
ENVIRONMENT AGENCY

Copenhagen, 15 February 1996
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Dear Colleague

It gives me great pleasure to provide you with a copy of the first edition of the joint EMEP/CORINAIR Atmospheric Emission Inventory Guidebook.

This Guidebook has been prepared by the expert panels of the UNECE/EMEP Task Force on Emission Inventories and is being published and distributed by the European Environment Agency. It will be used initially by national experts working with support from the European Topic Centre on Air Emissions (ETC/AEM) to produce annual national inventories for 1994 and can be used by all Parties to the Convention on Long Range Transboundary Air Pollution for reporting to the UNECE Secretariat in Geneva.

This first edition has been edited in line with the revised source nomenclature - SNAP94 - developed by ETC/AEM for the 1994 inventory. SNAP94 is (almost) fully consistent with the IPCC nomenclature developed for reporting under the UN Framework Climate Change Convention.

The Guidebook will also be published by the Agency on CD-ROM later this year. Further development and maintance of the Guidebook will then be continued collaboratively by the Task Force and ETC/AEM.

The Guidebook is the result of the efforts of many experts as listed in parts B and C. All have contributed to this product - drafting, reviewing and updating the texts and emission factors over a period of 30 months from July 1993 to December 1996. My role was to proof-read and edit the texts and layout to ensure readability and consistency and, in the final stages, to update the part B methodology chapters in line with the revised SNAP94 activity list. I therefore take full responsibility for any typing errors or inconsistencies which remain.

I hope that you will find the Guidebook a valuable reference document and will make use of it. It is a living, updateable guidebook and not a fixed rule book. It provides a distillation of the currently best available information. If you find anything that you consider incorrect, out-of-date or inappropriate, or you have access to anything better, or you have data or information on activities not included in this first edition, I would be grateful if you could let me know so that the Guidebook can be kept up-to-date and provide the basis for quality - complete, consistent, transparent and timely - atmospheric emission inventories.

Best regards

Yours sincerely

Gordon McInnes

ENC

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EMEP
Co-operative Programme for Monitoring and Evaluation of the Long Range Transmission of Air Pollutants in Europe

CORINAIR
The Atmospheric Emission Inventory for Europe

ATMOSPHERIC EMISSION INVENTORY GUIDEBOOK

First Edition

A joint EMEP/CORINAIR Production

Prepared by the
EMEP Task Force on Emission Inventories

Edited by
Gordon McInnes
European Environment Agency

February 1996

Joint EMEP/CORINAIR
Atmospheric Emission Inventory Guidebook,
First Edition,
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Published by
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EMISSION INVENTORY GUIDEBOOK

This document contains the first edition of the Emission Inventory Guidebook prepared by the UNECE/EMEP Task Force on Emissions Inventories.

The Guidebook is designed to provide a comprehensive guide to the state-of-the-art of atmospheric emissions inventory methodology for each of the emission-generating activities listed in the current version of the Selected Nomenclature for Air Pollution (SNAP94), initially developed for the 1985 Corinair Inventory

You are invited to use/review the document and provide comments and/or additional material either to the European Environment Agency in writing or by participating in the Task Force meetings and work of the Task Force.

An example of the assessment sheet to be used is included in the Guidebook; you should make additional copies as necessary. I would mainly like to have your comments on the content of the part B methodology chapters as well as additional material for inclusion in these chapters and those still to be prepared. However, if you have strong views on the structure or style of the Guidebook, you may also provide comments on this aspect.

You may use this Guidebook as source material for emission inventory compilation. If you do so, you should cite the source as 'Joint EMEP/CORINAIR Atmospheric Emission Inventory Guidebook, First Edition. Copenhagen : European Environment Agency, 1996'. However, you should use the Guidebook with caution and check emission factors against any more specific information available in your country. Some of the chapters are incomplete and will be updated as new information becomes available. As a recipient of this document, you will receive copies of updated and additional chapters as well as correction sheets for any serious errors found in the emission factors presented.

This first edition of the Guidebook will also be published by the Agency on CD-ROM later in 1996.

Finally, I would like to thank :

- the panel leaders and their panel members for their work in preparing, reviewing and updating the many chapters of the Guidebook,
- Silvia Molteni of the Agency for her enthusiastic assistance in correcting and formatting this first edition in line with SNAP94 as defined in late 1995, and
- Harald Dovland for his encouragement and leadership as Chairman during this first phase of the Task Force.

Gordon McInnes
Task Force Coordinator (1992-96)
February 1996

EMISSION INVENTORY GUIDEBOOK

Assessment Form

Chapter : ________ **Title :** ________________________
(eg B333) (eg Gray Iron Foundries)

Details of person completing questionnaire :

Name : ________________________________

Address : ________________________________
____
____

Phone : ________________________________
Fax : ________________________________

Please provide a score (1=very poor, 2=poor, 3=acceptable, 4=good, 5=very good) and/or comments, on additional sheets if necessary, alongside the symbol ¨ for the following general aspects of the chapter :

General Aspects : Completeness ☐

Readability ☐

Useability ☐

Length ☐

Organisation ☐

Errors (please specify)

Please return assessment forms to : European Environment Agency, Kongens Nytorv 6, DK1050 Copenhagen, Denmark (Fax nr +45 33 36 71 99).

Please indicate with a tick (ü) where you consider each section clear, acceptable or complete and provide additional comments where appropriate (on a separate sheet if necessary):

1. Activities included : Clear? ☐ Acceptable? ☐ Complete? ☐

2. Contributions to total emissions (to be updated with Corinair90 results)

3. General : Clear? ☐ Acceptable? ☐ Complete? ☐

4. Simpler methodology (Explain if unacceptable) Clear? ☐ Acceptable? ☐ Complete? ☐

5. Detailed methodology (Explain if unacceptable) Clear? ☐ Acceptable? ☐ Complete? ☐

6. Relevant activity statistics Clear? ☐ Acceptable? ☐ Complete? ☐

7. Point source criteria Clear? ☐ Acceptable? ☐ Complete? ☐

8. Emission factors etc Clear? ☐ Acceptable? ☐ Complete? ☐

9. Species profiles Clear? ☐ Acceptable? ☐ Complete? ☐

10. Uncertainty estimates Clear? ☐ Acceptable? ☐ Complete? ☐

11. Weakest aspects etc Clear? ☐ Acceptable? ☐ Complete? ☐

12. Spatial disssaggregation Clear? ☐ Acceptable? ☐ Complete? ☐

13. Temporal disaggregation Clear? ☐ Acceptable? ☐ Complete? ☐

PART A BACKGROUND

CHAPTER

PART B METHODOLOGY CHAPTERS

INDEX TO METHODOLOGY CHAPTERS ORDERED BY SNAP94 ACTIVITY

SNAP NAME OF THE CHAPTER

SNAP NAME OF THE CHAPTER

SNAP NAME OF THE CHAPTER

PART C ANNEXES

INTRODUCTION

1. Emissions and emission inventories

Substances emitted into the atmosphere by human and natural activities are the cause of many current and potential environmental problems, including :

- acidification
- air quality degradation
- global warming/climate change
- damage and soiling of buildings and other structures
- stratospheric ozone depletion.

It is necessary to have quantitative information on these emissions and their sources in order to help:

- inform the agencies and individuals involved (including the public)
- define environmental priorities and identify the activities and actors responsible for the problems
- set explicit objectives and constraints
- assess the potential environmental impacts and implications of different strategies and plans
- evaluate the environmental costs and benefits of different policies
- monitor the state of the environment to check that targets are being achieved
- monitor policy action to ensure that it is having the desired effects
- ensure that those responsible for implementing the policies are complying with their obligations.

There are many types of sources of atmospheric emissions and many examples (often millions) of each type, for example :

- power plants
- refineries
- incinerators
- factories
- domestic households

- cars and other vehicles
- animals and humans
- fossil fuel extraction and production sites
- offices and public buildings
- trees and other vegetation
- distribution pipelines
- fertilised land
- land with biological decay.

It is not possible to measure emissions from all of the individual examples of these sources or, in the short term, from all the different source types. In practice, atmospheric emissions are estimated on the basis of measurements made at selected or representative samples of the (main) sources and source types.

The basic model for an emission estimate is the product of (at least) two variables, for example:

- an activity statistic and a typical average emission factor for the activity, or
- an emission measurement over a period of time and the number of such periods emissions occurred in the required estimation period.

For example, to estimate annual emissions of sulphur dioxide in grams per year from an oil-fired power plant you might use, either :

- annual fuel consumption (in tonnes fuel/year) and an emission factor (in grams SO_2 emitted/tonne fuel consumed), or
- measured SO_2 emissions (in grams per hour) and number of operating hours per year.

In practice, the calculations tend to more complicated but the principles remain the same.

Emission estimates are collected together into inventories or databases which usually also contain supporting data on, for example: the locations of the sources of emissions; emission measurements where available; emission factors; capacity, production or activity rates in the various source sectors; operating conditions; methods of measurement or estimation, etc.

Emission inventories may contain data on three types of source, namely point, area and line. However, in some inventories all of the data may be on area basis - region, country, sub-region etc.

Point sources - emission estimates are provided on an individual plant or emission outlet (usually large) usually in conjunction with data on location, capacity or throughput, operating conditions etc. The tendency is for more sources to be provided as point sources as legislative requirements extend to more source types and pollutants as well as more openness provides more such relevant data.

Area sources - smaller or more diffuse sources of pollution are provided on am area basis either for administrative areas, such as counties, departement etc, or for regular grids (for example the EMEP 50x50 km grid)

Line sources - in some inventories, vehicle emissions from road transport, railways, inland navigation, shipping or aviation etc are provided for sections along the line of the road, railway-track, sea-lane etc.

2. International requirements for emission inventories

2.1 Long Range Transboundary Air Pollution Convention

The Convention on Long Range Transboundary Air Pollution (LRTAP) was adopted in Geneva in 1979. Reporting of emission data to the Executive Body of the Convention is required in order to fulfil obligations regarding strategies and policies in compliance with the implementation of Protocols under the Convention. These Protocols are :

- the Helsinki Sulphur Protocol (1985)
- the Sofia NOx Protocol (1988)
- the Geneva VOC Protocol (1991) and
- the Oslo Sulphur Protocol (1994).

Parties are required to submit annual national emissions of SO_2, NOx, NMVOC, CH_4, CO and NH_3 using the 11 main source categories agreed with Corinair by the 31 December following each year.

Parties are also required to provide EMEP periodically with emission data within grid elements of 50km x 50km, as defined by EMEP and known as the EMEP grid. Most recently, Parties were requested to submit gridded data for 1990 to the Executive Body by 31 December 1993.

The European Environment Agency (Task Force) agreed to transform Corinair 1990 emission estimates for each pollutant, main source sector and country into the 50km x 50km grid required by EMEP.

2.2 Framework Convention on Climate Change

"The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve stabilisation of greenhouse gas concentrations at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner." (Article 2).

All Parties to the Convention shall " develop, perodically update, publish and make available to the Conference of the Parties, in accordance with Article 12, national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies to be agreeed upon by the Conference of the Parties;" (Article 4, paragraph 1(a))

2.3 Council Decision 93/389/EEC on a Monitoring Mechanism of Community CO_2 and other Greenhouse Gas Emissions

The European Community has adopted Council Decision 93/389/EEC to help monitor progress towards stabilisation of the total CO_2 emissions by 2000 at the 1990 level in the Community as a whole.

Article 3.1 of Decision 93/389/EEC states "Member States shall determine their anthropogenic CO_2 emissions and removals by sinks in accordance with the best available methodology to be decided by the Commission in accordance with the procedure set out in Article 8. Such a methodology shall be either that being developed by the Intergovernmental Panel on Climatte Change (IPCC) or compatible with it."

Artice 7.1 of the Decision states "Member States shall also send to the Commission information on:

- data on emissions of other greenhouse gases not controlled by the Montreal Protocol on the basis of the best available methodology to be decided by the Commission in accordance with the procedure set out in Article 8. Such a methodology shall be either that developed by IPCC or compatible with it......".

Other greenhouse gases include CH_4 and N_2O. However (see below) greenhouse gas emission methodology usually also covers the ozone precursors, NOx, CO and NMVOC and may in future be extended to additional species.

3. European atmospheric emission inventory methodology

There have been several major international initiatives over the past 10 or so years which have built on each other and helped develop the emission inventory methodology to its current state. These include :

- the OECD Control of Major Air Pollutants (MAP) Project
- the DGXI Inventory
- the CORINE Programme and subsequent work by the European Environment Agency Task Force

- the Cooperative Programme for Monitoring and Evaluation of the Long Range Transmission of Air Pollutants in Europe (EMEP)
- the IPCC/OECD Greenhouse Gas Emissions Programme

3.1 OECD/MAP Project

The MAP Project was designed (OECD, 1990) to :

- assess pollution by large scale photochemical oxidant episodes in Western Europe and
- evaluate the impact of various emission control strategies for such episodes.

The Project started in 1983 and the report on the work was published in 1990.
The MAP emission inventory covered the following pollutannts :

sulphur dioxide - SO_2
nitrogen oxides - NOx, and
volatile organic compounds - VOC, including natural emissions.

The inventory quantified point and area source emissions in nine main source sectors from 17 European OECD countries - the current 15 Member States (excluding the former German Democratic Republic) plus Norway and Switzerland.

The nine main source sectors were:

- mobile
- power plant
- non-industrial combustion
- industry
- organic solvent evaporation
- waste treatment and disposal
- agriculture and food industry
- nature and
- miscellaneous.

In most but not all cases the inventory was compiled from emission estimates submitted officially by each country. OECD worked closely with each country and with the CEC (which funded activity on the inventory to regroup emission estimates into the OECD source sectors and to help countries complete their inventories).

3.2 The DGXI Inventory

In 1985, the CEC Environment Directorate (DGXI) funded the compilation of an emission inventory for the EU12 Member States (Spain and Portugal joined the European Community during the course of the work) in 1980 and 1983.

The aim of the DGXI Inventory was (CITEPA, 1988) to collect data on emissions from all relevant sources in order to produce a database for use in the study of air pollution problems and to base policy measures in the field of air pollution control.

The inventory covered four pollutants - SO_2, NOx, VOC and particulates - and recognised 10 main source sectors :

- utility power plant
- industrial combustion plant
- district heating
- oil refineries and petrochemical plant
- domestic heating
- industrial processes
- solvent use
- transportation
- agriculture and
- nature.

The work, which was completed with the publication of the report in 1988, was carried out under contract by a group of four national laboratories/consultancies in collaboration with the Member States and OECD, who were simultaneously compiling the MAP Inventory.

3.3 CORINE and the EEA Task Force

Council Decision 85/338/EEC (OJ, 1985) established a work programme concerning an "experimental project for gathering, coordinating and ensuring the consistency of information on the state of the environment and natural resources in the Community". The work programme was given the name CORINE - CO-oRdination d'INformation Environnementale and include a project to gather and organise information on emissions into the air relevant to acid deposition - Corinair. This poject started in 1986 with the objective of compiling a coordinated inventory of atmospheric emissions from the 12 Member States of the Community in 1985 (Corinair 1985).

The Corinair 1985 Inventory covered three pollutants - SO_2, NOx, and VOC (total volatile organic compounds) - and recognised eight main source sectors :

- combustion (including power plant but excluding other industry)
- oil refineries
- industrial combustion
- processes
- solvent evaporation
- road transportation
- nature and
- miscellaneous.

The project also developed :

- a source sector nomenclature - NAPSEA, Nomenclature for Air Pollution Socio-Economic Activity and SNAP, Selected Nomenclature for Air Pollution - for emission source sectors, sub-sectors and activities
- a Default Emission Factor Handbook and
- a computer software package for data input and the calculation of sectorial, regional and national emission estimates.

The Corinair 1985 Inventory was developed in collaboration with the Member States, Eurostat, OECD and UNECE/EMEP.

The Inventory was completed in 1990 and the results have been published (Eurostat, 1991; CEC, 1995) and widely distributed in tabular and map forms.

Pending a decision on the location of the EEA, it was agreed in 1991 to produce an update of Corinair for 1990 (Corinair 1990). This update has been performed in cooperation with EMEP and IPCC-OECD to assist in the preparation of inventories required under the Long Range Transboundary Air Pollution (LRTAP) Convention and the Framework Climate Change Convention (FCCC) respectively.

The Corinair90 system was made available to :

- the 12 member states of the European Community in 1990 : Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain and United Kingdom,
- 5 EFTA countries : Austria, Finland, Norway, Sweden and Switzerland,
- 3 Baltic States : Estonia, Latvia and Lithuania
- 9 Central and Eastern European countries : Albania, Bulgaria, Croatia, Czech Republic, Hungary, Poland, Romania, Slovakia and Slovenia and
- Russia.

This collaboration:

- produced a more developed nomenclature (source sector split) - SNAP90 - involving over 260 activities grouped into a three level hierarchy of sub-sectors and 11 main sectors,
- extended the list of pollutants to be covered to eight:

  sulphur dioxide (SO_2)

  oxides of nitrogen (NO_x) and

  non-methane volatile organic compounds (NMVOC)

  ammonia

  carbon monoxide

  methane

  nitrous oxide and

  carbon dioxide
- extended the number of sources to be considered as point sources (there were over 1400 large point sources in the Corinair85 inventory)
- recognised that an emission inventory needs to be complete, consistent and transparent
- extended the availability of the Corinair system to 30 countries and
- increased awareness of Corinair and the need to produce an inventory within a reasonable time-scale to serve the requirements of the user community (policy-makers, researchers etc).

The Corinair 1990 Inventory recognises 11 main source sectors (as agreed with EMEP, see below):

- Public power, cogeneration and district heating plants
- Commercial, institutional and residential combustion plants
- Industrial combustion
- Production processes
- Extraction and distribution of fossil fuels
- Solvent use
- Road transport
- Other mobile sources and machinery
- Waste treatment and disposal
- Agriculture
- Nature

Data are provided on large point sources on an individual basis and on other smaller or more diffuse on an area basis, usually by administrative boundary at the county, departement level (NUTS level 3). The sources to be provided as point sources are :

- Power plant with thermal input capacity >=300MW
- Refineries
- Sulphuric acid plant
- Nitric acid plant
- Integrated iron/steel with production capacity >3Mt/yr
- Paper pulp plant with production capacity > 100kt/yr
- Large vehicle paint plant with production capacity > 100000 vehicles/yr
- Airports with >100000 LTO cycles/yr
- Other plant emitting >=1000t/yr SO_2, NOx or VOC
  or >=300000t/yr CO_2

The **Goal of Corinair90** is to provide a complete, consistent and transparent air pollutant emission inventory for Europe in 1990 within a reasonable timescale to enable widespread use of the inventory for policy, research and other purposes.

Completeness covers two aspects : the Corinair90 system is available to almost all countries of Europe and the SNAP90 nomenclature has been designed to provide a comprehensive list of activities generating emissions of the eight pollutants to be quantified.

Consistency will be provided by the systematic application of the Corinair methodology - by using the Corinair software and the SNAP90 nomenclature - to provide emission estimates.

Transparency will be achieved through the provision within the inventory of activity statistics/data and emission factors (or details of emission measurements where available) used to calculate emissions and through the supply of full references to the sources of these data.

Initial data from Corinair90 became available in early 1994 and the project was completed and a series of reports prepared during 1995 and early 1996.

3.4 EMEP

The Cooperative Programme for Monitoring and Evaluation of the Long Range Transmission of Air Pollutants in Europe (EMEP) formed by a Protocol under the Long Range Transboundary Air Pollution Convention has arranged a series of workshops on Emission Inventory Techniques to develop guidelines for estimation and reporting of emission data for SOx, NOx, NMVOCs, CH_4, NH_3 and CO under the Convention. The 1991 Workshop agreed to recommend that :

- a task force on emission inventories should be established by the Executive Body of the Convention to review present emission inventories and repotrting procedures for the purpose of further improvement and harmonisation, and
- the EMEP Steering Body should approve the guidelines prepared by the workshop for estimation and reporting for submission to the Executive Body of the Convention.

These guidelines included a recommendation that emission data should be reported as totals and at least for the 11 major source categories agreed with Corinair and other experts for the Corinair 1990 Inventory (see above).

The proposed task force was set up under the EMEP Steering Body with leadership from the United Kingdom and support from Germany and the European Community (CEC/EEA-TF).

The objectives of the task force are to :

- provide a technical forum to discuss, exchange information and harmonise emission inventories including emission factors, methodologies and guidelines,
- conduct in-depth evaluation of emission factors and methodologies in current operation and
- cooperate with other international organisations working on emission inventories with the aim of harmonising methodologies and avoiding duplication of work.

The first meeting of the task force was held in London in 1992 (McInnes, Pacyna and Dovland, 1992) and established eight expert panels to progress the work of the task force. The second meeting was held in Delft in 1993 (McInnes, Pacyna and Dovland, 1993) and agreed the specification for the joint EMEP/Corinair Emission Inventory Guidebook. The third meeting was held in Regensburg, Germany and reviewed first drafts of the Guidebook and considered how to integrate into the task force work previously developed by the task force on emission projections. The fourth meeting was held in Oslo, Norway and reviewed/assessed the second draft of the Emission Inventory Guidebook and considered how to develop the second phase of the Task Force.

3.5 The IPCC/OECD Greenhouse Gas Emissions Programme

In February 1991 the OECD held a workshop in Paris on greenhouse gas emission inventory methodology to consider the OECD report 'Estimation of Greenhouse Gas Emissions and Sinks' (Background Report). The workshop produced (OECD,1991) consensus on :

a) a basic methodology document as the best available starting point for work on consistent national emission estimates and

b) a proposed plan for a two-year programme of work to improve and disseminate the inventory methodolgy.

IPCC subsequently adopted the Work Programme to be carried out by IPCC Working Group 1 with support from OECD and IEA and recognised that method development effort should (IPCC, 1992):

a) build on available information - both best available scientific data from ongoing research and currently available inventories and methods.
b) provide a simple default method accessible to all participating countries.
c) allow more detailed methods - those countries which have detailed emissions inventory capabilities should be encouraged to use them to provide the best possible data to the IPCC.
d) have careful documentation and review procedures to ensure consistency and transparency of results.

This Work Programme prepared Draft Guidelines for National Greenhouse Gas Inventories in three volumes - Reporting Instructions, Workbook and Reference Manual - in the six official languages of the United Nations for worldwide review during 1994. These guidelines were revised, updated and issued as a three volume set of Guidelines in early 1995 prior to the first Conference of the Parties held in Berlin in March-April 1995.

The Guidelines currently cover the main sources of the three major greenhouse gases - CO_2, CH_4 and N_2O - and three additional groups of greenhouse gases - HFCs, PFCs and SF_6 but also prompt for emission estimates from three ozone precursors - NOx, CO and NMVOC. Furthermore, it is likely that information may be requested on SO_2 and NH_3 (which are important in the formation of aerosols and hence cloud formation which may have a negative effect on global warming) and other greenhouse gases and precursors.

The IPCC Guidelines specifies six main sectors for reporting emissions and removals :

- All Energy (Combustion + Fugitive)
- Industrial Processes
- Solvent and other Product Use
- Agriculture
- Land Use Change and Forestry
- Waste.

Phase II of the joint IPCC/OECD/IEA programme to develop these Guidelines commenced in 1995 and established expert groups on agricultural soils, waste, new gases/industrial processes, land-use change and fule combustion.

The Corinair Technical Unit superceded by the European Topic Centre on Air Emissions has been working closely with the IPCC-OECD Liaison Group to ensure compatibility between the Corinair system and IPCC reporting formats and to ensure that harmonisation of the two systems can occur. This was all but completed by the development of the Corinair nomenclature to produce SNAP94 in late 1995 (see chapter ASVI).

4. Multi-media integrated inventories

In reviewing the requirements of the Fifth Environmental Action Programme (5EAP) 'Towards Sustainability' and developing the work programme for the EEA, the EEA Task Force has recognised the potential for extending the Corinair methodology to other media - a common, core set of relevant activity data would be collected and emission factors applied to these data to provide estimates of emissions or releases into all media - air, water and land - as well as waste.

An initial feasibility study carried out for the EEA-TF recommended that an integrated emission inventory should, in the long term, aim to :

- cover all the emittants relevant to the Fifth Environmnetal Action Programme
- cover emissions from both anthropogenic and natural sources
- include emissions to all the environmental media relevant to the Fifth Environmmnetal Action Programme (air, surface waters, groundwaters, land)
- be capable of defining major point and line emission sources, as well as diffuse emissions
- be based upon a combined methodology of self-monitoring (for point sources) and centralised assessment (for non-point sources)
- be based on a modular structure, allowing data on emissions to be combined and aggregated by environmental medium, socio-economic activity/sector, product, geographic area etc according to need
- provide a survey of emissions on an annual cycle
- include rigorous procedures for data quality control and documentation
- provide support for access-by-request from *bona fide* users, including policy makers, scientists and public
- provide regular publications and summaries of results in an accessible form (including CD-ROM)
- be built upon the wide body of experience and data which already exist in member states and international agencies
- be managed to ensure that data are collated and stored at the most appropriate institutional level and that only data explicitly required at a European level need be transferred to the central coordinating agency
- be coordinated by the European Environment Agency with the support of a Topic Centre and national focal points.

To achieve these long-term aims, the report also recommended a number of steps to be taken, including

- the development of a conceptual model of emissions including sources, pathways and receiving media of concern
- development (in collaboration with Eurostat and other international statistics agencies) of a source classification, consistent with the general structure of the hierarchical NAPSEA nomenclature but covering other media and emission pathways and formally and explicitly linked to exsisting statistical classifications (for example NACE, ISIC, PRODCOM)
- development of a list of priority emittants
- definition of clear criteria for the identification and selection of point sources
- formulation of agreed reporting procedures
- definition of approved measurement methods
- establishment of a network of reporting agencies
- specification of inventory structure and database
- development of quality control procedures
- agreement on access conditions.

Finally, since an integrated inventory cannot be achieved in a single step, the report recommended that a phased approach should be adopted with piloting of some of the required features, as was carried out for Corinair with the 1985 inventory.

The feasibility study recognised a two-pronged strategy for developing integrated emission inventories, based on :

- the use of plant-specific information, where available from measurements, permits and registers developed for the purposes of emission abatement and control, and
- modelling emissions from appropriate activity data and emission factors for other sources.

This work is now continuing as part of the work programme of the European Environment Agency to progressievly develop source-oriented inventories covering emissions to air, water and soil as well as waste releases and transfers.

The OECD has been asked by its member countries and the Intergovernmental Panel on Chemical Safety to develop a guidance document for governments who are considering establishing a national pollutant release and transfer register (PRTR) and is currently organising a series of workshops in order to obtain broad input for this document.

The first meeting, organised jointly with the CEC and held in Brussels in January 1994 :

- outlined several benefits to a national government in instuting a PRTR
- listed various aspects that would need to be taken into account to realise these benefits
- listed the processes necessary to achieve creation of a PRTR and
- started to consider various issues which would need to be addressed.

5. The European Environment Agency

The European Environment Agency was established by EC Regulation 1210/90 and commenced operation in Copenhagen on 30 October 1993.

The overall objective of the Agency as specified in the Regulation is "to provide the European Community and the Member States with objective, reliable and comparable information at European level enabling them to take the requisite measures to protect the environment, to assess the results of such measures and to ensure that the public is properly informed about the state of the environment".

The Multiannual Workprogramme for 1994-1999 was adopted by the Management Board of the Agency in July 1994. The Regulation specifies that the Agency shall furnish information which can be directly used in the implementation of Community environmental policy and that it should give priority to a number of areas including atmospheric emissions.

As part of the first workprogramme the Agency in December 1994 designated five Eureopan Topic Centres to address inland waters, marine & coastal environment, air quality, nature conservation and air emissions respectively.

The European Topic Centre on Air Emissions (ETC/AEM) is led by the Umweltbundesamt (UBA), Germany supported by a consortium of partners involving :

- Umweltbundesamt (UBA), Austria
- Centre Interprofessionel Technique de la Pollution Atmospherique (CITEPA), France
- POSEIDON, Greece and
- the European Network of Environmetal Research Organisations (ENERO, which includes - NETCEN, United Kingdom
RISO, Denmark
ENEA, Italy
TNO, Netherlands).

Two projects from the Agency's Annual Workprogramme 1994-1995 were addressed in 1995 by the ETC/AEM. These projects had the following objectives :

- to provide an analysis of the situation and recommenfdations for a general approach and assessment for the development of guidelines for air emissions inventories at different levels and Europe wide (scoping study)
- to compile an emissions inventory for Europe for the year 1994 covering the eight pollutants of the Corinair 1990 as well as heavy metals, persistent organics and other pollutants required under the various conventions and commitments of countries involved.
- to review, consolidate and adjust the Corinair methodology to contribute to the development of the common tools for integrated inventories

The ETC/AEM prepared a first report 'Review of Corinair 90 - Proposals for Air Emissions 94' (European Environment Agency, 1995) which sets out its proposals on how to develop annual atmospheric emissions from 1994 onwards. In late 1995 the ETC/AEM developed the Corinair system in line with these proposals and in 1996 started to work with national experts to help them prepare the 1994 annual inventory and make the results available to the widest possible range of users.

TASK FORCE ON EMISSION INVENTORIES

The Task Force on Emission Inventories was initiated in 1991 following agreement by the Executive Body for the Convention on Long-range Transboundary Air Pollution on a new work-plan item to evaluate emission inventory requirements of the Co-operative Programme for Monitoring and Evaluation of Air Pollutants in Europe (EMEP) to ensure an adequate flow of reliable information to support the work under the Convention and to take account of the emission data needs of other relevant bodies under the Executive Body.

The Task Force is led by the United Kingdom in collaboration with Germany and the European Community and has set the following objectives :

a) to provide a technical forum to discuss, exchange information and harmonise emission inventories including emission factors, methodologies and guidelines,

b) conduct in-depth evaluation of emission factors and methodologies in current operation and

c) co-operate with other international organisations working on emission inventories with the aim of harmonising methodologies and avoiding duplication of work.

The first meeting of the Task Force held in London in May 1992 :

- reviewed on-going activities
- presented a background paper on emission inventory methodology and
- agreed to set up eight expert panels to address various aspects of inventories :
    - Strategic overview
    - Volatile organic compounds
    - Ammonia
    - Heavy metals and persistent organic compounds
    - Power plant and industry
    - Mobile sources
    - Marine sources
    - Verification.

A leader was appointed for each panel and with panel members prepared work-plans, including further panel meetings, for the following year.

The second meeting of the Task Force was held in Delft in June 1993 :

- to review progress since May 1992 and

- to review and agree workplans for the next two years, inparticular for the development of the Emission Inventory Guidebook.

The Stategic Overview expert panel had prepared a draft specification for the Guidebook which was reviewed by each panel and in plenary sessions. With some amendments/refinements the draft was accepted as the specification for the Guidebook.

Work began on preparation of the Guidebook immediately after the meeting, including a study, contracted by the European Environment Agency Task Force, to consider and make recommendations on publication aspects.

The third meeting of the Task Force was held in Regensburg in June 1994 :

- to review and assess the first drafts of the Emission Inventory Guidebook, and

- to plan, review and agree workplans for the coming year, in particular for the completion of the first edition of Emission Inventory Guidebook and for the development of emission projection methodology.

The first three-year phase of the Task Force was completed with the fourth meeting held in Oslo in June 1995:

- to review and assess the first draft of the Emission Inventory Guidebook, and

- to plan, review and agree workplans for the next phase of the Task Force.

The Executive Body agreed that the Task Force should continue beyond June 1995 and that it should continue to be led by the United Kingdom with support from Germany and the European Community (which will be effected through the European Environment Agency). The meeting in 1996 is to be held in Oxford, United Kingdom and will identify priorities for the Task Force, decide on the reorganisation of the Task Force expert panels and plan the work for the following year.

EMISSION INVENTORY GUIDEBOOK

1. Guidebook Specification

The aim of the Guidebook is to provide an up-to-date comprehensive summary of emission inventory methodology for each of the pollutants and sources to be quantified.

The Guidebook is systematically organised and will be maintained as the reference document for emission inventory methodology. It provides guidance on methodology which could be adopted/followed without making or suggesting that such adoption is mandatory.

The methodology can be used for national, regional and local emission inventories.

The Guidebook is structured in Chapters with each chapter presenting information to a common format. The common format for each chapter will be a key feature of the Guidebook, designed to ensure that users (familiar or unfamiliar with the technical details of the area covered by each section) can readily locate and understand the essential aspects of the area covered.

Emission inventory nomenclature and hence the Guidebook will develop over time. However the Guidebook will initially address the source sector split and activity list given by SNAP90 (see CONTENTS).

The EEA-TF is currently assessing the feasibility of extending the CORINAIR methodology to other media - water, land - as well as waste. If this proves to be feasible then the Guidebook will be developed (in a second phase) to address these other media.

The EEA-TF is also supporting development of a general environmental thesaurus, including surveys of nomenclatures used (or to be used) in different media and sectors, in order to obtain sets of common standard terms. Development of the Guidebook will need to be coordinated with this activity to help ensure harmonisation.

Each chapter of the Guidebook covers a homogeneous Source Sector, Sub-sector, Activity or Group of Activities as listed in the latest version of SNAP (or subsequent multi-media nomenclature). For example a Section might cover Sector 2 (Commercial, institutional and residential combustion) or Sub-sector 4.7 (Cooling plant) or Activity 8.4.1 (Harbours) or Combustion Plant >=300MW (see Table 6).

Each chapter is arranged pollutant (within medium) within activity and should be as self-contained as possible. It should provide, in most cases, the main reference point for information and guidance on the essential requirements for compiling the emission estimates for the emission source covered. However, in some cases, the text will direct the user to supplementary documents and other relevant data sources which will help completion of this compilation.

An example of a supplementary document would be the COPERT User Manual and computer program, which would need to be used in conjunction with the Guidebook to work up the required inventory for mobile source emissions. Examples of other relevant data sources could be reports or on-line databases with information on Best Available Technology and/or emission factors used elsewhere (for example the IPCC Draft Guidelines for National Greenhouse Gas Inventories and the USEPA's AirCHIEF system).

The Guidebook will be developed via an agreed computer package which will need to include facilities to track additions and updates, their source and dates of occurence.

The computer-based Guidebook will make use of appropriate software, screen-interfaces and bulk-storage media (for example CD-ROM). It will also be designed to connect directly with the CORINAIR data entry system to facilitate selection of the most appropriate emission factors.

This first draft of the Guidebook includes contents pages arranged by SNAP code for quick reference to the various emission-generating activities and is in loose-leaf format to allow users to add new sections and updates as they become available.

The first edition of the Guidebook to be produced in 1995 will also have contents pages arranged alphabetically by activity and by pollutant.

2. Guidebook Format

Subject to further development by the Guidebook Coordinating Group, the common format for each Chapter is as follows (small changes have been introduced since the structure was agreed at the meeting of the Task Force held in Delft in May 1993) :

SNAP SECTOR, SUB-SECTOR OR ACTIVITY CODE(S) :

SOURCE SECTOR, SUB-SECTOR OR ACTIVITY TITLE(S) :

1. ACTIVITIES INCLUDED :

For chapters covering a source sector, sub-sector or parts thereof, provide codes and names for each of the activities covered within this chapter.

2. CONTRIBUTION TO TOTAL EMISSIONS :

Provide tables summarising current state of knowledge on (a selection of) national and multi-national (CORINAIR, EMEP, OECD) weight and percent contributions to total emissions for each relevant pollutant.

Sectors and sub-sectors producing more than one percent of total emissions of any pollutant should be disaggregated as far as practicable within these tables to show contributions from the main sub-sectors and/or activities producing at least one percent of the most significant pollutant.

3. GENERAL : Description

Provide general introduction to explain what the section covers. Use ISIC, NACE, PRODCOM (or other) codes and definitions where these can help in the definition of the activities covered.

Definitions
Provide definitions of important terms.

Techniques
Describe the relevant techniques/technologies (reference may be given to additional sources of information).

Emissions
Present the relevant pollutants and describe where and how they are emitted.

Controls
Describe the controls/abatement techniques available, how these have been introduced over time and their effects on emissions.

Each of the above should include reference to the source of the definitions of terms and classification.

4. SIMPLER METHODOLOGY :

Describe the minimum acceptable approach for quantifying emissions from this source. The rationale for the approach should be presented and should have been confirmed as acceptable by several experts (some of whom will use this approach and some a more advanced approach). Appropriate base statistics and emission factors to be used should be clearly specified and explained.

5. DETAILED METHODOLOGY :

Describe the methodology, the benefits in terms of detail, improved accuracy and precision etc and how it relates to the simpler approach. (In some case the simpler and detailed methodology may be the same).

6. RELEVANT ACTIVITY STATISTICS :

Provide lists and possible sources of statistcs/data on activities relevant to the estimation of emissions. Example activities are fuel consumption, traffic, industrial consumption/output and example data sources are national statistics offices, Eurostat, UNECE, OECD, IEA.

7. POINT SOURCE CRITERIA :

List the current criteria to be used to split sources into point and area/line sources.

Provide an estimate of the number of likely point sources using these criteria. For example plant relevant to the Large Combustion Plant Directive could be listed.

8. EMISSION FACTORS, QUALITY CODES AND REFERENCES :

Provide tables of emission factors for each pollutant, medium, technique, activity and fuel covered with associated quality codes and references (to the literature sources of the emission factors). Where appropriate and available, uncontrolled techniques should be given first and the temporal development of emissions/abatement should be included.

9. SPECIES PROFILES :

Provide available information on species profiles, for example NO_x and VOCs, with associated quality codes (A-E) and references, as for emission factors above.

10. UNCERTAINTY ESTIMATES :

Provide current estimates in the uncertainties of base statistics, emission factors, dissaggregation factors and emission estimates as percentages and/or quality codes (A-E).

11. WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY :

Provide a summary of these aspects with suggestions/proposals on how they can be addressed or on how they are being addressed.

12. SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES :

Provide recommendations for activity or surrogate statistics to be used for spatial dissaggregation.

13. TEMPORAL DISAGGREGATION CRITERIA :

Provide a summary of what is known or what needs to be considered to dissaggregate annual totals to shorter time periods.

14. ADDITIONAL COMMENTS :

15. SUPPLEMENTARY DOCUMENTS :

Provide a summary of documents which are to be used in conjunction with the Guidebook and which provide supplementary information necessary for completion of this part of the inventory, for example COPERT manuals.

16. VERIFICATION PROCEDURES :

Describe verification procedures relevant to this section and who should apply them (national expert, central team, statistical office etc). The Verification Expert Panel will provide advice/examples to the other Panel Leaders to help develop this section.

17. REFERENCES :

Provide list of references quoted within this section.

18. BIBLIOGRAPHY :

Provide list of additional relevant literature.

19. RELEASE VERSION, DATE AND SOURCE :

Editor provides release version number, date of preparation (date of release is provided in the footer and identity of source of text.

3. Tasks for the Expert Panels

The Expert Panels set up by the ECE Task Force on Emission Inventories include the following :

- Volatile organic compounds (VOC)
- Ammonia (NH_3)
- Heavy metals & Persistent organic pollutants (HM/POP)
- Power plant & industry (PP/Ind)
- Mobile sources (Mobile)and
- Marine (mobile) sources (Marine).
- Verification

The first six 'technical' panel leader with support from other members of his panel and from the verification panel, will:

1. Collect/review available information on activities and inventory methodology (emission estimates, emission factors, activity statistics etc) allocated to the panel; this should include national and international methodologies for emission inventories using both emission factor and plant specific (for example Toxic Release Inventory -TRI) approaches. Major sources of information which should be considered are :

- CORINAIR Default Emission Factor Handbook (2nd Edition, dated January 1992),
- USEPA AirCHIEF (CD-ROM containing (parts of) emission factor document AP42 and other emission factor and methodology reports)
- IPCC/OECD greenhouse gas programme reports (guidelines, workbooks etc)
- PARCOM/ATMOS Emission Factor Handbook.
- CORINAIR 1990 Emission Inventory
- Process descriptions from the SPIN-Project of the Netherlands

2. Consider the significance of each of these activities in terms of their contribution to emissions, the scope to sub-divide activities and the case for adding related activities (not included specifically in the latest nomenclature).

3. Prioritise the order in which activities will be addressed for inclusion in the Guidebook.

4. Consider the scope for simplifying the methodologies to be recommended so that they can be adopted by the widest range of countries yet maintain a reasonable level of accuracy. There is no point in recommending a methodology which requires detail beyond the available information or is beyond the financial resources of most countries or the timescales of the inventory programme.

5. Prepare text, tables, figures etc to the required format in priority order.

6. Circulate draft text etc for review, correction, amendment by the rest of the panel.

7. Submit agreed text etc to publisher or to lead panel.

8. Continue to collect data on activities already submitted in item 6 for later updates.

9. Liaise with lead/supporting panel leader as necessary.

10. Liaise with/participate in the Verification expert panel.

11. Attend Coordination Group Meetings as required.

12. Make proposals for further research/study to improve the methodology.

CORINAIR NOMENCLATURES

A detailed nomenclature called NAPSEA (Nomenclature for Air Pollution Socio-Economic Activities) was developed for the the Corinair 1985 Project. NAPACT consisted of three daughter nomenclatures :

- NAPACT : Nomenclature for Air Pollution ACTivities
- NAPTEC : Nomenclature for Air Pollution TEChniques
- NAPFUE : Nomenclature for Air Pollution Fuels

From these nomenclatures, a selected sub-set was established as the basis for the prototype Corinair 1985 inventory : SNAP P, Selected Nomenclature for Air Pollution Prototype. SNAP P links directly to the various components of NAPSEA.

In 1990/91, when preparation were being made to prepare a Corinair 1990 inventory, discussions were held with experts from EMEP and OECD to develop a common nomenclature for Corinair and for reporting under the LRTAP Convention. SNAP90 emerged from these discussions but the detailed link to NAPACT and NAPFUE was not made.

In 1995, the European Topic Centre on Air Emissions (ETC/AEM) developed the Corinair nomenclature further to produce SNAP94 as presented in this edition of the Guidebook. SNAP94 has been developed to cover additional activities that are sources of the heavy metals and persistent organics to be included in the 1994 inventory and to be as consistent as possible with the IPCC nomenclature developed for reporting under the UN Framework Climate Change Convention (see chapter ASVI).

Eurostat has also initiated a project to develop source nomenclatures such as SNAP94 to be more consistent with the NACE socio-economic nomenclatures.

CORRESPONDENCE BETWEEN SNAP 94 AND IPCC SOURCE CATEGORIES

This document provides the corresponding allocation of all SNAP 94 items in IPCC source categories. It is to be noticed that each SNAP item corresponds to only one IPCC source category as defined in standard data tables except in the case of autoproduction of electricity or heat for which the correspondence is provided within the NAD module (cf SNAP 94 general comment A).

All codes used in this document refer to :
- CORINAIR / SNAP 94 version 1.0 dated 21/12/95
- IPCC / Guidelines for National Greenhouse Gas Inventories / Reporting Instructions (Volume 1) dated 1995.

Users are invited to check whether CORINAIR or IPCC categories are not modified.

	CORINAIR / SNAP classification	IPCC classification
01	**COMBUSTION IN ENERGY PRODUCTION AND ENERGY TRANSFORMATION**	
01 01	**Public power** Items 01.01.01 to 01.01.05	1A1a Electricity and heat production
01 02	**District heating plants** Items 01.02.01 to 01.02.05	1A1a Electricity and heat production
01 03	**Petroleum refining plants** Items 01.03.01 to 01.03.06	1A1b Petroleum refining 1A1a Electricity and heat production (*)
01 04	**Solid fuel transformation plants** Items 01.04.01 to 01.04.07	1A1c Solid fuel transformation and other energy industries 1A1a Electricity and heat production (*)
01 05	**Coal mining, oil, gas / extraction plants** Items 01.05.01 to 01.05.05	1A1c Solid fuel transformation and other energy industries 1A1a Electricity and heat production (*)
02	**COMBUSTION IN COMMERCIAL, INSTITUT., RESIDENT. SECTORS AND AGRICULTURE, FORESTRY, FISHING**	
02 01	**Commercial and institutional plants** Items 02.01.01 to 02.01.06	1A4a Small combustion-Commercial/Institutional 1A1a Electricity and heat production (*)
02 02	**Residential plants** Items 02.02.01 to 02.02.05	1A4b Small combustion-Residential
02 03	**Plants in agriculture, forestry and fishing** Items 02.03.01 to 02.03.05	1A4c Small combustion-Agriculture/Forestry/Fishing 1A1a Electricity and heat production (*)
03	**COMBUSTION IN INDUSTRY**	
03 01	**Combustion in boilers, gas turbines and stationary engines** Items 03.01.01 to 03.01.06	1A2 Industry When relevant economic sector split data are available in CORINAIR, data can be allocated to sub-categories a to f. 1A1a Electricity and heat production (*)
03 02	**Process furnaces without contact**	
03 02 03	Blast furnaces cowpers	1A2a Industry-Iron and steel
03 02 04	Plaster furnaces	1A2f Industry-Other
03 02 05	Other furnaces	1A2f Industry-Other by default

(*) Autoproduction of energy in this sector must be reported in IPCC source category 1A1. This allocation is performed within CORINAIR considering relevant data for autoproduction of energy at national level in the CORINAIR/NAD module.

Code	CORINAIR / SNAP classification		IPCC classification
03 03	**Processes with contact**		
	Items 03.03.01 to 03.03.03	1A2a	Industry-Iron and steel
	Items 03.03.04 to 03.03.10 and 03.03.22 to 03.03.24	1A2b	Industry-Non ferrous metals
	Items 03.03.11 to 03.03.20 and 03.03.25 and 03.03.26	1A2f	Industry-Other
03 03 21	Paper-mill industry (drying processes)	1A2d	Industry-Pulp,paper and print
04	PRODUCTION PROCESSES		
04 01	**Processes in petroleum industries**		
	Items 04.01.01 to 04.01.05	1B2a	Fugitive emissions from fuels-Oil and natural gas/Oil
04 02	**Processes in iron and steel industries and collieries**		
	Items 04.02.01 and 04.02.04	1B1b	Fugitive emissions from fuels-Solid fuels/Transformation
	Items 04.02.02 , 04.02.03 and 04.02.05 to 04.02.10	2A	Industrial processes-Iron and steel
04 03	**Processes in non ferrous metal industries**		
04 03 01	Aluminium production (electrolysis)	2B1	Industrial processes-Non ferrous metals/Aluminium
	Ferro alloys and galvanizing (items 04.03.02 and 04.03.07)	2A	Industrial processes-Iron and steel
	Items 04.03.03 to 04.03.06 and 04.03.08 to 04.03.09	2B2	Industrial processes-Non ferrous metals/Other
04 04	**Processes in inorganic chemical industries**		
	Items 04.04.01 , 04.04.03 and 04.04.09 to 04.04.12	2C3	Industrial processes-Inorganic chemicals/Other
	Items 04.04.15 and 04.04.16	2C3	Industrial processes-Inorganic chemicals/Other
04 04 02	Nitric acid	2C1	Industrial processes-Inorganic chemicals/Nitric acid
	Items 04.04.04 to 04.04.08 and 04.04.14	2C2	Industrial processes-Inorganic chemicals/Fertiliser
04 05	**Processes in organic chemical industries (bulk production)**		
	Items 04.05.01 to 04.05.20 and 04.05.22 to 04.05.27	2D2	Industrial processes-Organic chemicals/Other
04 05 21	Adipic acid	2D1	Industrial processes-Organic chemicals/Adipic acid
04 06	**Proc. in wood, paper pulp, food and drink ind. & other ind.**		
	Items 04.06.01 to 04.06.08 and 04.06.15 and 04.06.17	2 F	Industrial processes-Other
	Items 04.06.10 to 04.06.11 and 04.06.13 and 04.06.16	2E3	Industrial processes-Non metallic mineral products/Other
04 06 12	Cement (decarbonizing)	2E1	Industrial processes-Non metallic mineral products/Cement
04 06 14	Lime (decarbonizing)	2E2	Industrial processes-Non metallic mineral products/Lime
04 07	**Cooling plants**	2 F	Industrial processes-Other
05	EXTRACTION AND DISTRIBUTION OF FOSSIL FUELS		
05 01	**Extraction and 1st treatment of solid fossil fuels**		
	Items 05.01.01 to 05.01.03	1B1a	Fugitive emissions from fuels-Solid fuels/Coal mining
05 02	**Extraction, 1st treatment and loading of liquid fossil fuels**		
	Items 05.02.01 to 05.02.02	1B2a	Fugitive emissions from fuels-Oil and natural gas/Oil
05 03	**Extraction, 1st treat. and loading of gaseous fossil fuels**		
	Items 05.03.01 to 05.03.03	1B2b	Fugitive emissions from fuels-Oil and natural gas/Natural gas
05 04	**Liquid fuel distribution (except gasoline distribution)**		
	Items 05.04.01 to 05.04.02	1B2a	Fugitive emissions from fuels-Oil and natural gas/Oil
05 05	**Gasoline distribution**		
	Items 05.05.01 to 05.05.03	1B2a	Fugitive emissions from fuels-Oil and natural gas/Oil
05 06	**Gas distribution networks**		
	Items 05.06.01 to 05.06.02	1B2b	Fugitive emissions from fuels-Oil and natural gas/Natural gas

Code	CORINAIR / SNAP classification		IPCC classification
06	**SOLVENT AND OTHER PRODUCT USE**		
06 01	**Paint application** Items 06.01.01 to 06.01.09	3A	Solvent and other product use-Paint application
06 02	**Degreasing, dry cleaning and electronics** Items 06.02.01 to 06.02.04	3B	Solvent and other product use-Degreasing and dry cleaning
06 03	**Chemical products manufacturing or processing** Items 06.03.01 to 06.03.14	3C	Solvent and other product use-Chemical products
06 04	**Other use of solvents and related activities** Items 06.04.01 to 06.04.12	3D	Solvent and other product use-Other
06 05	**Use of N2O** Items 06.05.01 to 06.05.02	3D	Solvent and other product use-Other
07	**ROAD TRANSPORT**		
07 01	**Passenger cars** Items 07.01.01 to 07.01.03	1A3b	Transport-Road (1-Cars)
07 02	**Light duty vehicles < 3.5 t** Items 07.02.01 to 07.02.03	1A3b	Transport-Road (2-Light duty trucks)
07 03	**Heavy duty vehicles > 3.5 t and buses** Items 07.03.01 to 07.03.03	1A3b	Transport-Road (3-Heavy duty trucks and buses)
07 04	**Mopeds and Motorcycles < 50 cm3**	1A3b	Transport-Road (4-Motorcycles)
07 05	**Motorcycles > 50 cm3** Items 07.05.01 to 07.05.03	1A3b	Transport-Road (4-Motorcycles)
07 06	**Gasoline evaporation from vehicles**	1A3b	Transport-Road
07 07	**Automobile tyre and brake wear**	1A3b	Transport-Road
08	**OTHER MOBILE SOURCES AND MACHINERY**		
08 01	**Military (if not included elsewhere)**	1A5	Other
08 02	**Railways** Items 08.02.01 to 08.02.03	1A3c	Transport-Railways
08 03	**Inland waterways** Items 08.03.01 to 08.03.04	1A3d	Transport-Navigation
08 04	**Maritime activities**		
08 04 02	National sea traffic within EMEP area	1A3d	Transport-Navigation (2-Internal navigation)
08 04 03	National fishing	1A4c	Small combustion-Agriculture/Forestry/Fishing
08 04 04	International sea traffic (international bunkers)	1A3d	Transport-Navigation (1-International marine/bunkers)

CORINAIR / SNAP classification		IPCC classification	
08 05	**Air traffic**		
08 05 01	Domestic airport traffic (LTO cycles - <1000 m)	1A3a	Transport-Civil aviation (2-Domestic)
08 05 02	International airport traffic (LTO cycles - <1000 m)	1A3a	Transport-Civil aviation (1-International)
08 05 03	National cruise traffic (>1000 m)	1A3a	Transport-Civil aviation (2-Domestic)
08 05 04	International cruise traffic (>1000 m)	1A3a	Transport-Civil aviation (1-International)
08 06	**Agriculture**	1A4c	Small combustion-Agriculture/Forestry/Fishing
08 07	**Forestry**	1A4c	Small combustion-Agriculture/Forestry/Fishing
08 08	**Industry**	1A2f	Industry-Other by default
08 09	**Household and gardening**	1A4b	Small combustion-Residential
08 10	**Other**	1A3e	Transport-Other
09	**WASTE TREATMENT AND DISPOSAL**		
09 02	**Waste incineration**		
	Items 09.02.01 and 09.02.02	6C	Waste-Incineration
	Items 09.02.03 and 09.02.06	1B2c	Fugitive emissions from fuels-Oil and natural gas/Flaring
	Items 09.02.04 to 09.02.05 and 09.02.07 to 09.02.08	6C	Waste-Incineration
09 07	**Open burning of agricultural wastes (except 10.03)**	6C	Waste-Incineration
09 09	**Cremation**		
	Items 09.09.01 to 09.09.02	6C	Waste-Incineration
09 10	**Other waste treatment**		
09 10 01	Waste water treatment in industry	6B1	Waste-Wastewater treatment/Industrial
09 10 02	Waste water treatment in residential and commercial sect.	6B2	Waste-Wastewater treatment/Domestic and commercial
09 10 03	Sludge spreading	6D	Waste-Other
09 10 04	Land filling	6A1	Waste-Solid waste disposal on land/Landfills
09 10 05	Compost production from waste	6D	Waste-Other
09 10 06	Biogas production	6D	Waste-Other
09 10 07	Latrines	6B2	Waste-Wastewater treatment
09 10 08	Refused Derived Fuel production	6C	Waste-Incineration
10	**AGRICULTURE, FORESTRY AND LAND USE CHANGE**		
10 01	**Cultures with fertilizers (except animal manure)**		
	Items 10.01.01 to 10.01.02 and 10.01.04 to 10.01.06	4D	Agriculture-Agricultural soils
10 01 03	Rice field	4C	Agriculture-Rice cultivation
10 02	**Cultures without fertilizers**		
	Items 10.02.01 to 10.02.02 and 10.02.04 to 10.02.06	4D	Agriculture-Agricultural soils
10 02 03	Rice field	4C	Agriculture-Rice cultivation
10 03	**On field burning of stubble, straw,...**	4 F	Agriculture-Field burning of agricultural residues

CORINAIR / SNAP classification		IPCC classification	
10 04	**Enteric fermentation**		
10 04 01	Dairy cows	4A1a	Agriculture-Enteric fermentation/Cattle/Dairy
10 04 02	Other cattle	4A1b	Agriculture-Enteric fermentation/Cattle/Non-dairy
10 04 03	Ovines	4A3	Agriculture-Enteric fermentation/Sheep
	Items 10.04.04 and 10.04.12	4A8	Agriculture-Enteric fermentation/Swine
10 04 05	Horses	4A6	Agriculture-Enteric fermentation/Horses
10 04 06	Mules and asses	4A7	Agriculture-Enteric fermentation/Mules and asses
10 04 07	Goats	4A4	Agriculture-Enteric fermentation/Goats
	Items 10.04.08 to 10.04.10	4A9	Agriculture-Enteric fermentation/Poultry
	Items 10.04.11 and 10.04.15	4A10	Agriculture-Enteric fermentation/Other
10 04 13	Camels	4A5	Agriculture-Enteric fermentation/Camels and llamas
10 04 14	Buffalos	4A2	Agriculture-Enteric fermentation/Buffalos
10 05	**Manure management**		
10 05 01	Dairy cows	4B1a	Agriculture-Manure management/Cattle/Dairy
10 05 02	Other cattle	4B1b	Agriculture-Manure management/Cattle/Non-dairy
	Items 10.05.03 and 10.05.04	4B8	Agriculture-Manure management/Swine
10 05 05	Sheep	4B3	Agriculture-Manure management/Sheep
10 05 06	Horses	4B6	Agriculture-Manure management/Horses
	Items 10.05.07 to 10.05.09	4B9	Agriculture-Manure management/Poultry
	Items 10.05.10 and 10.05.15	4B10	Agriculture-Manure management/Other
10 05 11	Goats	4B4	Agriculture-Manure management/Goats
10 05 12	Mules and asses	4B7	Agriculture-Manure management/Mules and asses
10 05 13	Camels	4B5	Agriculture-Enteric fermentation/Camels and llamas
10 05 14	Buffalos	4B2	Agriculture-Enteric fermentation/Buffalos
10 06	**Use of pesticides**	4G	Agriculture-Other
10 07	**Managed deciduous forests**		
	Items 10.07.01 to 10.07.03	7	Other
10 08	**Managed coniferous forests**	7	Other
10 11	**LUC-Wood biomass stock change /annual growth**		
	Items 10.11.01 to 10.11.03	5A1	Changes in forest and other woody biomass stocks/Tropical
	Items 10.11.04 to 10.11.06	5A2	Changes in forest and other woody biomass stocks/Temperate
10 11 07	Boreal forests	5A3	Changes in forest and other woody biomass stocks/Boreal
10 11 08	Other ecosystem types	5A5	Changes in forest and other woody biomass stocks/Grassland
10 11 09	Non-forest trees	5A5	Changes in forest and other woody biomass stocks/Other
10 12	**LUC-Wood Biomass stock change /annual harvest**		
	Items 10.12.01 to 10.12.03	5A	Changes in forest and other woody biomass stocks
10 13	**LUC-Conversion /Burning aboveground biomass**		
	Items 10.13.01 to 10.13.02	5B1	Forest and grassland conversion/Tropical
	Items 10.13.03 to 10.13.04	5B2	Forest and grassland conversion/Temperate
	Items 10.13.05 to 10.13.06	5B3	Forest and grassland conversion/Boreal
	Items 10.13.07 to 10.13.08	5B4	Forest and grassland conversion/Grassland
	Items 10.13.09 to 10.13.10	5B5	Forest and grassland conversion/Other
10 14	**LUC-Conversion /Aboveground biomass decay**		
10 14 01	Tropical forests	5B1	Forest and grassland conversion/Tropical
10 14 02	Temperate forests	5B2	Forest and grassland conversion/Temperate
10 14 03	Boreal forests	5B3	Forest and grassland conversion/Boreal
10 14 04	Grassland	5B4	Forest and grassland conversion/Grassland
10 14 05	Other	5B5	Forest and grassland conversion/Other

CORINAIR / SNAP classification		IPCC classification	
10 15	**LUC-Conversion /Soil carbon release**		
10 15 01	Tropical forests	5B1	Forest and grassland conversion/Tropical
10 15 02	Temperate forests	5B2	Forest and grassland conversion/Temperate
10 15 03	Boreal forests	5B3	Forest and grassland conversion/Boreal
10 15 04	Grassland	5B4	Forest and grassland conversion/Grassland
10 15 05	Other	5B5	Forest and grassland conversion/Other
10 16	**LUC-Managed land abandonment < 20years / Aboveground biomass**		
10 16 01	Tropical forests	5C1	Abandonment of managed lands/Tropical
10 16 02	Temperate forests	5C2	Abandonment of managed lands/Temperate
10 16 03	Boreal forests	5C3	Abandonment of managed lands/Boreal
10 16 04	Grassland	5C4	Abandonment of managed lands/Grassland
10 16 05	Other	5C5	Abandonment of managed lands/Other
10 17	**LUC-Managed land abandonment < 20 years / Soil carbon uptake**		
10 17 01	Tropical forests	5C1	Abandonment of managed lands/Tropical
10 17 02	Temperate forests	5C2	Abandonment of managed lands/Temperate
10 17 03	Boreal forests	5C3	Abandonment of managed lands/Boreal
10 17 04	Grassland	5C4	Abandonment of managed lands/Grassland
10 17 05	Other	5C5	Abandonment of managed lands/Other
10 18	**LUC-Managed land abandonment > 20 years / Aboveground biomass**		
10 18 01	Tropical forests	5C1	Abandonment of managed lands/Tropical
10 18 02	Temperate forests	5C2	Abandonment of managed lands/Temperate
10 18 03	Boreal forests	5C3	Abandonment of managed lands/Boreal
10 18 04	Grassland	5C4	Abandonment of managed lands/Grassland
10 18 05	Other	5C5	Abandonment of managed lands/Other
10 19	**LUC-Managed land abandonment > 20 years / Soil carbon uptake**		
10 19 01	Tropical forests	5C1	Abandonment of managed lands/Tropical
10 19 02	Temperate forests	5C2	Abandonment of managed lands/Temperate
10 19 03	Boreal forests	5C3	Abandonment of managed lands/Boreal
10 19 04	Grassland	5C4	Abandonment of managed lands/Grassland
10 19 05	Other	5C5	Abandonment of managed lands/Other
11	**NATURE**		
11 01	**Non managed deciduous forests**	-	Not included
11 02	**Non managed coniferous forests**	-	Not included
11 03	**Forest fires**	-	Not included
11 04	**Natural grassland**	-	Not included
11 05	**Wetlands (marshes - swamps)**	-	Not included
11 06	**Waters**	-	Not included
11 07	**Animals**	-	Not included
11 08	**Volcanoes**	-	Not included
11 09	**Near surface deposits**	-	Not included

CORRESPONDENCE BETWEEN IPCC SOURCE CATEGORIES AND SNAP 94

This document provides the corresponding allocation of IPCC source categories into SNAP 94 items.

All codes used in this document refer to :
- CORINAIR / SNAP 94 version 1.0 dated 21/12/95
- IPCC / Guidelines for National Greenhouse Gas Inventories / Reporting Instructions (Volume 1) dated 1995.

Users are invited to check whether CORINAIR or IPCC categories are not modified.

1 ENERGY

1 A FUEL COMBUSTION ACTIVITIES

IPCC classification	CORINAIR / SNAP classification	
1 A 1 Energy and Transformation Industries		
1 A 1 a Electricity and Heat production	01 01	Public power (01.01.01 to 01.01.05)
	01 02	District heating plants (01.02.01 to 01.02.05)
	01 03 (a)	Petroleum refining plants (01.03.01 to 01.03.06
	01 04 (a)	Solid fuel transformation plants (01.04.01 to 01.04.07)
	01 05 (a)	Coal mining, oil, gas / extraction plants (01.05.01 to 01.05.05)
	02 01 (a)	Commercial and institutional plants (02.01.01 to 02.01.06)
	02 02 (a)	Residential plants (02.02.01 to 02.02.05)
	02 03 (a)	Plants in agriculture, forestry and fishing (02.03.01 to 02.03.05)
	03 01 (a)	Industrial combustion in boilers, gas turbines and stationary engines (03.01.01 to 03.01.06)
1 A 1 b Petroleum refining	01 03	Petroleum refining plants (01.03.01 to 01.03.06
1 A 1 c Solid fuel Transformation and Other Energy Industries	01 04	Solid fuel transformation plants (01.04.01 to 01.04.07)
	01 05	Coal mining, oil, gas / extraction plants (01.05.01 to 01.05.05)

(a) Partly in 1 A 1 a with regard to autoproduction which is allocated within CORINAIR considering relevant data for autoproduction of energy at national level in the CORINAIR/NAD module.

1 A 2 Industry		
1 A 2 a Iron and Steel	03 01 (b)	Industrial combustion in boilers, gas turbines and stationary engines (03.01.01 to 03.01.06)
	03 02 03	Blast furnaces cowpers
	03 03 01	Sinter plants
	03 03 02	Reheating furnaces steel and iron
	03 03 03	Gray iron foundries
1 A 2 b Non-Ferrous Metals	03 01 (b)	Industrial combustion in boilers, gas turbines and stationary engines (03.01.01 to 03.01.06)
	03 03 04 to 03 03 09	Primary and secondary Pb/Zn/Cu production
	03 03 10	Secondary Al production
	03 03 22 to 03 03 24	Alumina, Magnesium and Nickel production
1 A 2 c Chemicals	03 01 (b)	Industrial combustion in boilers, gas turbines and stationary engines (03.01.01 to 03.01.06)
1 A 2 d Pulp, Paper and Print	03 01 (b)	Industrial combustion in boilers, gas turbines and stationary engines (03.01.01 to 03.01.06)
	03 03 21	Paper-mill industry (drying processes)

IPCC classification	CORINAIR / SNAP classification	
1 A 2 e Food Processing, Beverages and Tobacco	03 01 (b)	Industrial combustion in boilers, gas turbines and stationary engines (03.01.01 to 03.01.06)
1 A 2 f Other	03 01 (b)	Industrial combustion in boilers, gas turbines and stationary engines (03.01.01 to 03.01.06)
	03 02 04	Plaster furnaces
	03 02 05	Other furnaces
	03 03 11 to 03 03 20	Cement, Lime, Asphalt concrete, Glass, Mineral wool, Bricks and Tiles, Fine Ceramic materials
	03 03 25	Enamel production
	03 03 26	Other process with contact
	08 08	Other mobile and machinery/Industry

(b) When relevant economic sector split data are available in CORINAIR/NAD module, data can be allocated to sub-categories a to f. Autoproduction is allocated in 1 A 1 (cf note a)

1 A 3 Transport		
1 A 3 a Civil Aviation		
i International	08 05 02	Internat. airport traffic (LTO cycles - <1000 m)
	08 05 04	International cruise traffic (>1000 m)
ii Domestic	08 05 01	Domestic airport traffic (LTO cycles - <1000 m)
	08 05 03	National cruise traffic (>1000 m)
1 A 3 b Road Transportation	07 01	Passenger cars (07.01.01 to 07.01.03)
	07 02	Light duty vehicles < 3.5 t (07.02.01 to 07.02.0
	07 03	Heavy duty vehicles > 3.5 t and buses (07.03.0 to 07.03.03)
	07 04	Mopeds and Motorcycles < 50 cm3
	07 05	Motorcycles > 50 cm3 (07.05.01 to 07.05.03)
	07 06	Gasoline evaporation
	07 07	Automobile tyre and brake wear
1 A 3 c Railways	08 02	Railways (08.02.01 to 08.02.03)
1 A 3 d Navigation		
i International Marine	08 04 04	International sea traffic (internat. bunkers)
ii Internal navigation	08 04 02	National sea traffic within EMEP area
	08 03 01 to 08 03 04	Inland waterways
1 A 3 e Other Transportation	08 10	Other mobile sources and machinery
1 A 4 Small Combustion		
1 A 4 a Commercial / Institutional	02 01	Commercial and institutional plants (02.01.01 to 02.01.06)
1 A 4 b Residential	02 02	Residential plants (02.02.01 to 02.02.05)
	08 09	Household and gardening
1 A 4 c Agriculture / Forestry / Fishing	02 03	Plants in agriculture, forestry and fishing (02.03.01 to 02.03.05)
	08 04 03	National fishing
	08 06	Agriculture
	08 07	Forestry
1 A 5 Other		
1 A 5 a Stationary		
1 A 5 b Off-road and Other Machinery	08 01	Military (if not included elsewhere)
1 A 6 Traditional Biomass burned for Energy	All above items when wood, charcoal or vegetal wastes are used as fuels	

1 B FUGITIVE EMISSIONS FROM FUELS

IPCC classification	CORINAIR / SNAP classification	
1 B 1 Solid fuels		
1 B 1 a Coal Mining	05 01	Extraction and 1st treatment of solid fossil fuels (05.01.01 to 05.01.03)
1 B 1 b Solid fuel transformation	04.02.01	Coke oven (door leakage and extinction)
	04 02 04	Solid smokeless fuel
1 B 1 c Other		
1 B 2 Oil and natural gas		
1 B 2 a Oil	04 01	Processes in petroleum industries (04.01.01 to 04.01.05)
	05 02	Extraction, 1st treatment and loading of liquid fossil fuels (05.02.01 to 05.02.02)
	05 04	Liquid fuel distribution (except gasoline distribution) (05.04.01 to 05.04.02)
	05 05	Gasoline distribution (05.05.01 to 05.05.03)
1 B 2 b Natural gas	05 03	Extraction, 1st treat. and loading of gaseous gaseous fossil fuels (05.03.01 to 05.03.03)
	05 06	Gas distribution networks (05.06.01 to 05.06.0
1 B 2 c Venting and flaring	09.02.03	Flaring in oil refinery
	09.02.06	Flaring in oil and gas extraction

2 INDUSTRIAL PROCESSES

2 A IRON AND STEEL

	04 02 02	Blast furnace charging
	04 02 03	Pig iron tapping
	04 02 05 to 04 02 10	Furnace steel plant, Rolling mills, Sinter plants (except combustion), Other
	04 03 02 and 04 03 07	Ferro alloys and galvanizing

2 B NON-FERROUS METALS

2 B 1 Aluminium production	04 03 01	Aluminium production (electrolysis)
2 B 2 Other	04 03 03 to 04 03 05	Silicium, Magnesium, Nickel production
	04 03 06	Allied metal manufacturing
	04 03 08	Electroplating
	04 03 09	Other processes in non-ferrous industries

2 C INORGANIC CHEMICALS

2 C 1 Nitric Acid production	04 04 02	Nitric acid
2 C 2 Fertiliser production	04 04 04 to 04 04 06	Ammonium sulphate / nitrate / phosphate
	04 04 07 and 04 04 08	NPK fertikisers, Urea
	04 04 14	Phosphate fertilisers
2 C 3 Other	04 04 01	Sulfuric acid
	04 04 03	Ammonia
	04 04 09 to 04 04 11	Carbon black, Titanium dioxide, Grahite
	04 04 12	Calcium carbide production
	04 04 15	Storage and handling of inorganic products
	04 04 16	Other process in inorganic chemical indust.

2 D ORGANIC CHEMICALS

2 D 1 Adipic acid	04 05 21	Adipic acid
2 D 2 Other	04 05	Processes in organic chemical industry except adipic acid (04.05.01 to 04.05.20 and 04.05.22 to 04.05.27)

2 E NON-METALLIC MINERAL PRODUCTS

IPCC classification		CORINAIR / SNAP classification	
2 E 1	**Cement**	04 06 12	Cement (decarbonizing)
2 E 2	**Lime**	04 06 14	Lime (decarbonizing)
2 E 3	**Other**	04 06 10	Asphalt roofing materials
		04 06 11	Road paving with asphalt
		04 06 13	Glass (decarbonizing)
		04 06 16	Extraction of mineral ores

2 F OTHER

	04 06 01	Chipboard
	04 06 02 to 04 06 04	Paper pulp
	04 06 05 to 04 06 08	Bread, Wine, Beer
	04 06 15	Batteries manufacturing
	04 06 17	Other (including amiante production)
	04 07	Cooling plants

3 SOLVENT AND OTHER PRODUCT USE

3 A PAINT APPLICATION

	06 01	Paint application (06.01.01 to 06.01.09)

3 B DEGREASING AND DRY CLEANING

	06 02	Degreasing, dry cleaning and electronics (06.02.01 to 06.02.04)

3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING

	06 03	Chemical products manufacturing or processing (06.03.01 to 06.03.14)

3 D OTHER

	06 04	Other use of solvents and related activities (06.04.01 to 06.04.12)
	06 05	Use of N2O (06.05.01 to 06.05.02)

4 AGRICULTURE

4 A ENTERIC FERMENTATION

4 A 1	**Cattle**		
	4 A 1 a Dairy	10 04 01	Dairy cows
	4 A 1 b Non-Dairy	10 04 02	Other cattle
4 A 2	**Buffalo**	10 04 14	Buffalos
4 A 3	**Sheep**	10 04 03	Ovines
4 A 4	**Goats**	10 04 07	Goats
4 A 5	**Camels and Llamas**	10 04 13	Camels
4 A 6	**Horses**	10 04 05	Horses
4 A 7	**Mules and Asses**	10 04 06	Mules and asses
4 A 8	**Swine**	10 04 04 and 10 04 12	Fattening pigs, Sows
4 A 9	**Poultry**	10 04 08 to 10 04 10	Laying hens, Broilers, Other poultry
4 A 10	**Other**	10 04 11 and 10 04 15	Fur animals, Other animals

4 B MANURE MANAGEMENT

IPCC classification		CORINAIR / SNAP classification	
4 B 1	Cattle		
	4 B 1 a Dairy	10 05 01	Dairy cows
	4 B 1 b Non-Dairy	10 05 02	Other cattle
4 B 2	Buffalo	10 05 14	Buffalos
4 B 3	Sheep	10 05 05	Sheep
4 B 4	Goats	10 05 11	Goats
4 B 5	Camels and Llamas	10 05 13	Camels
4 B 6	Horses	10 05 06	Horses
4 B 7	Mules and Asses	10 05 12	Mules and asses
4 B 8	Swine	10 05 03 and 10 05 04	Fattening pigs, Sows
4 B 9	Poultry	10 05 07 to 10 05 09	Laying hens, Broilers, Other poultry
4 B 10	Other	10 05 10 and 10 05 15	Fur animals, Other animals

4 C RICE CULTIVATION

4 C 1	Continuously flooded	10 01 03 and 10 02 03	Rice field with/without fertilisers
4 C 2	Intermittently flooded	(c)	
4 C 3	Other	(c)	

(c) Low emissions are expected for European countries and deals mainly with continuously flooded process.

4 D AGRICULTURAL SOILS

	10 01 except 10 01 03	Cultures with fertilizers (except animal manure) (10 01 01, 10 01 02 and 10 01 04 to 10 01 06)
	10 02 except 10 02 03	Cultures without fertilizers (10 02 01, 10 02 02 and 10 02 04 to 10 02 06)

4 E PRESCRIBED BURNING OF SAVANNAS

	Not relevant for Europe	

4 F FIELD BURNING OF AGRICULTURAL WASTES

	10 03	On field burning of stubble, straw,...

4 G OTHER

	10 06	Use of pesticides

5 LAND USE CHANGE AND FORESTRY

5 A CHANGES IN FOREST AND OTHER WOODY BIOMASS STOCKS

	10 11	Land Use Change - Wood biomass stock change / annual growth (10.11.01 to 10.11.09)
	10 12	Land Use Change - Wood biomass stock change / annual harvest (10.12.01 to 10.12.03)

5 B FOREST AND GRASSLAND CONVERSION

	10 13	Land Use Change - Conversion / Burning aboveground biomass (10.13.01 to 10.13.10)
	10 14	Land Use Change - Conversion / Aboveground biomass decay (10.14.01 to 10.14.05)
	10 15	Land Use Change - Conversion / Soil carbon release (10.15.01 to 10.15.05)

5 C ABANDONMENT OF MANAGED LANDS

IPCC classification	CORINAIR / SNAP classification	
	10 16	Land Use Change - Managed land abandonment < 20 years / Aboveground biomass 10.16.01 to 10.16.05)
	10 17	Land Use Change - Managed land abandonment < 20 years / Soil carbon uptake (10.17.01 to 10.17.05)
	10 18	Land Use Change - Managed land abandonment > 20 years / Aboveground biomass 10.18.01 to 10.18.05)
	10 19	Land Use Change - Managed land abandonment > 20 years / Soil carbon uptake (10.19.01 to 10.19.05)

5 D OTHER

6 WASTE

6 A SOLID WASTE DISPOSAL ON LAND

6 A 1 Landfills	09 10 04	Land filling
6 A2 Open dumps		
6 A3 Other		

6 B WASTEWATER TREATMENT

6 B 1 Industrial Wastewater	09 10 01	Waste water treatment in industry
6 B 2 Domestic and Commercial Was	09 10 02	Waste water treatment in residential and commercial sectors
	09 10 07	Latrines
6 B 3 Other		

6 C WASTE INCINERATION

	09 02 01 and 09 02 02	Incineration of municipal/industrial wastes
	09 02 04	Flaring in chemical industry
	09 02 05	Incineration of sludges from wastewater
	09 02 07	Incineration of hospital wastes
	09 02 08	Incineration of waste oil
	09 07	Open burning of agricultural wastes (not on field)
	09 09	Cremation (09.09.01 to 09.09.02)
	09 10 08	Refused Derived Fuel production

6 D OTHER WASTE

	09 10 03	Sludge spreading
	09 10 05	Compost production from waste
	09 10 06	Biogas production

7 OTHER

	10 07	Managed deciduous forests (10.07.01 to 10.07.03)
	10 08	Managed coniferous forests

CORINAIR 1990 SUMMARY OF EMISSIONS

This section presents a summary of the emissions reported for each SNAP activity and the eight main pollutants in the Corinair 1990 Inventory.

The tables present :

- a main summary for the 28 countries presenting total emissions and percent contributions from the 11 main source groups for each pollutant, then
- on the left hand pages, the total emissions from 28 European countries per activity and pollutant and
- on the right hand pages, the percent contribution of each activity to the overall totals for each pollutant.

The 28 countries included are as follows :

Belgium	Denmark	Spain
Germany	Greece	France
Ireland	Italy	Luxembourg
Netherlands	Portugal	United Kingdom
Austria	Finland	Sweden
Norway	Switzerland	
Bulgaria	Czech Republic	Hungary
Poland	Romania	Slovakia
Estonia	Latvia	Lithuania
Slovenia		
Malta		

Croatia has also provided summary tables for Corinair 1990 but not a complete database. Hence Croatia has been included in some Corinair 90 summary tables and reports but is <u>not</u> included in the results tables presented here.

These tables are still being checked and verified but have been produced for inclusion in the first edition of the Guidebook for your information. If necessary, a revised/updated set of tables will be provided in future editions of the Guidebook. The results presented here have also been incorporated in the appropriate chapters of the Guidebook.

It should be noted that the results presented here are for activities as listed under SNAP90 codes. The Guidebook is presented on the basis of SNAP94 codes and some differences occur between SNAP90 and SNAP94 as summarised in the Content Pages.

CORINAIR 1990 SUMMARY

8/25/95

EUROPE (28 countries)	SO2	NOx as NO2	NMVOC	CH4	CO	CO2	N20	NH3
1 Public power, cogeneration and district heating	14947500	3758590	55023	42999	807111	1332194000	96939	1405
2 Commercial, institutional and residential combustion	3045695	753956	989439	618669	9946611	849641000	44921	2491
3 Industrial combustion	6967997	2438689	154014	92168	8200489	1140657000	53809	1357
4 Production processes	922703	391759	1220294	75893	3187774	179916000	355672	172331
5 Extraction and distribution of fossil fuels	45111	82174	1376403	10408375	62851	27048000	83	0
6 Solvent use	301	900	4920258	20	960	379000	0	107
7 Road transport	718230	7846112	6765744	200037	38919349	695497000	29886	13351
8 Other mobile sources and machinery	565032	2309640	676573	25287	2223182	138733000	6269	225
9 Waste treatment and disposal	86557	241094	506961	8752435	4426583	83173000	13366	127851
10 Agriculture	1402	49621	758756	14793437	579196	22450000	726021	5266873
11 Nature	573037	50013	4347357	10405808	1358327	294778000	552718	114992
TOTAL in tonnes	27873565	17922548	21770822	45415128	69712433	4764466000	1879684	5700983
TOTAL (excluding Nature), kg per head	56	37	36	72	140	9166	3	11

Percentages

EUROPE (28 countries)	SO2	NOx as NO2	NMVOC	CH4	CO	CO2	N2O	NH3
1 Public power, cogeneration and district heating	54	21	0	0	1	28	5	0
2 Commercial, institutional and residential combustion	11	4	5	1	14	18	2	0
3 Industrial combustion	25	14	1	0	12	24	3	0
4 Production processes	3	2	6	0	5	4	19	3
5 Extraction and distribution of fossil fuels	0	0	6	23	0	1	0	0
6 Solvent use	0	0	23	0	0	0	0	0
7 Road transport	3	44	31	0	56	15	2	0
8 Other mobile sources and machinery	2	13	3	0	3	3	0	0
9 Waste treatment and disposal	0	1	2	19	6	2	1	2
10 Agriculture	0	0	3	33	1	0	39	92
11 Nature	2	0	20	23	2	6	29	2

Status : all national tables except Switzerland final (contact EEA for update)

SNAP CODE	DESCRIPTION	SO2	NOX as NO2	NMVOC	CH4	CO	CO2	N20	NH3
GROUP 1	PUBLIC POWER, COGENERATION AND DISTRICT HEATING								
10100	PUBLIC POWER AND COGENERATION PLANTS								
10101	COMBUSTION PLANTS > = 300 MW	13691	3316	41	33	650	1160	84	1
10102	COMBUSTION PLANTS > = 50 AND < 300 M	385	161	2	2	25	58	5	
10103	COMBUSTION PLANTS < 50 MW	110	29	1	1	8	19	2	
10104	GAS TURBINES	8	38			11	10		
10105	STATIONARY ENGINES	25	28	1		6	1		
10200	DISTRICT HEATING PLANTS								
10201	COMBUSTION PLANTS > = 300 MW	129	46	1	1	6	19	2	
10202	COMBUSTION PLANTS > = 50 MW AND < 30	326	67	2	2	23	27	3	
10203	COMBUSTION PLANTS < 50 MW	272	69	5	4	80	36	2	
10204	GAS TURBINES		2			1	1		
10205	STATIONARY ENGINES		2						
GROUP 2	COMMERCIAL, INSTITUTIONAL & RESIDENTIAL COMBUSTION								
20001	COMBUSTION PLANTS > = 50 MW	163	44	15	3	20	19	2	1
20002	COMBUSTION PLANTS < 50 MW	2865	708	973	615	9916	829	43	1
20003	GAS TURBINES								
20004	STATIONARY ENGINES	18	2	1	1	11	2		
GROUP 3	INDUSTRIAL COMBUSTION								
30100	IND. COMBUS. IN BOILERS, GAS TURBINES &	19	23	3	1	6	8	1	
30101	PLANTS > = 300 MW	1782	431	5	5	214	179	11	
30102	PLANTS > = 50 MW AND < 300 MW	1236	274	9	7	586	180	6	
30103	PLANTS < 50 MW	2309	571	31	23	654	358	18	
30104	GAS TURBINES	1	35	1	3	13	14		
30105	STATIONARY ENGINES	14	31	3		10	5		
30200	PROCESS FURNACES WITHOUT CONTACT	12	4			1	1		
30201	REFINERY PROCESSES FURNACES	380	89	40	4	44	47	4	
30202	COKE OVEN FURNACES	130	53	5	3	155	50		
30203	BLAST FURNACES COWPERS	14	37	1	3	1136	62	1	
30204	PLASTER FURNACES	6	1			3	1	2	

Units = kilotonnes
except CO2 in megatonnes

SNAP CODE	DESCRIPTION	SO2	NOX as NO2	NMVOC	CH4	CO	CO2	N20	NH3
GROUP 1	PUBLIC POWER, COGENERATION AND DISTRICT HEATING								
10100	PUBLIC POWER AND COGENERATION PLAN								
10101	COMBUSTION PLANTS > = 300 MW	**49.1**	**18.5**	0.2	0.1	0.9	**24.3**	4.5	
10102	COMBUSTION PLANTS > = 50 AND < 300 M	1.4	0.9				1.2	0.3	
10103	COMBUSTION PLANTS < 50 MW	0.4	0.2				0.4	0.1	
10104	GAS TURBINES		0.2				0.2		
10105	STATIONARY ENGINES	0.1	0.2						
10200	DISTRICT HEATING PLANTS								
10201	COMBUSTION PLANTS > = 300 MW	0.5	0.3				0.4	0.1	
10202	COMBUSTION PLANTS > = 50 MW AND < 3	1.2	0.4				0.6	0.2	
10203	COMBUSTION PLANTS < 50 MW	1.0	0.4			0.1	0.8	0.1	
10204	GAS TURBINES								
10205	STATIONARY ENGINES								
GROUP 2	COMMERCIAL, INSTITUTIONAL & RESIDENTIAL COMBUSTION								
20001	COMBUSTION PLANTS > = 50 MW	0.6	0.2	0.1			0.4	0.1	
20002	COMBUSTION PLANTS < 50 MW	**10.2**	4.0	4.4	1.3	**14.0**	**17.6**	2.3	
20003	GAS TURBINES								
20004	STATIONARY ENGINES	0.1							
GROUP 3	INDUSTRIAL COMBUSTION								
30100	IND. COMBUS. IN BOILERS, GAS TURBINES &	0.1	0.1				0.2	0.1	
30101	PLANTS > = 300 MW	6.4	2.4			0.3	3.8	0.6	
30102	PLANTS > = 50 MW AND < 300 MW	4.4	1.5			0.8	3.8	0.3	
30103	PLANTS < 50 MW	8.3	3.2	0.1	0.1	0.9	7.5	1.0	
30104	GAS TURBINES		0.2				0.3		
30105	STATIONARY ENGINES	0.1	0.2				0.1		
30200	PROCESS FURNACES WITHOUT CONTACT								
30201	REFINERY PROCESSES FURNACES	1.4	0.5	0.2		0.1	1.0	0.2	
30202	COKE OVEN FURNACES	0.5	0.3			0.2	1.0		
30203	BLAST FURNACES COWPERS	0.1	0.2			1.6	1.3	0.1	
30204	PLASTER FURNACES							0.1	

Units = percent (%)

SNAP CODE	DESCRIPTION	SO2	NOX as NO2	NMVOC	CH4	CO	CO2	N20	NH3
30300	INDUSTRIAL COMBUSTION - PROCESSES WITH CONTACT								
30301	SINTER PLANT	356	177	19	30	3383	20		
30302	REHEATING FURNACES STEEL AND IRON	76	50	4	2	124	30	1	
30303	GRAY IRON FOUNDRIES	13	7	8	1	987	7		
30304	PRIMARY LEAD PRODUCTION	47	3			2	1		
30305	PRIMARY ZINK PRODUCTION	24				2			
30306	PRIMARY COPPER PRODUCTION	33	1			118	1		
30307	SECONDARY LEAD PRODUCTION	10							
30308	SECONDARY ZINK PRODUCTION					1			
30309	SECONDARY COPPER PRODUCTION	3		1		1			
30310	SECONDARY ALUMINIUM PRODUCTION	1	1	3					
30311	CEMENT	211	413	5	5	110	100	5	
30312	LIME	28	28	1	1	219	15		
30313	ASPHALT CONCRETE PLANTS	14	2	1		2	3		
30314	FLAT GLASS	28	59	1		2	6		
30315	CONTAINER GLASS	40	44	1		1	5		
30316	GLASS WOOL	1	2						
30317	OTHER GLASS	7	26			1	1		
30318	MINERAL WOOL	8	1			3	1		
30319	BRICKS AND TILES	81	49	5	3	225	27	1	
30320	FINE CERAMICS MATERIALS	52	14			182	13	1	
30321	PAPER MILL INDUSTRY (DRYING PROCES.)	18	8	5		17	3	1	
30322	ALUMINA PRODUCTION	12	2						
GROUP 4	INDUSTRIAL PROCESSES								
40100	PRODUCTION PROCESSES - PETROLIUM INDUSTRIES (introd			1		6			
40101	PETROLIUM PRODUCTS PROCESSING	130	26	150	9	10	10	1	
40102	FLUID CATALYTIC CRACKING - CO BOILER	115	23	4		28	4		
40103	SULPHUR RECOVERY PLANTS	89		1		2			
40104	STORAGE &HANDL. OF PRODUCTS IN REFINERY			93				1	
40200	PRODUCTION PROC. - IRON & STEEL INDUST	7	4	2		211			
40201	COKE OVEN	30	9	38	30	333	4		5
40202	BLAST FURNACE CHARGING	8	1	3	16	475	5		
40203	PIG IRON TAPPING	5	2		2	1			
40204	SOLID SMOKELESS FUEL			1	1				
40205	OPEN HEARTH FURNACE STEEL PLANT	9	10	1	1	3			
40206	BASIC OXYGEN FURNACE	48	7	1		1019	1		
40207	ELECTRIC FURNACE STEEL PLANT	2	13	4		435			
40208	ROLLING MILLS	3	3	8		2	1		
40300	PRODUCTION PROC. - NON FERROUS METAL	2				10			1
40301	ALUMINIUM PRODUCTION (electrolysis)	34	4	1		276	5		
40302	FERRO ALLOYS	22	6	2	1	246	4		
40303	SILICIUM PRODUCTION					1			
40304						26			
40400	PRODUCTION PROC. - INORGANIC CHEMICA	9	3			7		1	5
40401	SULFURIC ACID	201	7	1		13	1		
40402	NITRIC ACID		111	17		3		101	

Units = kilotonnes
except CO2 in megatonnes

SNAP CODE	DESCRIPTION	SO2	NOX as NO2	NMVOC	CH4	CO	CO2	N20	NH3
30300	INDUSTRIAL COMBUSTION - PROCESSES WITH CONTACT								
30301	SINTER PLANT	1.3	1.0	0.1	0.1	4.9	0.4		
30302	REHEATING FURNACES STEEL AND IRON	0.3	0.3			0.2	0.6	0.1	
30303	GRAY IRON FOUNDRIES					1.4	0.1		
30304	PRIMARY LEAD PRODUCTION	0.2							
30305	PRIMARY ZINK PRODUCTION	0.1							
30306	PRIMARY COPPER PRODUCTION	0.1				0.2			
30307	SECONDARY LEAD PRODUCTION								
30308	SECONDARY ZINK PRODUCTION								
30309	SECONDARY COPPER PRODUCTION								
30310	SECONDARY ALUMINIUM PRODUCTION								
30311	CEMENT	0.8	2.3			0.2	2.1	0.3	
30312	LIME	0.1	0.2			0.3	0.3		
30313	ASPHALT CONCRETE PLANTS	0.1					0.1		
30314	FLAT GLASS	0.1	0.3				0.1		
30315	CONTAINER GLASS	0.1	0.2				0.1		
30316	GLASS WOOL								
30317	OTHER GLASS		0.1						
30318	MINERAL WOOL								
30319	BRICKS AND TILES	0.3	0.3			0.3	0.6	0.1	
30320	FINE CERAMICS MATERIALS	0.2	0.1			0.3	0.3	0.1	
30321	PAPER MILL INDUSTRY (DRYING PROCES.)	0.1					0.1	0.1	
30322	ALUMINA PRODUCTION								
GROUP 4	INDUSTRIAL PROCESSES								
40100	PRODUCTION PROCESSES - PETROLIUM IND								
40101	PETROLIUM PRODUCTS PROCESSING	0.5	0.1	0.7			0.2	0.1	
40102	FLUID CATALYTIC CRACKING - CO BOILER	0.4	0.1				0.1		
40103	SULPHUR RECOVERY PLANTS	0.3							
40104	STORAGE &HANDL. OF PRODUCTS IN REFIN			0.4				0.1	
40200	PRODUCTION PROC. - IRON & STEEL INDUST					0.3			
40201	COKE OVEN	0.1	0.1	0.2	0.1	0.5	0.1		0.1
40202	BLAST FURNACE CHARGING					0.7	0.1		
40203	PIG IRON TAPPING								
40204	SOLID SMOKELESS FUEL								
40205	OPEN HEARTH FURNACE STEEL PLANT		0.1						
40206	BASIC OXYGEN FURNACE	0.2				1.5			
40207	ELECTRIC FURNACE STEEL PLANT		0.1			0.6			
40208	ROLLING MILLS								
40300	PRODUCTION PROC. - NON FERROUS METAL								
40301	ALUMINIUM PRODUCTION (electrolysis)	0.1				0.4	0.1		
40302	FERRO ALLOYS	0.1				0.4	0.1		
40303	SILICIUM PRODUCTION								
40304									
40400	PRODUCTION PROC. - INORGANIC CHEMICA							0.1	0.1
40401	SULFURIC ACID	0.7							
40402	NITRIC ACID		0.6	0.1				5.4	0.1

Units = percent (%)

SNAP CODE	DESCRIPTION	SO2	NOX as NO2	NMVOC	CH4	CO	CO2	N20	NH3
40403	AMMONIA	1	28	19	1	7	16	18	30
40404	AMMONIUM SULPHATE	3	1	1		1			8
40405	AMMONIUM NITRATE		5						13
40406	AMMONIUM PHOSPHATE								3
40407	NPK FERTILISERS	26	48	38					65
40408	UREA					1			29
40409	CARBON BLACK	13			6	4			
40410	TITANIUM DIOXIDE	11		41					
40411	GRAPHITE	1							
40412	CALCIUM CARBIDE PRODUCTION	1					2		
40500	PRODUCTION PROC. - ORGANIC CHEMICAL INDUSTRY			14		5			
40501	ETHYLENE	1	6	60	4	8	6	2	
40502	PROPYLENE			41					
40503	1,2 DICHOROETHANE (ecxept 040505)			8					
40504	VINYLCHLORIDE (ecxept 040505)			10		1			
40505	1,2 DICHLOROETH. + VINYLCHL.(balanced proc)			5					
40506	POLYETHYLENE LOW DENSITY			34					
40507	POLYETHELENE HIGH DENSITY			20					
40508	POLYVINYLCHLORIDE			12					
40509	POLYPROPYLENE			25					
40510	STYRENE			1					
40511	POLYSTYRENE			4					
40512	STYRENE BUTADIENE			36					
40513	STYRENE-BUTADIENE LATEX			2					
40514	STYRENE-BUTADIENE RUBBER (SBR)			5					
40515	ACRYLONIT. BUTADIENE STYRENE (ABS) RESINS			7					
40516	ETHYLENE OXYDE			5					
40517	FORMALDEHYDE			11		6			
40518	ETHYLBENZENE			2					
40519	PHTALIC ANHYDRIDE	1		18		21			
40520	ACRYLONITRILE			3					
40521	ADIPIC ACID		1					233	
40522	STORAGE & HANDLING OF CHEMICAL PRODUCTS			78					
40600	PRODUCTION PROC. - WOOD,PAPER PULP,FO	2	2	4		1			
40601	CHIPBOARD	5	7	27	2	6	1		
40602	PAPER PULP (kraft process)	27	11	32		5			
40603	PAPER PULP (acid sulfite process)	52	2	17					
40604	PAPER PULP (neutral sulphite semi-chimi.)	14							
40605	BREAD			157			2		
40606	WINE			10			18		
40607	BEER			55					
40608	SPIRITS			56					
40609	BARK GASIFIERB								
40610	ASPHALT ROOFING MATERIALS	1		11		5			
40611	ROAD PAVING WITH ASPHALT			23					
40612	CEMENT	31	34			5	82		
40613	LIME	18	13				4		
40614	GLASS	3	1	1		4	11		
40700	PRODUCTION PROC. - COOLING PLANTS								

Units = kilotonnes
except CO2 in megatonnes

SNAP CODE	DESCRIPTION	SO2	NOX as NO2	NMVOC	CH4	CO	CO2	N20	NH3
40403	AMMONIA		0.2	0.1			0.3	1.0	0.5
40404	AMMONIUM SULPHATE								0.1
40405	AMMONIUM NITRATE								0.2
40406	AMMONIUM PHOSPHATE								0.1
40407	NPK FERTILISERS	0.1	0.3	0.2					1.1
40408	UREA								0.5
40409	CARBON BLACK								
40410	TITANIUM DIOXIDE			0.2					
40411	GRAPHITE								
40412	CALCIUM CARBIDE PRODUCTION								
40500	PRODUCTION PROC. - ORGANIC CHEMICAL I			0.1					
40501	ETHYLENE			0.3			0.1	0.1	
40502	PROPYLENE			0.2					
40503	1,2 DICHOROETHANE (ecxept 040505)								
40504	VINYLCHLORIDE (ecxept 040505)								
40505	1,2 DICHLOROETH. + VINYLCHL.(balanced pr								
40506	POLYETHYLENE LOW DENSITY			0.2					
40507	POLYETHELENE HIGH DENSITY			0.1					
40508	POLYVINYLCHLORIDE			0.1					
40509	POLYPROPYLENE			0.1					
40510	STYRENE								
40511	POLYSTYRENE								
40512	STYRENE BUTADIENE			0.2					
40513	STYRENE-BUTADIENE LATEX								
40514	STYRENE-BUTADIENE RUBBER (SBR)								
40515	ACRYLONIT. BUTADIENE STYRENE (ABS) RE								
40516	ETHYLENE OXYDE								
40517	FORMALDEHYDE			0.1					
40518	ETHYLBENZENE								
40519	PHTALIC ANHYDRIDE			0.1					
40520	ACRYLONITRILE								
40521	ADIPIC ACID							12.4	
40522	STORAGE & HANDLING OF CHEMICAL PROD			0.4					
40600	PRODUCTION PROC. - WOOD,PAPER PULP,F								
40601	CHIPBOARD			0.1					
40602	PAPER PULP (kraft process)	0.1	0.1	0.1					
40603	PAPER PULP (acid sulfite process)	0.2		0.1					
40604	PAPER PULP (neutral sulphite semi-chimi.)	0.1							
40605	BREAD			0.7					
40606	WINE						0.4		
40607	BEER			0.3					
40608	SPIRITS			0.3					
40609	BARK GASIFIERB								
40610	ASPHALT ROOFING MATERIALS			0.1					
40611	ROAD PAVING WITH ASPHALT			0.1					
40612	CEMENT	0.1	0.2				1.7		
40613	LIME	0.1	0.1				0.1		
40614	GLASS						0.2		
40700	PRODUCTION PROC. - COOLING PLANTS								0.1

Units = percent (%)

SNAP CODE	DESCRIPTION	SO2	NOX as NO2	NMVOC	CH4	CO	CO2	N20	NH3
GROUP 5	EXTRACTION & DISTRIBUTION OF FOSSIL FUELS								
50100	EXTRACTION AND 1ST TREATMENT OF SOLID FUELS			3					
50101	OPEN CAST MINING		1		2396				
50102	UNDERGROUNG MINING				4546				
50103	STORAGE				563	33			
50200	EXTRACTION, 1ST TREATMENT AND LOADING OF LIQUID FUELS				30				
50201	LAND-BASED			2	3				
50202	OFF-SHORE		51	346	100	1	6		
50300	EXTRACT., 1ST TREATMENT AND LOADING OF GASEOUS F			12	10				
50301	DESULFURA.	44	1						
50302	OTHER LAND-BASED	1	13	119	28	1	18		
50303	OFF-SHORE		4	5	33	1	1		
50400	LIQUID FUEL DISTRIBUTION (except gasoline)			2					
50401	MARINE TERMINALS (tankers, handl., stor.)			137	1				
50402	OTHER HANDLING AND STORAGE			32					
50500	GASOLINE DISTRIBUTION			6					
50501	REFINERY DESPATCH STATION			41					
50502	TRANSP. AND DEPOTS (exc. serv. station)			154					
50503	SERVICE STATIONS			396					
50600	GAS DISTRIBUTION NETWORKS			29	361				
50601	PIPELINES			2	128				
50602	PIPELINE COMPRESSOR STATIONS		12	7	125	3	2		
50603	DISTRIBUTION NETWORKS			83	2084	23			

Units = kilotonnes
except CO2 in megatonnes

SNAP CODE	DESCRIPTION	SO2	NOX as NO2	NMVOC	CH4	CO	CO2	N20	NH3
GROUP 5	EXTRACTION & DISTRIBUTION OF FOSSIL FUELS								
50100	EXTRACTION AND 1ST TREATMENT OF SOLI								
50101	OPEN CAST MINING				5.3				
50102	UNDERGROUNG MINING				**10.0**				
50103	STORAGE				1.2				
50200	EXTRACTION, 1ST TREATMENT AND LOADI				0.1				
50201	LAND-BASED								
50202	OFF-SHORE		0.3	1.6	0.2		0.1		
50300	EXTRACT., 1ST TREATMENT AND LOADING			0.1					
50301	DESULFURA.	0.2							
50302	OTHER LAND-BASED		0.1	0.5	0.1		0.4		
50303	OFF-SHORE				0.1				
50400	LIQUID FUEL DISTRIBUTION (except gasoline)								
50401	MARINE TERMINALS (tankers, handl., stor.)			0.6					
50402	OTHER HANDLING AND STORAGE			0.1					
50500	GASOLINE DISTRIBUTION								
50501	REFINERY DESPATCH STATION			0.2					
50502	TRANSP. AND DEPOTS (exc. serv. station)			0.7					
50503	SERVICE STATIONS			1.8					
50600	GAS DISTRIBUTION NETWORKS			0.1	0.8				
50601	PIPELINES				0.3				
50602	PIPELINE COMPRESSOR STATIONS		0.1		0.3				
50603	DISTRIBUTION NETWORKS			0.4	4.6				

Units = percent (%)

SNAP CODE	DESCRIPTION	SO2	NOX as NO2	NMVOC	CH4	CO	CO2	N20	NH3
GROUP 6	SOLVENT USE								
60000	SOLVENT USE (introduction)								
60100	SOLVENT USE - PAINT APPLICATION			510					
60101	MANUFACTURE OF AUTOMOBILES			131		1			
60102	OTHER INDUS. APPLICATION			719					
60103	CONSTRUCTION AND BUILDINGS			365					
60104	DOMESTIC USE			199					
60200	SOLVENT USE - DEGREASING AND DRY CLEANING								
60201	METAL DEGREASING			400					
60202	DRY CLEANING			125					
60300	SOLVENT USE - CHEMICALS PRODUCTS MANUFACTORING			138					
60301	POLYESTER PROCESSING			10					
60302	POLYVINYLCHLORIDE PROCESSING			76					
60303	POLYURETHANE PROCESSING			18					
60304	POLYSTYRENE FOAM PROCESS.			24					
60305	RUBBER PROCESSING			79					
60306	PHARMACEUTICAL PROD. MANU.			116					
60307	PAINTS MANUFACTURING			75					
60308	INKS MANUFACTURING			4					
60309	GLUES MANUFACTURING			80					
60310	ASPHALT BLOWING			29					
60311	ADHESIVE TAPES MANUFACT.			24					
60400	SOLVENT USE - OTHER USE OF SOLVENTS AND RELATED			457					
60401	GLASS WOOL ENDUCTION			86					
60402	MINIRAL WOOL ENDUCTION			1					
60403	PRINTING INDUSTRY			278					
60404	FAT EDIBLE AND NOT EDIBLE OIL EXTRACTION			88					
60405	APPLICATION OF GLUES AND ADHESIVES			186					
60406	PRESERVATION OF WOOD			136					
60407	UNDERSEAL TREATMENT OF VEHICLES			31					
60408	DOMISTIC SOLVENT USE (other than paint appl.)			492					
60409	VEHICLES DEWAXING			43					

Units = kilotonnes
except CO2 in megatonnes

SNAP CODE	DESCRIPTION	SO2	NOX as NO2	NMVOC	CH4	CO	CO2	N20	NH3
GROUP 6	SOLVENT USE								
60000	SOLVENT USE (introduction)								
60100	SOLVENT USE - PAINT APPLICATION			2.3					
60101	MANUFACTURE OF AUTOMOBILES			0.6					
60102	OTHER INDUS. APPLICATION			3.3					
60103	CONSTRUCTION AND BUILDINGS			1.7					
60104	DOMESTIC USE			0.9					
60200	SOLVENT USE - DEGREASING AND DRY CLE								
60201	METAL DEGREASING			1.8					
60202	DRY CLEANING			0.6					
60300	SOLVENT USE - CHEMICALS PRODUCTS MA			0.6					
60301	POLYESTER PROCESSING								
60302	POLYVINYLCHLORIDE PROCESSING			0.3					
60303	POLYURETHANE PROCESSING			0.1					
60304	POLYSTYRENE FOAM PROCESS.			0.1					
60305	RUBBER PROCESSING			0.4					
60306	PHARMACEUTICAL PROD. MANU.			0.5					
60307	PAINTS MANUFACTURING			0.3					
60308	INKS MANUFACTURING								
60309	GLUES MANUFACTURING			0.4					
60310	ASPHALT BLOWING			0.1					
60311	ADHESIVE TAPES MANUFACT.			0.1					
60400	SOLVENT USE - OTHER USE OF SOLVENTS A			2.1					
60401	GLASS WOOL ENDUCTION			0.4					
60402	MINIRAL WOOL ENDUCTION								
60403	PRINTING INDUSTRY			1.3					
60404	FAT EDIBLE AND NOT EDIBLE OIL EXTRACT			0.4					
60405	APPLICATION OF GLUES AND ADHESIVES			0.9					
60406	PRESERVATION OF WOOD			0.6					
60407	UNDERSEAL TREATMENT OF VEHICLES			0.1					
60408	DOMISTIC SOLVENT USE (other than paint appl.			2.3					
60409	VEHICLES DEWAXING			0.2					

Units = percent (%)

SNAP CODE	DESCRIPTION	SO2	NOX as NO2	NMVOC	CH4	CO	CO2	N20	NH3
GROUP 7	ROAD TRANSPORT								
70100	ROAD TRANSPORT - PASSENGER CARS	2	161	138	12	1182	17		
70101	HIGHWAY DRIVING	36	1007	340	22	3536	71	4	3
70102	RURAL DRIVING	93	1704	1014	38	8187	135	7	5
70103	URBAN DRIVING	115	1198	1965	78	18521	180	6	4
70200	ROAD TRANSPORT - LIGHT DUTY VEHICLES < 3.5 t		14	12	1	71	1		
70201	HIGHWAY DRIVING	11	93	35	1	231	9	1	
70202	RURAL DRIVING	31	204	108	3	914	22	1	
70203	URBAN DRIVING	57	240	228	7	2111	42	1	
70300	ROAD TRANSPORT - HEAVY DUTY VEHICLES	7	166	22	2	53	9	1	
70301	HIGHWAY DRIVING	91	1006	169	6	480	62	3	
70302	RURAL DRIVING	174	1360	229	7	1085	86	3	
70303	URBAN DRIVING	96	678	245	6	1028	49	2	
70400	ROAD TRANSPORT - MOPEDS AND MOTERCY	2	3	318	6	492	3		
70500	ROAD TRANSPORT - MOTERCYCLES > 50 CM3			7		19			
70501	HIGHWAY DRIVING		2	55	2	138	1		
70502	RURAL DRIVING	2	6	158	6	377	3		
70503	URBAN DRIVING	2	6	163	5	494	3		
70600	ROAD TRANSPORT - GASOLINE EVAPORATION FROM VEHI			1550					
GROUP 8	OTHER MOBILSE SOURCES AND MACHINERY								
80100	OTHER MOB. SOURCES - OFF ROAD VEHICLE	7	100	23	2	72	6		
80101	AGRICULTURE	115	733	210	7	1000	46	1	
80102	FORESTRY	1	13	13	1	33	1		
80103	INDUSTRY	27	258	73	2	131	16	2	
80104	MILITARY	3	41	19	1	101	3		
80105	HOUSEHOLS / GARDENING		3	79	1	351	1		
80200	OTHER MOB. SOURCESS -RAILWAYS	40	199	33	1	83	14		
80300	OTHER MOB. SOURCES - INLAND WATERWA	12	71	29		33	5		
80400	OTHER MOB. SOURCES - MARINE ACTIVITIES	5	21	14	2	40	1		
80401	HARBOURS	59	82	10	1	19	5		
80402	NATIONAL SEA TRAFFIC	249	468	94	3	166	15	1	
80403	NATIONAL FISHING	25	143	7	1	17	8		
80500	OTHER MOB. SOURCES - AIRPORTS (LTO cycle	20	179	71	4	174	18	1	

Units = kilotonnes
except CO2 in megatonnes

SNAP CODE	DESCRIPTION	SO2	NOX as NO2	NMVOC	CH4	CO	CO2	N20	NH3
GROUP 7	ROAD TRANSPORT								
70100	ROAD TRANSPORT - PASSENGER CARS		0.9	0.6		1.7	0.4		
70101	HIGHWAY DRIVING	0.1	5.6	1.6		5.1	1.5	0.2	0.1
70102	RURAL DRIVING	0.3	9.5	4.7	0.1	**11.7**	2.8	0.4	0.1
70103	URBAN DRIVING	0.4	6.7	9.0	0.2	**26.6**	3.8	0.3	0.1
70200	ROAD TRANSPORT - LIGHT DUTY VEHICLES		0.1	0.1		0.1			
70201	HIGHWAY DRIVING		0.5	0.2		0.3	0.2	0.1	
70202	RURAL DRIVING	0.1	1.1	0.5		1.3	0.5	0.1	
70203	URBAN DRIVING	0.2	1.3	1.0		3.0	0.9	0.1	
70300	ROAD TRANSPORT - HEAVY DUTY VEHICLE		0.9	0.1		0.1	0.2	0.1	
70301	HIGHWAY DRIVING	0.3	5.6	0.8		0.7	1.3	0.2	
70302	RURAL DRIVING	0.6	7.6	1.1		1.6	1.8	0.2	
70303	URBAN DRIVING	0.3	3.8	1.1		1.5	1.0	0.1	
70400	ROAD TRANSPORT - MOPEDS AND MOTERC			1.5		0.7	0.1		
70500	ROAD TRANSPORT - MOTERCYCLES > 50 C								
70501	HIGHWAY DRIVING			0.3		0.2			
70502	RURAL DRIVING			0.7		0.5	0.1		
70503	URBAN DRIVING			0.7		0.7	0.1		
70600	ROAD TRANSPORT - GASOLINE EVAPORATI			7.1					
GROUP 8	OTHER MOBILSE SOURCES AND MACHINER								
80100	OTHER MOB. SOURCES - OFF ROAD VEHICL		0.6	0.1		0.1	0.1		
80101	AGRICULTURE	0.4	4.1	1.0		1.4	1.0	0.1	
80102	FORESTRY		0.1	0.1					
80103	INDUSTRY	0.1	1.4	0.3		0.2	0.3	0.1	
80104	MILITARY		0.2	0.1		0.1	0.1		
80105	HOUSEHOLS / GARDENING			0.4		0.5			
80200	OTHER MOB. SOURCESS -RAILWAYS	0.1	1.1	0.2		0.1	0.3		
80300	OTHER MOB. SOURCES - INLAND WATERWA		0.4	0.1			0.1		
80400	OTHER MOB. SOURCES - MARINE ACTIVITIE		0.1	0.1		0.1			
80401	HARBOURS	0.2	0.5				0.1		
80402	NATIONAL SEA TRAFFIC	0.9	2.6	0.4		0.2	0.3	0.1	
80403	NATIONAL FISHING	0.1	0.8				0.2		
80500	OTHER MOB. SOURCES - AIRPORTS (LTO cycl	0.1	1.0	0.3		0.2	0.4	0.1	

Units = percent (%)

SNAP CODE	DESCRIPTION	SO2	NOX as NO2	NMVOC	CH4	CO	CO2	N20	NH3
GROUP 9	WASTE TREATMENT AND DISPOSAL ACTIVITIES								
90100	WASTE WATER TREATMENT	2	1	32	211			8	10
90200	WASTE INCINERATION		1						
90201	INCINERATION OF DOMISTIC/MUNICIPAL W	29	43	4	9	114	17		
90202	INCINERATION OF INDUSTRIAL WASTES	14	4	5	1	14	2		
90203	FLARING IN OIL INDUSTRY	35	10	1		3	2		
90204	FLARING IN CHEMICAL INDUSTRIES	1				14	1		
90205	INCINERATION OF SLUDGES FROM WATER T	1	1			1			
90206 (new)	FLARING IN OIL AND GAS PRODUCTION								
90300	SLUDGE SPREADING			16	155				7
90400	LANDFILES	5	29	45	7932	267	19		
90500	COMPOST PRODUCTION FROM WASTE				27		27		
90600	BIOGAS PRODUCTION				40				
90700	OPEN BURNING OF AGRICULTURAL WASTES (except		153	401	358	4014	15	5	
90800	LATRINES				18				37

Units = kilotonnes
except CO2 in megatonnes

SNAP CODE	DESCRIPTION	SO2	NOX as NO2	NMVOC	CH4	CO	CO2	N20	NH3
GROUP 9	WASTE TREATMENT AND DISPOSAL ACTIVI								
90100	WASTE WATER TREATMENT			0.1	0.5			0.4	0.2
90200	WASTE INCINERATION								
90201	INCINERATION OF DOMISTIC/MUNICIPAL W	0.1	0.2			0.2	0.4		
90202	INCINERATION OF INDUSTRIAL WASTES	0.1							
90203	FLARING IN OIL INDUSTRY	0.1	0.1						
90204	FLARING IN CHEMICAL INDUSTRIES								
90205	INCINERATION OF SLUDGES FROM WATER								
90206 (new)	FLARING IN OIL AND GAS PRODUCTION								
90300	SLUDGE SPREADING			0.1	0.3				0.1
90400	LANDFILLS		0.2	0.2	**17.5**	0.4	0.4		1.3
90500	COMPOST PRODUCTION FROM WASTE				0.1		0.6		
90600	BIOGAS PRODUCTION				0.1				
90700	OPEN BURNING OF AGRICULTURAL WASTES		0.9	1.8	0.8	5.8	0.3	0.3	
90800	LATRINES								0.6

Units = percent (%)

SNAP CODE	DESCRIPTION	SO2	NOX as NO2	NMVOC	CH4	CO	CO2	N20	NH3
GROUP 10	AGRICULTURE ACTIVITIES								
100100	CULTURES WITH FERTILIZERS (except animal manure)			46	468			179	226
100101	PERMANENT CROPS	1	16	50	38	7	1	42	59
100102	ARABLE LAND CROPS			61	244			322	693
100103	RICE FIELD			3	47			1	7
100104	MARKET GARDENING		7	6	24	1	6	8	54
100105	GRASSLAND		4	101	195			84	56
100106	FALLOWS				1			1	
100200	CULTURES WITHOUT FERTILIZERS								
100201	PERMANENT CROPS			24	15			9	
100202	ARABLE LAND CROPS			10	10			17	
100203	RICE FIELD				84			1	
100204	MARKET GARDENING			1	1			1	
100205	GRASSLAND			42	16			33	3
100206	FALLOWS				8			13	
100300	STUBBLE BURNING		21	34	35	571	4		
100400	ANIMAL BREEDING (enteric fermentation)								
100401	DAIRY COWS				3895				12
100402	OTHER CATTLE				4149				11
100403	OVINES				975				6
100404	PIGS				215				
100405	HORSES				80				
100406	ASSES				5				
100407	GOATS				66				1
100500	ANIMAL BREEDING (excretions)				150				21
100501	DAIRY COWS			31	850		2	4	1430
100502	OTHER CATTLE			12	1092		2	7	[illegible]
100503	FATTENING PIGS			289	1353		1	3	[illegible]
100504	SOWS			26	259		4		195
100505	SHEEP			3	216		2	1	316
100506	HORSES			2	80				56
100507	LAYING HENS			5	115				140
100508	BOILERS			9	70				101
100509	OTHER POULTRY			3	33				36
100510	FUR ANIMALS				2				10

Units = kilotonnes
except CO2 in megatonnes

SNAP CODE	DESCRIPTION	SO2	NOX as NO2	NMVOC	CH4	CO	CO2	N20	NH3
GROUP 10	AGRICULTURE ACTIVITIES								
100100	CULTURES WITH FERTILIZERS (except animal			0.2	1.0			9.5	4.0
100101	PERMANENT CROPS		0.1	0.2	0.1			2.2	1.0
100102	ARABLE LAND CROPS			0.3	0.5			**17.1**	**12.2**
100103	RICE FIELD				0.1			0.1	0.1
100104	MARKET GARDENING				0.1		0.1	0.4	0.9
100105	GRASSLAND			0.5	0.4			4.5	1.0
100106	FALLOWS							0.1	
100200	CULTURES WITHOUT FERTILIZERS								
100201	PERMANENT CROPS			0.1				0.5	
100202	ARABLE LAND CROPS							0.9	
100203	RICE FIELD				0.2			0.1	
100204	MARKET GARDENING							0.1	
100205	GRASSLAND			0.2				1.8	0.1
100206	FALLOWS							0.7	
100300	STUBBLE BURNING		0.1	0.2	0.1	0.8	0.1		
100400	ANIMAL BREEDING (enteric fermentation)								
100401	DAIRY COWS				8.6				0.2
100402	OTHER CATTLE				9.1				0.2
100403	OVINES				2.1				0.1
100404	PIGS				0.5				
100405	HORSES				0.2				
100406	ASSES								
100407	GOATS				0.1				
100500	ANIMAL BREEDING (excretions)				0.3				0.4
100501	DAIRY COWS			0.1	1.9			0.2	**25.1**
100502	OTHER CATTLE			0.1	2.4			0.4	**21.5**
100503	FATTENING PIGS			1.3	3.0			0.2	**10.6**
100504	SOWS			0.1	0.6		0.1		3.4
100505	SHEEP				0.5			0.1	5.5
100506	HORSES				0.2				1.0
100507	LAYING HENS				0.3				2.5
100508	BOILERS				0.2				1.8
100509	OTHER POULTRY				0.1				0.6
100510	FUR ANIMALS								0.2

Units = percent (%)

SNAP CODE	DESCRIPTION	SO2	NOX as NO2	NMVOC	CH4	CO	CO2	N20	NH3
GROUP 11	NATURE								
110100	NATURE - DECIDUOUS FORESTS		15	188	83	23		19	19
110101	HIGH ISOPRENE EMITTERS			910	354			39	
110102	LOW ISOPRENE EMITTERS			91	10	1		1	
110103	NON ISOPRENE EMITTERS			578	257			24	
110200	NATURE - CONIFEROUS FORESTS			2342	1259	2		184	27
110300	NATURE - FOREST FIRES	3	35	105	83	1332	56	1	
110400	NATURE - NATURAL GRASSLAND			135	192			54	19
110500	NATURE - HUMID ZONES				68			1	
110501	UNDRAINED AND BRACKISH MARSHES				2444			16	
110502	DRAINED MARSHES				25			3	
110503	RAISED BOGS				238			1	
110600	NATURE - WATERS				10			7	
110601	LAKES				4716			15	
110602	SHALLOW SALTWATERS				363			13	
110603	GROUND WATERS				6				
110604	DRAINAGE WATERS				1			3	
110605	RIVERS				32			1	
110606	DITCHES AND CANALS				33			2	
110607	OPEN SEA (> 6m)				3			167	
110700	NATURE - ANIMALS								
110701	TERMITTES								
110702	MAMMALS				99		171		19
110800	NATURE - VOLCANOS	570							
110900	NATURE - NEAR SURFACE DEPOSITS				120				
111000	NATURE - HUMANS				8		68		30
	TOTAL	27873	17923	21770	45415	69712	4764	1880	5701

Units = kilotonnes
except CO2 in megatonnes

SNAP CODE	DESCRIPTION	SO2	NOX as NO2	NMVOC	CH4	CO	CO2	N20	NH3
GROUP 11	NATURE								
110100	NATURE - DECIDUOUS FORESTS		0.1	0.9	0.2			1.0	0.3
110101	HIGH ISOPRENE EMITTERS			4.2	0.8			2.1	
110102	LOW ISOPRENE EMITTERS			0.4				0.1	
110103	NON ISOPRENE EMITTERS			2.7	0.6			1.3	
110200	NATURE - CONIFEROUS FORESTS			**10.8**	2.8			9.8	0.5
110300	NATURE - FOREST FIRES		0.2	0.5	0.2	1.9	1.2	0.1	
110400	NATURE - NATURAL GRASSLAND			0.6	0.4			2.9	0.3
110500	NATURE - HUMID ZONES				0.1			0.1	
110501	UNDRAINED AND BRACKISH MARSHES				5.4			0.9	
110502	DRAINED MARSHES				0.1			0.2	
110503	RAISED BOGS				0.5			0.1	
110600	NATURE - WATERS							0.4	
110601	LAKES				**10.4**			0.8	
110602	SHALLOW SALTWATERS				0.8			0.7	
110603	GROUND WATERS								
110604	DRAINAGE WATERS							0.2	
110605	RIVERS				0.1			0.1	
110606	DITCHES AND CANALS				0.1			0.1	
110607	OPEN SEA (> 6m)							8.9	
110700	NATURE - ANIMALS								
110701	TERMITTES								
110702	MAMMALS				0.2		3.6		0.3
110800	NATURE - VOLCANOS	2.0							
110900	NATURE - NEAR SURFACE DEPOSITS				0.3				
111000	NATURE - HUMANS						1.4		0.5

Units = percent (%)

EMISSION PROJECTIONS:
SIMILARITIES AND DIFFERENCES IN METHODS

INTRODUCTION

In most countries the history of emission projections is very short. Experience is in the phase of development and too limited to make general evaluations. For this reason it is considered rather premature to present guidelines for emissions projections. Although this chapter is part of a guidebook it mainly shows the similarities as well as the differences in emissions projections in practice. Especially the similarities may lead to improvement of the relation between emission inventories and projections, being a base for emission assessment or calculation in general. It can also be important as a guide for validation, for which an explicit presentation of the differences, mainly the result of specific assumptions, are essential.

EMISSION PROJECTIONS

The difficult and the easy way to make them

There seem to be many different methods to design emission projections. The word 'seems' is chosen here, because in many cases the differences are the assumptions made. In fact it can be stated that:

there are no different methods for emission projections, but there are differences in assumptions and simplifications.

A complete detailed procedure includes many steps. This suggests a quite difficult task. However, many steps can be realized in a simple manner by using rather straight-forward assumptions. The acceptability of these simplifications depends on the application of the results.

The work on emission projections in practice shows many variations of complex and simple methods. Simple methods seem to exclude many of the steps mentioned. However, this is not the case. The assumptions for certain steps sometimes are so simple, that one is almost unaware of them. Awareness of the simplifications is important.
Furthermore it should be realized:

An (emission) projection is not an (emission) prediction

Emission is put between brackets, because a consistent outlook for possible developments of emissions is based on possible economic developments (scenarios). It implies that there is not one projection for a certain country, which is the best. It should be noted that emission projections are mainly meant to inform policy makers. Any decision they take might change the situation. So maybe it can be stated: The aim of emission projections is to help make the future in a different way.

In this respect an overview of emission goals (policy goals) for a future year is not an emission projection.

A GENERAL FORMULA TO START WITH

In emission inventories as well as projections the processes (or economic or human activities) represent the level of the calculations. Examples are 'steel production', 'transport by trucks', 'milk production by cows', 'application of paint' or 'waste incineration', but several levels of aggregations are possible in practice. In many cases for inventories, but in all cases for projections, emission factors are used to calculate the emissions. The basic (and widely used) formula is:

$$E = EEV x EF$$
$$with$$
$$E: emission$$
$$EEV: emission\ explaining\ variable$$
$$EF: emission\ factor \qquad 1$$

The EEV can be regarded as a process level or activity level, like the production of steel or the number of cows. In this formula a technical relation is supposed to exist between EEV and E. So, if the EEV increases with 20% also E increases with 20%. On the level of individual plants this relation it not always valid, but for calculations on a national level it is accurate enough.

So all activities are focused on the EEV and EF for a certain year (in the past for inventories and in the future for projections). Still we have to make the projections, based on the facts we know. The EEV in general is the result of economic scenarios, the EF is a technical parameter. Both can be influenced by environmental policy as is shown in figure 1.
However, in theory the following formula, also presented in figure 2, is more appropriate for the emission of one source category:

$$E = EEVx \sum_{i=1}^{n} (EF_i \, x \, P_i)$$
$$with$$
$$EF_i: emission\ factor\ for\ technology\ i$$
$$P_i: penetration\ of\ technology\ i \qquad 2$$

P_i is the penetration (as a fraction of the total of the EEV) of technology i. This implies SPi = 1.

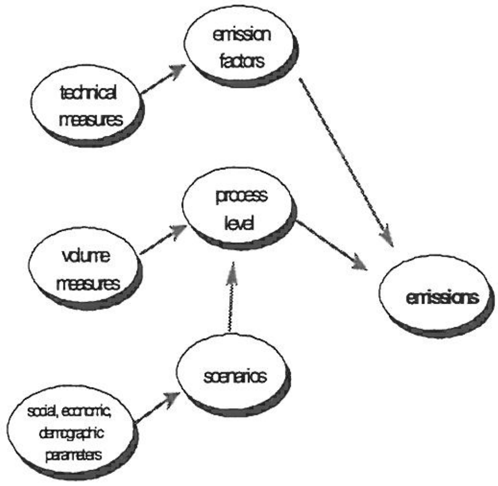


Figure 1 From economic scenarios and environmental policy to emission projections

It could be stated the EEV is the economic factor, the EF is the technical factor and the P represents the behavioural factor of the sectors running the processes, in fact the behaviour of people, of course within technical and economical boundaries.
This formula represents the base for all emission projections. But many simplifications, based on assumptions, are applied in practice. In the next sections these assumptions are discussed. The formula can be used for the calculation of energy demand, waste production and water consumption as well, which are the EEV for emission projections as well.

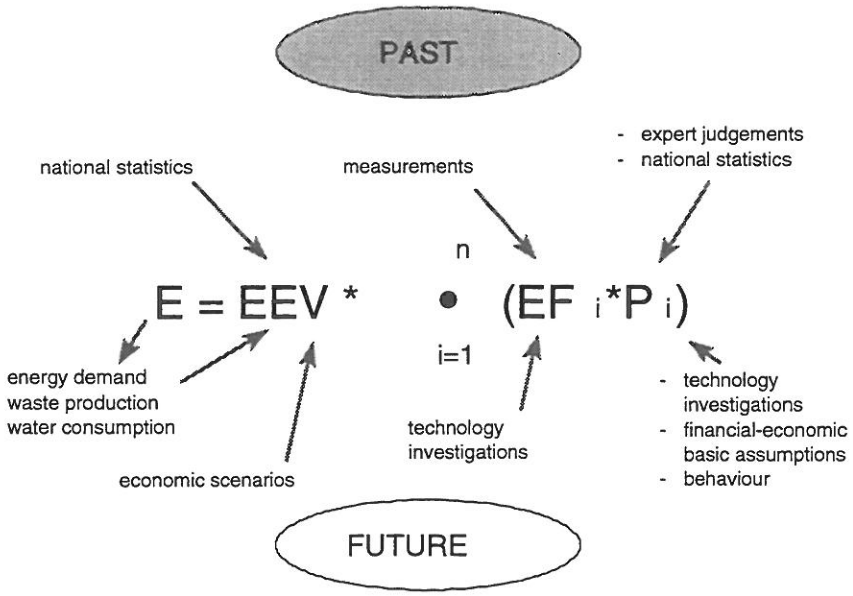


Figure 2 The fundamental formula for emission calculations and its application in inventories and projections

EMISSION FACTORS

The emission factor is the technical parameter in the emission calculation. For the prognosis of EF assumptions on the application of new technologies are necessary.
In the basic form an emission factor is related to a technically well-defined unit.
In case detailed emissions within a company have to be calculated, emission factors for every specific apparatus or process unit are used (even for pumps, tanks etc.). The EF is related to a very specific physical EEV. Examples are:

* EF for a specific type of car (built in 1990) driving 80 km/hour steadily on gasoline with a catalyst; the EEV is in km driven with that type of car at this speed.
* EF for well-defined modern stables (including specific measures) with cows; the EEV is the number of cows.
* EF for the application of a certain type of paint on houses; the EEV is the amount of paint used.
* EF for the production of styrene in a well-defined plant (including pollution control measures); the EEV is the production volume of styrene.

However in practice emission factors on several levels, even on a global scale, are used. In general there are two types of adjustments because of a lack of data on the detailed level:

a. assumptions on the penetration P are included in the EF
b. the EF is related to another EEV than the best one from a technological point of view

It should be noted that statistics are necessary for quantifying of P and EEV in emission inventories. However in emission projections they are the result of economic scenarios and assumptions about the behaviour of people and (or in) sectors. But also in these cases these simplifications might be useful.

ad a.

For every example in practice simplifications might be necessary, leading to the following EF used in practice in some cases:

* EF for all cars on gasoline under all circumstances in a specific country, in which the penetration of the catalyst is included
* EF for cows in all kinds of stables, which means an average for modern and old stables including a penetration
* EF for paint application on houses in general, including assumptions on the types of paint used.
* an average EF for styrene production in the world, also used for a specific country.

ad b.

The ideal situation is to be able to make projections for each EEV, which has a good technical relation with the emission E. In almost all cases these EEV should be defined in physical terms. However, it would be an impossible job to make all these detailed projections. That is why other EEV are often used, in many cases based on economic scenarios and in monetary terms, even if the relation with the emission E is less clear.

Also the EF should be adjusted and defined in another way as is shown in the following examples:

* EF for cars related to the number of inhabitants
* EF for cows in general related to the 'added value' of this part of agriculture
* EF for paint application related to the number of houses (or inhabitants)
* EF for styrene production related to the 'added value' of the chemical industry.

In case of styrene production the emission in the base year itself could be used as the EF related to an index, which is 1 in the base year and represent the growth of the chemical industry. A further simplification is not to distinguish processes within the chemical industry for projections. In that case the total emission for the chemical industry can be related to the relative growth of this sector as can be done for other sectors as well.

It is clear that these simplifications (prior aggregations rather than post aggregations) also imply a devaluation of the information. Because emission projections are based on economic scenarios and penetration of technologies, which are both the result of many assumptions, this can be acceptable in some cases. However, the acceptability depends on the goal of these projections and too much aggregation makes the result useless. In case the question is: 'what result could be achieved with full penetration of catalysts in cars?', it is better to make the calculations explicitly for the penetration of the catalyst and use EF for cars with and without catalysts.

SCENARIOS: EMISSION EXPLAINING VARIABLES

The EEV (also called activity levels) are the mainly economic parameters in the emission calculation. An economic scenario is based on economic theories and relations and includes many assumptions. The aim of a scenario is to show its consequences. Therefore more (different) scenarios are interesting for many purposes. The following steps might be distinguished.

General scenarios for international development

A country is not a closed system. For many countries assumptions on developments in the rest of the world, specifically countries with important interrelationships, are important as a general framework. These interrelationships are not fixed, so different scenarios could be worked out. Another important parameter, which is internationally determined, is the energy price.

National economic scenarios

Based on possible international developments national scenarios can be designed. The number of inhabitants (more the base than the result of an economic scenario) is an important starting-point. For short-term scenarios (say less than 10 years) the actual structure of the economy is the base for the developments. However in countries rapid changes may lead to new situations. In these cases the probability of completely different scenarios is higher.

These scenarios are presented in monetary terms, in general on a high level of aggregation (say 10 to 20 sectors).

Scenarios on a process level

In many cases further details are necessary, especially if emissions are related to a limited number of processes (heavy metals, POP, VOC). This fine-tuning can be realized in two steps.

The first is to distinguish more processes than is generally done in economic scenarios. The number of processes could be several hundreds, including many consumption processes. The macro-economic approach could be supplemented with micro-economic information, i.e. about plants, which will be closed or started up.

The second step is the transformation of monetary data into physical data. From a technological (and environmental) point of view physical EEV are more suitable. This asks for information about the flows of materials and products through society and its relation with processes. This can be developed with the help of input-output matrices.

Based on the chapters about the EF and the EEV it can be stated:

For emission scenarios there are two options:

* *redefine EF in a way that they can be correlated with economic scenarios (the rough approach);*
* *redesign economic scenarios in a way that EEV can be correlated to E and EF (the detailed approach).*

ENERGY AND WASTE SCENARIOS

In a more fundamental discussion about emission scenarios, there is no special reason to focus on energy and waste scenarios. In the discussion in practice however, especially energy scenarios play an important role.

Energy scenarios are mentioned as a specific item in this report, because the energy demand can be seen as EEV (for emissions per J), but at the same time energy projections can be designed in a similar way as emission projections (using energy factors instead of emission factors).

Especially energy conversion processes based on fossil fuels are important regarding emissions of components such as CO_x, NO_x and SO_x, which play a major role in several international environmental issues

For projections of the energy demand approaches on macro- and microscale can be distinguished. The latter approach is based on knowledge of the energy demand of production and consumption processes, using energy factors the same way as emission factors can be used. Energy conservation measures can be translated into new energy factors. For this approach EEV on the process level must be available.

On the other hand the national energy demand can be related to national parameters like GNP and/or the number of inhabitants. In this approach general assumptions on energy conservation are included.

In both approaches the driving forces behind energy conservation must be quantified. One of the main driving forces is the energy price. But also other factors (age of installations, strength of sectors) and a specific energy conservation policy can play an important role.

Energy in the form of electricity or heat can be produced in several ways. So the second step is to divide the total energy demand into several energy conversion processes, for which emission factors are known. In short-term projections this division will not be very different from the present situation, but in long-term projections a quite different situation is possible.

For emission projections the analogy between energy and waste is apparent. Also waste is the result of production and consumption processes (waste production instead of energy demand) with all kind of preventive options. Waste can be treated in different processes like waste combustion and landfills (waste treatment instead of energy conversion). These processes have specific emission factors.

PENETRATION OF TECHNOLOGIES OR BEHAVIOUR OF ACTORS

The third parameter in the basic formula deals with a projected penetration of technologies. It can be regarded as a parameter representing the behaviour of actors within sectors, which means people. Depending on the goals of an emission projection calculation different approaches for quantifying this behaviour can be applied. Some examples:

* What is the potential emission reduction of certain technologies?
  In this case the technology is assumed to penetrate up to 100%, unless this is technically impossible. Where in the environmental policy, the technical measures to be taken are clear, this kind of projection also shows the result of the policy with the assumption every actor follows this policy.
* What will be the effect of financial instruments on emissions (penetration)?
  Eco taxes or energy taxes could be examples. They will have effect on the decisions of different actors to invest in energy conservation or pollution reduction. If some criteria can be developed (i.e. for the rate of return) the actual penetration might be calculated.
* What will be the emissions in a future year based on the actual policy, supported by a certain budget for inspection?
  This scenario can only be calculated, if the efficiency of inspection and its dependency on a budget can be quantified. This efficiency on inspection can be translated in the penetration of technologies.

Because of a lack of knowledge about the real driving forces for the penetration of technologies in general quite simple assumptions are used. However, it is important to make these assumptions explicit to be able to compare different emission projections.

THE INTEGRAL APPROACH FOR PROCESSES

In figure 3 a simple scheme of a process is meant to show that there are different factors, which are strongly related. These factors are not only for emissions, but also for other aspects like waste generation and energy demand.
The integrated approach is important for three reasons:

* it leads to consistency on the technical level; especially in case of measures in general more than one factor will be influenced
* it helps to realize consistency in different scenarios by relating the emissions to water, air and soil, energy use and waste production to the same EEV; however for some

processes the best EEV might not be the best Waste Explaining Variable or Energy Explaining Variable, but in practice these differences only appear on a detailed level and in a few cases

* it is important that environmental costs and environmental benefits (like emission reductions) are related, which means for projections they are based on the same assumptions about technologies, their penetration and the development of the activity level of processes.

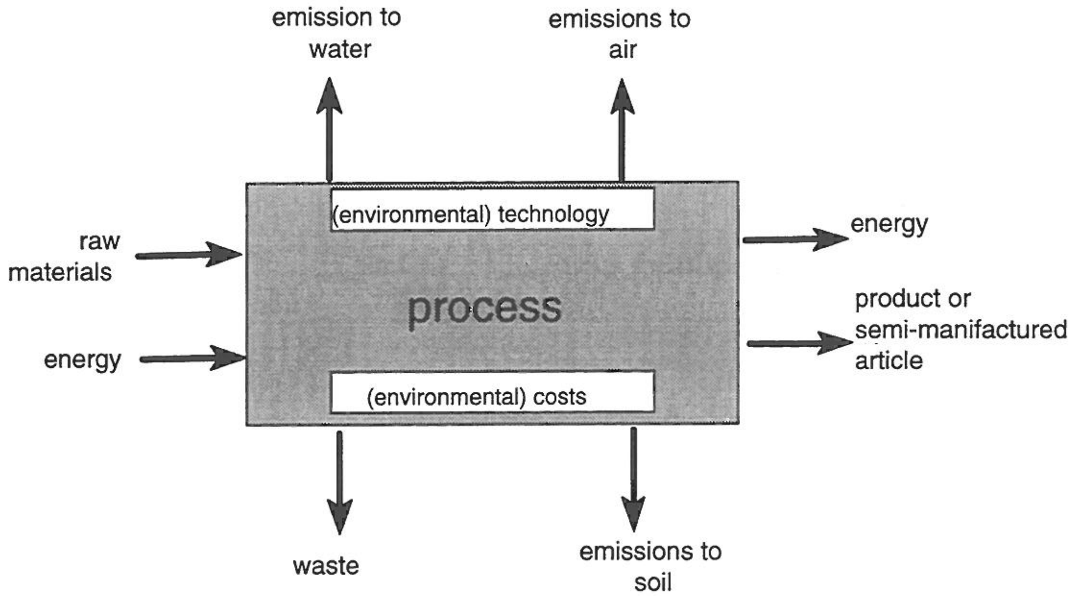


Figure 3 A schematic approach for all production (and consumption) processes

THE LINK BETWEEN INVENTORIES AND PROJECTIONS

The formula in figure 2 is not only applied for projections, in many cases emissions in a base year are calculated in the same way. The main difference is the EEV and Pi are not the result of economic scenarios or expected behaviour, but they are facts, actual developments and so in practice often the result of statistics.

Consistency between inventories and projections is guaranteed by using the same type of EEV, by taking the Pi in a base year as a starting point for projections and by using the same emission factors in case the technology is the same.

This implies that emission factors presented in the this guidebook for emission inventories can be applied for projections as well. However it should be realized that abatement technologies and process improvement normally reduce these factors. But an old factor for one country might be a new factor for another. To be able to use them it is important to relate an emission factor to a well-defined technical situation, at least in general terms (mentioning the abatement technology, an indication of the process itself, an indication of 'best available technology' in a certain year).

In case emission data for inventories are the result of actual measurements at the source, these data can be translated into emission factors to be used for this source if the technology is not changed.

An explicit presentation of the penetration Pi of a certain technology in inventories is quite helpful for projections. An example: if the penetration of catalysts in cars in a certain year is 40%, it is easier to calculate the emission under the assumption of 100% penetration in future than without this knowledge.

APPENDIX

SUMMARY OF OBSERVATIONS AND RECOMMENDATIONS FROM THE UN-ECE TASK FORCE ON EMISSION PROJECTIONS 1991 - 1993.

ABSTRACT

The paper contains documentation of the work, conclusions and recommendations from the TF on emission projections.

- Various approaches and assumptions about key factors for projections are used on the national level. These projections do basically serve national purposes.
- Some countries have little relevant experience in this field and intend to develop better national methods.
- Projections must in general be regarded as scenarios rather than predictions.
- Model based projections have only to a limited degree been reported by the Parties to the Convention.
- A more consistent and complete set of projections would provide valuable data also for integrated assessment modelling.
- Various substances requires different tools for projections.
- Factors like energy prices, international economic growth and trade, population growth and technological developments, are common input to all models. Projections should be explicit on these inputs and they could be based on widely used international sources which should serve as default values.
- Guidelines on reporting of emission projections including standard use of baseline scenarios are given. These are generally reflected in the questionnaire for the 1994 major review of policies and strategies under the Convention.
- Linkages between emission inventories and projections are described.
- Some thoughts on possible roles for a panel on emission projections are given.

BACKGROUND

In 1991 the Task Force (TF) on Emission Projections was established with Norway as lead country. As stated in the "Draft Terms of Reference..." given in the ECE-document EB.AIR/GE.2/12 Annex I, the TF should ".... investigate the feasibility of developing a common framework for the ECE region to forecast emissions for major pollutants, e.g. SO_x, NO_x, VOC, NH_3 and CO_2." Further the TF " .... should develop guidelines to help in the preparation of forecasts". The TF was subsumed under the programme of work of the TF on Emission Inventories in December 1993.

The TF held meetings in Oslo 17-18 April 1991, Paris 11-12 June 1992 and Risø 3-4 June 1993. The last meeting was combined with a workshop held 1-2 June. The arrangements have been attended by national experts involved in making national and/or international emission projections based in governments and research institutions, and international institutions like IIASA, OECD and the European Community. The TF has produced several recommendations to the Working Group on Strategies and the Executive Body of the Convention, documentation of a questionnaire and proceedings from the workshop.

INTRODUCTION

This chapter about emission projections reflects the discussions in the Task Force in the period 1991-1993 before it became part of the TF on Emission Inventories as an expert panel. The TF has been a forum for modellers from both the economic and the technical communities. This forum has had participants from countries with a long tradition for making such projections and countries who have not and were represented basically to learn.

Making emission projections require policy assumptions, models and input representing technology (emission factors). This is reflected in the scope of issues that have been discussed in the TF; national, regional and global projection experiences, presentations of various model frameworks for national and regional levels, sectoral and source split, identification of major technological and economic parameters, possible harmonization of underlying assumptions etc. These discussions have been transformed into guidelines and suggested procedures for reporting.

Projections have been used in the integrated assessment modelling that has been carried out by several research groups as background for the negotiations of the second sulphur protocol. There is a separate Task Force on Integrated Assessment Modelling to deal with such projections under the Convention. Projections make it easier to define overall targets of agreements and negotiate national commitments on the basis of abatement costs and critical loads reflecting the sensitivity of ecosystems. Projections may play a similar role for the negotiations of a second NO_x-protocol and possibly also for other substances.

Apart from the use of projections data in the integrated assessment modelling, the TF considered that a consistent and complete set of data could give an early indication of compliance or non-compliance with the requirements of the substantive protocols under the Convention and would thus allow additional measures to be introduced, if necessary.

OBSERVATIONS FROM NATIONAL PROJECTION EXPERIENCES

Countries usually carry out national emissions projections as background for developing a policy on the control of the projected substances. These data also fulfill an important role in informing the general public of progress in abating air pollutants in the region. Normally such studies require considerable resources both in competence, time and money. Emissions projections on the national level are often linked to broader macroeconomic projections, especially for substances that relates heavily to the economic development. This serves two purposes, it saves resources by avoiding reruns of the economic models, and the projected emissions will be consistent with the economic projections. However, this procedure also implies that basic assumptions may vary from country to country.

Projections are usually intended to be scenarios rather than predictions. In most cases a "baseline" scenario is developed as a point of reference. This will generally reflect all the control measures that have been decided upon at a given point of time time. Usually, but not always, some alternative scenarios are developed which may be used to investigate additional measures to control pollution or to review the effects of alternative values of the exogenous factors, like higher or lower economic growth or different energy prices than in the baseline case.

Scenarios elaborated for official national publications or for reporting at the international level serve political purposes and this will influence the determination of key variables. All scenarios need an explicit description of the policy measures assumed; this concerns both environmental policy and economic factors. A clear description of the scenario assumptions is crucial in order to achieve transparency.

Most emission projections from economic models concern SO_2 , NO_x and CO_2 , while emission projections related to VOC, NH_3 and CH_4 basically need other modelling approaches. Also for the first mentioned substances there are systematic differences; for emissions of CO_2 and SO_2 the developments in the use of fossil fuel energy sources and commodities, and hence economic factors play a crucial role, for NO_x the technological factors are more important.

The countries are in different stages concerning development of models and use of projections. The models employed at the national level differ in many important aspects. They have been developed for different purposes, they originally attempted to answer different questions and cover different time horizons. Some models follow a simulation approach, others are based on economic optimization techniques, and there are combined approaches. Most models have been computerized, but the level of aggregation differs widely; some use information from databases at a very detailed level (in one case, data on more than 2000 individual sources).

Some countries make projections according to source while others make projections according to economic sectors. The TF saw advantages to both approaches. For example, regulations are performed according to source; emission factors are often by source; source can be the right departure for compiling inventories; point of emission is usually of importance. A split according to economic sector can utilize the knowledge of economic factors as driving forces behind the development in emissions. As abatement becomes more expensive, it is important to know the distribution of costs by sector.

Since macroeconomic variables have a major impact on emission projections, the values and uncertainties connected to these are crucial. A description of the uncertainties in economic factors will often have to be of a qualitative nature.

Most key factors have to be interpreted at the national level, dependent on the structure of the economy. The impact of assumptions concerning internationally common key factors varies from country to country as the dependence on international trade of various goods and services or oil prices varies.

For various reasons countries use different macroeconomic assumptions to make projections. In addition the factors which are taken as exogenous also vary as models differs. Factors that are exogenous in some models may be derived endogenously for other models, or may not be considered at all in the analysis.

Structural change has historically been a very important determinant of emissions and will probably remain so in the future. Particularly for central and eastern Europe, the process of economic restructuring is expected to change the emissions and consequently the basis for emission projection modelling substantially in the course of the next decade. National and international models cover structural changes to a different degree. Apart from the modelling difficulties, the issue is also politically sensitive, as it usually touches upon certain industrial sectors, regions and employment questions.

Countries in transition to a market based economy face a special situation also regarding emission projections. The economic structures have been and will probably still be rapidly changing for a number of years, and economic models can to a very little extent be built on econometric studies that reflect past market behaviour, which they often do in the established market economies.

THE LINK BETWEEN EMISSION INVENTORIES AND PROJECTIONS

Two distinct approaches with regards to making emission projections could be identified during the TFs work: an *inventory approach* that derived emissions based on a given activity level from an inventory of sources using emission factors; and an *economic approach* where an emission inventory database was used within an economic model that determined emissions on the basis of development of economic sectors. The two approaches overlap and, depending on the level of detail of the available data, can be linked. The inventory approach is based on emission factors that are calculated for certain economic activities, which are sometimes specified at a very disaggregate level.

The macroeconomic approach is usually more aggregated, since describing scenarios for every detailed sector seldom brings major insights in the overall picture. They are well suited for analyzing effects of policy instruments like taxes, but generally have a very rough representation of technology. Scenarios based on these economic models can be supplemented by less aggregated sector studies in a fruitful way. Detailed projection models that are closer to the information contained in the inventories, have their strength when used for technologically oriented scenarios. Such scenarios can be used to check whether certain developments are physically possible and they could be valuable tests for the parameters used in the macroeconomic models. The various levels of aggregation means that emission factors in inventories will have to be interpreted in the macroeconomic models.

Several countries or institutions have started to link emission projections and inventories or have initiated steps in this direction. Such a combination of models employed for estimating historical emission data on those used for projections is considered very useful, especially for a comparison of the different results at the sector level. Similarly, it is considered important to link the economic modelling activities closely to the emission projections work, where this is not done already.

In order to reduce the delay in reporting it was suggested to estimate the development of these emission factors on the basis of process analysis and thus develop some preliminary set of emission data. The Task Force agreed that such an approach was useful for short term projections and might, in addition, help to bring methods used for projections and inventories closer together.

In principle all emissions from national economic activities should be covered by the inventories and projections. Today it appears that it is mostly domestic activities that are included while foreign economic activities within the territorial waters are excluded. Some countries report that, for instance, fishing done abroad is included in the national statistics. International air transport is often not included. The Task Force considers that it is important to be aware that there is a statistical problem that should be solved. The problem of accounting and double accounting can only be handled adequately by an international body like ECE.

EXPERIENCES WITH REPORTING OF PROJECTIONS UNDER THE CONVENTION

Emissions projections are not specifically required in the original legal instruments of the Convention. However, the Executive Body in 1989 gave some very brief recommendations on how such projections should be made and after that the Working Group on Strategies have endorsed conclusions from the TF. Following the outline on national strategies and policies (EB.AIR/R.41), the Parties to the Convention in 1993 had been requested to report on projections for the years 1990, 1993, 1995 and 2000 for national emissions of SO_2 , NO_x , NH_3 , VOCs and CO_2 .

The reports have been far from complete up to -93. A lot of the Parties that have reported emissions have reported either their national obligations according to the protocols under the Convention or their national targets. This could be perfectly rational given that the governments intend to fulfill their obligations by introducing necessary measures along the way. However, this is a completely different exercise than reporting emission projections as results of modelling.

In its final meeting in 1993 the TF concentrated on guidelines that should be incorporated in outline for the 1994 major review on strategies and policies. In general the advice from the TF have been endorsed, and the recommendations was well reflected in the questionnaire and background paper for the ongoing review. The interesting thing now is whether the Parties are willing and able to report after these requirements.

The TF did not consider it feasible to include in these guidelines a requirement for reporting of emission projections on a subnational scale, such as the EMEP grid squares, since most national projections models do not have a spatial dimension. It was noted, however, that a transfer of data on the level of administrative units to the EMEP grid was possible and that such an approach was followed in the CORINAIR work. Only emission projections on the national level are asked for in the questionnaire for the major report.

Comparison and possible harmonisation of projections from different nations has been a major subject for the discussions in the TF. As mentioned earlier, a problem for the model comparison exercise is that some parameters were endogenous, i.e. determined within a model, in some cases, and exogenous, i.e. assumed as model input, in others. For model comparison key assumptions have to be selected and therefore set as exogenous for all models. For the long term one approach could be to develop a simple parameterized country model to be used in a harmonized approach. However, national models will still be used. Rather, these should also be developed further to reflect development in economic and technical factors better.

The TF recommended that for the reviews, a set of external factors should be specified as default values for all models and that they should cover: (1) socio-economic factors (growth in gross domestic product in ECE countries, population growth, expected national inflation, interest rates, and oil, gas and coal price developments), to be based upon UN/ECE, OECD and International Energy Agency (IEA) publications; and (2) technological factors (emission factors and energy coefficients) to be elaborated under the Task Force on Emission Inventories.

Such an explicit set of default values has not been put together, but the crucial element is the reference to common sources that do exist and could be used if countries so wish. After all, most of these sources are regularly updated, in some cases annually, so such a set would have a short lifetime. Also, many countries already use these sources either directly or as a basis for their own thinking. In the questionnaire, countries are asked to be explicit on the use of such background data, which is the important element to make submissions more transparent.

On this issue, the questionnaire says that "Reports should include an indication of methodologies and the external factors (socio-economic and technological factors) employed in the projections", which reflects the intention behind the recommendations discussed above.

The TF also gave the following recommendations regarding scenarios which has been incorporated in the questionnaire; the following two scenarios should be covered by the reports: (1) current reduction plans, reflecting the politically determined intention to reach specific targets; and (2) the baseline scenario, reflecting the state of legal/regulatory provisions in place as of 31 December of the year prior to the reporting deadline; Reports should give an indication of the uncertainty of projections, stating, besides the outcome of the baseline scenario, an upper and a lower limit for emission projections. The years 1995, 2000, 2005 and 2010 should be covered.

Reports should include SO_x, NO_x and non-methane volatile organic compounds (NMVOC) and attempts should be made also to cover NH_3, CH_4, CO and CO_2, (which are now asked for in the major review,) persistent organic pollutants and heavy metals, following the specifications as contained in the annex to document EB.AIR/GE.1/R.65.

The questionnaire also asks for projections on energy consumption in 2000 and 2005.

The TF also recommended that emission projections should be reported using the following source category split, also employed for emission inventories (EB.AIR/GE.1/R.65, Annex). This is still very ambitious for most countries, but the questionnaire asks for reporting in this format for the year 2000.

Source category*	SO_2	NO_x	NMVOCs	CH_4	NH_3	CO
1. Public power, cogeneration and district heating	xx	xx	xx	xx		xx
2. Commercial, institutional and residential combustion plants	xx	xx	xx	xx		xx
3. Industrial combustion plants and processes with combustion	xx	xx	xx	xx		xx
4. Non-combustion processes	xx	xx	xx	xx	xx	(xx)
5. Extraction and distribution of fossil fuels	xx	xx	xx	xx		xx
6. Solvent use			xx			
7. Road transport	xx	xx	xx	xx		xx
8. Other transport	xx	(xx)	xx	xx		xx
9. Waste treatment and disposal	xx	xx	xx	xx	xx	xx
10. Agriculture			xx	xx	xx	
11. Nature			(xx)	xx		
TOTAL						

* Relevant sources are given and major source categories are underlined. The parentheses indicate that the given source category may be a major one for some countries.

THE TEMPORAL VARIATION OF EMISSION DATA AND THE GENEMIS PROJECT

1. INTRODUCTION

Not much attention has been paid to the temporal variation of emissions in the past. While emission inventories and emission inventory methodologies experienced considerable improvements and the quantity of information has increased enormously, not much information is available about the temporal variation of emissions. In contrast to this lack of information, however, episodic phenomena of air pollution gained growing importance in the past years. Particularly, photo-oxidant formation is highly dependant on short-term atmospheric conditions like daily or hourly emissions of pollutants with short atmospheric lifetimes. Hence, a scientific understanding of photo-oxidant pollution and the elaboration and optimization of responses to this growing pollution problem in Europe require sufficient knowledge about the temporal variation of emissions.

A number of sophisticated atmospheric transport and chemistry models have been developed and used to enhance the scientific understanding of pollution episodes, calculate pollution transport and balances, and provide a better basis of knowledge for political decision making. It has become evident that such model simulations require reliable information about emissions with a high temporal resolution. In past years, modellers had to use simple temporal patterns describing the temporal variation of total emissions. These patterns are based on educated guesses and only to a very small extent on empirical information. They usually do not take into consideration regional and national differences and provide only very rough and averaged information.

Such simple temporal patterns can be considered satisfactory only for rather simple atmospheric models with low temporal, spatial, and vertical resolution and low sensitivity with regard to the temporal variation of emissions. Simulation results based on simple models and rough input data, therefore, have to be treated with utmost care. Emission data, simulation mechanisms and verification procedures are imperfect and cause smaller and larger errors introducing a more or less high uncertainty of estimation results.[1] It has become evident that the increasing complexity and detail of simulation models on the one hand, and the increasing need of reliable information for environmental policies on the other hand call for an increased detail and an increased quality of input data. This is particularly true for the application of simulation models in the development, assessment, and optimization of abatement strategies in Europe.

To address these requirements, a comprehensive investigation has been performed by the GENEMIS-project (Generation of European Emission Data for Episodes) in the framework of the EURECA-project EUROTRAC. Within GENEMIS empirical data have been collected and models for the simulation of the temporal variation of emissions been developed in order to examine the quality of the data used in the past, to enhance the state of the art and to provide

[1] It has to be emphasized that successful simulations with coarse data are at least partly due to little detail, coarse spatial and vertical resolution and imperfection of simulation models. For a discussion of the imperfection of atmospheric models see e.g. Carlier P., Atmosphärischer Transport und Umwandlung der VOC, Bericht der VOC- Landeskommission, Heft 21, 1993, S.91-135.

improved monthly, daily, and hourly emission data for the whole area of Europe (e.g. Friedrich 1993, Friedrich et al. 1993, Friedrich et al. 1994, Heymann 1992, Heymann 1992a, Heymann 1993, Heymann 1993a, Heymann 1994).

The investigations of GENEMIS have shown, that:

- information about the variation of activities is available for many source sectors in many countries;
- a considerable temporal variation of emissions from all major source sectors can be observed. This variation is highly variable not only from sector to sector, but also from country to country;
- coarse time patterns as used by many modellers in the past should be improved to enhance the quality of the temporal resolution

Of course, uncertainty margins increase with higher resolution of emission data. Calculations of monthly, weekly, daily or hourly emission data can not be regarded as precise descriptions of real emissions. As for all emission inventories, high temporal resolution data also pose the general problem, that they cannot be verified easily, and uncertainty margins can only be roughly estimated. Nevertheless, the reliability of emission data increases with the amount and quality of base data used in the calculations.

This chapter will give an overview of the information about the temporal variation of emissions, which is currently available for all major source sectors.[2] Section 2 summarizes calculation approaches that had been used to estimate the variation of emissions. Section 3 describes detailed new models for a more reliable estimation of the temporal variation of emissions in all major sectors and results that have been achieved with these models within EUROTRAC-GENEMIS. In section 4 results of the total variation of emissions in Europe in 1990 are presented and regional difference highlighted. In the conclusion in section 5 the progress that have been made within GENEMIS and the state of knowledge that has been achieved is summarized.

2. CALCULATION APPROACHES OF EMISSION DATA WITH HIGH TEMPORAL RESOLUTION

In Europe millions of vehicles, production plants, heating installations, etc. cause emissions of air pollutants. It is impossible to collect individual information about all these emission sources. Instead, simplifying top-down procedures based on averaged emission behaviours have to be applied. The averaged emission behaviour is described by emission factors, statistical activity data, and information about the temporal variation of activities.

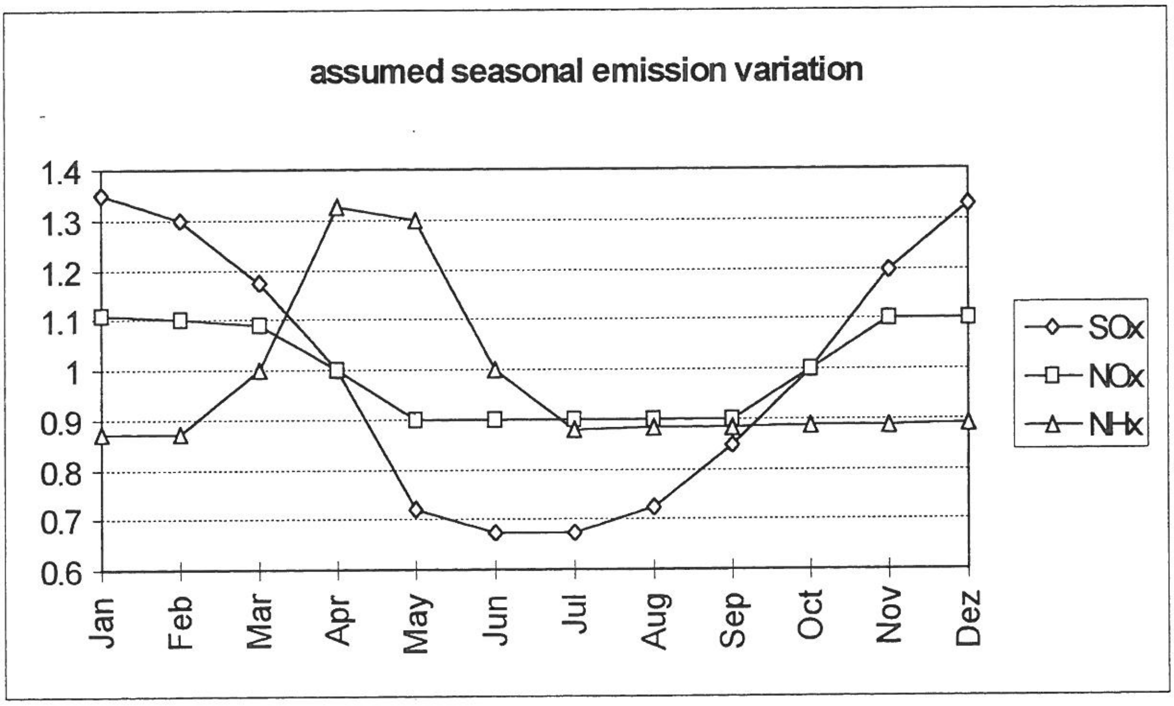
The simplest approach to consider the temporal variation of emissions is the estimation and application of patterns of relative total emissions in time, which can be multiplied by total annual emissions in order to get monthly, weekly, daily, or hourly emission data. Such rough

[2] It has been considered more useful to give a comprehensive discussion of the temporal variation of emissions for all source sectors in this chapter to provide an appropriate overview.

and general time patterns are being used by many modelers. In figure 1 such simple monthly time patterns as used by EMEP and EURAD are presented. These time patterns are based on a simple set of plausible assumptions. They do not contain detailed information about individual emission sectors in different regions.

Temporal patterns with some more detail had been estimated for the PHOXA and the LOTOS inventory (Axenfeld 1987, Meinl et al. 1989, Hulshoff 1991, Veldt 1992). These patterns are represented by different monthly, daily, and hourly time factors for 12 source sectors. By multiplication with appropriate LOTOS time factors hourly emission intensities can easily be calculated from annual emissions. LOTOS time factors take into consideration different emissions in summer and winter, on working-days and at weekend-days, and during day-time and night-time. These factors are presented in table 1.

Figure 1: Temporal patterns for the monthly distribution of total emissions as used by EMEP and EURAD



LOTOS time-factors are also based on reasonable, simplified assumptions. Statistical data have only been considered for power plants and road traffic from the Netherlands and from Germany (Veldt 1992a). The factors are assumed to be generally applicable to all European countries and to all years. National or regional differences of the temporal behaviour of emission sources are not taken into consideration.

Table 1: LOTOS time-factors for the estimation of emission data with high temporal resolution (Source: TNO, Delft).

LOTOS-Category	Sector	Winter	Summer	Working-day	Weekend-day	Day-time	Night-time	Temperature-dependency
1	Power plants	1.1	0.9	1.06	0.85	1.1	0.9	no
2	Area source combustion	1.04	0.96	1.08	0.8	1.24	0.76	no
3	Small cons. combustion	1.55	0.45	1	1	1.5	0.5	no
4	Refineries	1	1	1	1	1	1	no
5	Industrial processes	1	1	1	1	1	1	no
6	Solvent use	1	1	1	1	1	1	no
7	Road traffic gasoline	1	1	1	1	1.8	0.2	yes
8	Road traffic diesel	1	1	1	1	1.8	0.2	yes
9	Road traffic evaporation	1	1	1	1	1.8	0.2	yes
10	Coniferous	1	1	1	1	1	1	yes
11	Deciduous isoprene	1	1	1	1	1	1	yes
12	Deciduous non-isoprene	1	1	1	1	1	1	yes

The LOTOS-approach represents an attempt to include some more detail in the estimation of emission data with high temporal resolution and preserve a simple structure and minimum storage capacity needs for this information. However, these factors do not consider developments such as variations of fuel use or variation of production due to economic developments, changing climatic conditions, and changing user behaviour. The GENEMIS exercise has shown that the difference between this approach and more detailed calculations might add factor of 2 to the temporal variation of emissions for some sectors, regions, and periods.

Therefore, the LOTOS-concept has been extended and generalized within GENEMIS. In GENEMIS a large number of time factors have been derived. These calculations were based on actual statistical data, so-called *indicator data*, and on appropriate simulation models developed for the estimation of the temporal variation of emissions (e.g. Friedrich et al. 1993). The exercise of GENEMIS has proven that for the most important sectors appropriate indicator data are available. These indicator data change from sector to sector and depend on the temporal resolution to be achieved. The most important and useful indicator data used are production data (or production indices), fuel use data, traffic counts, meteorological data (temperature), and data on holidays and working times. In table 2 the most appropriate indicator data used to model the temporal variation of emissions are shown for the main sectors.

Table 2: Indicator data for the estimation of emission data with high temporal resolution (Source: GENEMIS data base, IER, Stuttgart).

Sector	Indicator data for monthly resolution	Indicator data for daily resolution	Indicator data for hourly resolution
Power plants	fuel use	load curves	load curves
Industrial combustion	fuel use, temperature, degree days, production	working times, holidays	working times
Commercial, institutional and residential combustion	fuel use, degree days	user behaviour	user behaviour
Refineries	oil troughput, fuel use	working times, holidays	working times, shift times
Industrial processes	production	working times, holidays	working times, shift times
Solvent use	production	working times, holidays	working times, shift times, user behaviour
Road traffic	traffic counts	traffic counts	hourly traffic counts
Air traffic	LTO cycles, number of passengers and freight	LTO cycles, number of passengers and freight	LTO cycles, number of passengers and freight
Biogenic emissions	temperatur, radiation	temperature, radiation	temperature, radiation

These indicator data allow the estimation of representative time-factors. Actual economic developments, climatic conditions, and changes of behaviour are implicitly considered by the indicator. Therefore, these indicator data provide the best basis for a description of the average temporal behaviour of emission sources in different sectors, regions, and times.

3 MODELLING THE TEMPORAL VARIATION OF EMISSIONS IN EUROPE

Only very few investigations have been made to estimate the temporal variation of emissions thoroughly. Most modellers are still used to apply simple time patterns to total emissions in order to obtain higher resolution data as needed by atmospheric transport and transformation models. It has not been examined how good or how bad these approaches are. The more elaborated investigations within GENEMIS provide more detailed information and show the shortcomings of time patterns used in the past. The simulation models developed and the resulting time variations will be presented in this sector for the major source categories. For a comparison, other time-patterns, which represented the best information available in past years, are included in the graphs.

3.1 Snap Sector 1 - Public power plants

a. Indicator data and simulation models for public power plants

Emissions of all combustion sources are related to the actual fuel use of these sources. Fuel use data with higher temporal resolution than annual provide a good estimate for the temporal variation of emissions. In the case of public power plants monthly fuel use data by fuel types are usually available. For European Union member states such data are available from the statistical office of the European Union, EUROSTAT, in Luxemburg. For other countries fuel use data are usually available from national statistical offices or from the utilites.

Daily and hourly power plant emissions can be estimated from load curves. For all UCPTE member states total national grid loads are available for the average Wednesday of every month. In some countries more and more detailed load curves are available from national load dispatch stations or from utilities. In some countries even data on hourly total load for all power plants are available. Such load curves provide a good basis for the estimation of emissions with high temporal resolution.

In the case of aggregated national (or regional) load curves, at least base load, medium load and peak load power plants have to be distinguished. This information is available from energy statistics or utilities or can be estimated from energy production or total power of individual power plants. Base load power plants (including nuclear power plants) must be assumed to be in continuous operation, while medium power plants cover the medium share and peak power plants cover the peak share of total energy production (Adolph 1994).[3]

b. The variation of power plant emissions

Usually, power plant combustion shows a typical seasonal variation: higher loads in the winter and lower loads in the summer. Data on monthly fuel use of public utilities from 1985-1992 confirm this behaviour for many countries. The individual patterns (distribution of maxima and minima) and magnitudes of the seasonal variation, however, look very different for different countries (see figure 2). While the seasonal variation of fuel use in power plants in Germany, Italy, Poland, Hungary and the UK ranges between 30% and 40%, it is much stronger in France and reaches up to 270%. The high share of nuclear power in France causes an extreme variation of monthly fuel use with almost no fuel use from May to August.

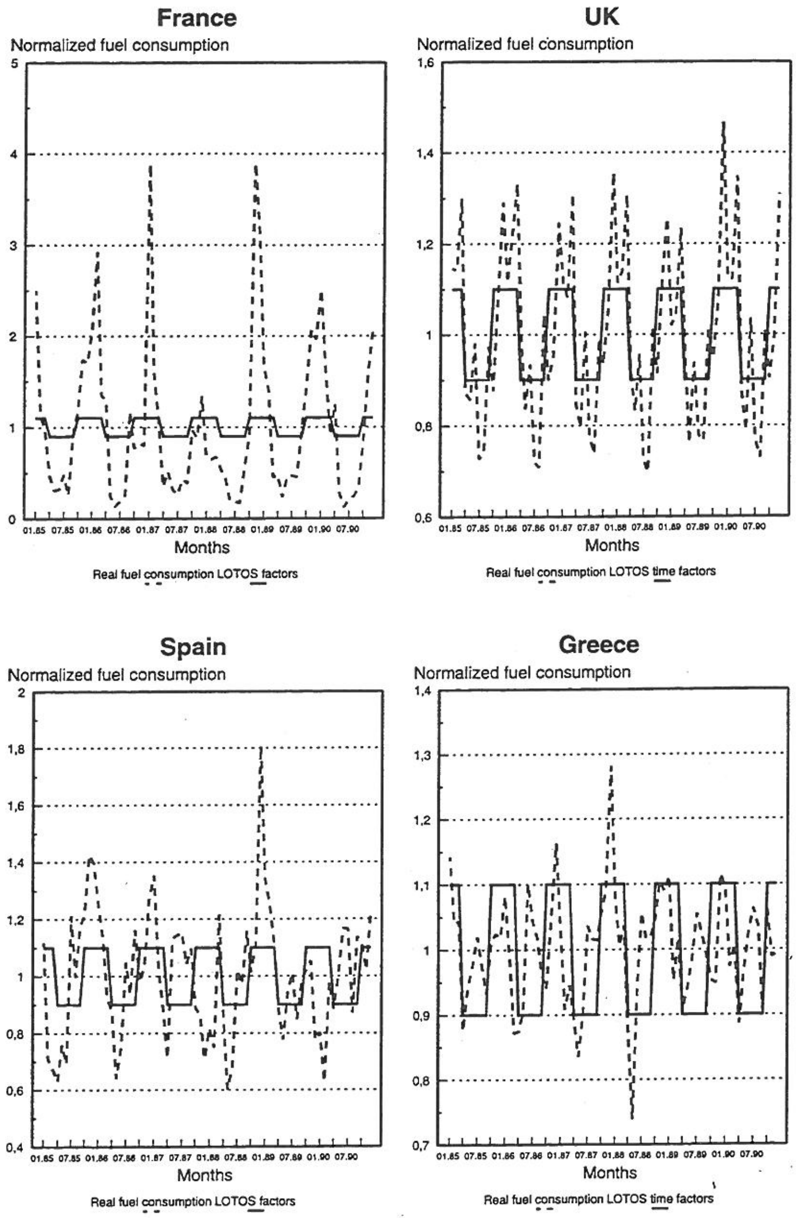
In small countries like Portugal and Greece the monthly fuel use shows a more unregular behaviour with peaks in the summer and for minimum fuel use in spring. This behaviour is due to factors like availability of water power, import of electricity, etc. The UK and Ireland, additionally, show a strong monthly oszillation. In Hungary total national load curves typically show a higher fuel use in the winter and a lower fuel use in the summer. Load curves for individual power plants, however, do not always follow this characteristic, but show a completely different temporal behaviour, especially for some big power plants.

These investigations showed considerable differences to older time factors, which generally assume a smaller seasonal variation of power plant emissions. While for most countries summer emissions from power plants are overestimated by approximately 20%, for France this overestimation reaches 600%. The overestimation in summer is contrasted by a clear

[3] Detailed data from some countries (e.g. Hungary) show, however, that single base load power plants in operation display variations of up to 20-30% (Török 1995).

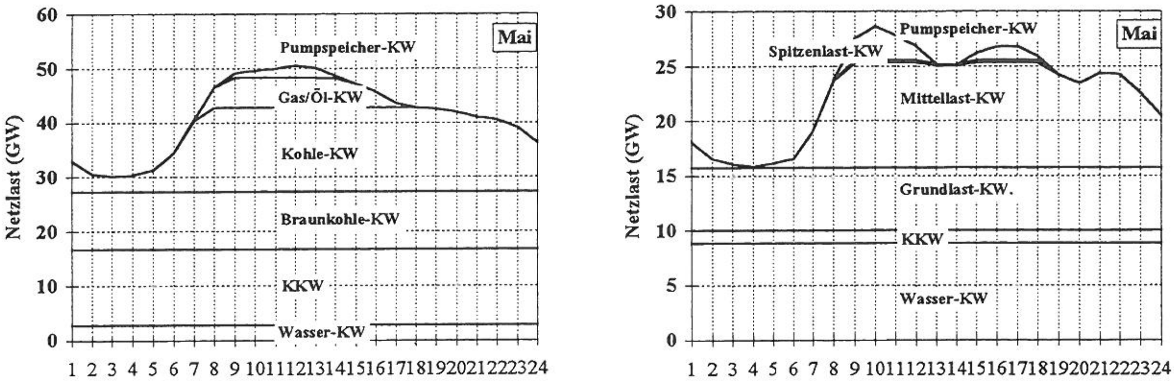
underestimation of emission in the winter. For a couple of smaller countries the reversed seasonal behaviour of power plant activity (higher activity in the summer, lower activity in the winter) is not represented by other time-factors.

Figure 2: Monthly total fuel use of public power plants 1985-1990 for France, UK, Spain, and Greece in relative units (Source: EUROSTAT, LOTOS)



Power plant loads also show strong daily and hourly variations. Curves of total hourly loads on a Wednesday in May as presented on figure 3 all show a strong variation between night and day. The variation is strongest for Portugal and the Netherlands (40% difference between minimum night and maximum day load) and much lower for the remaining countries (usually between 20% and 25%). The individual structure of hourly load curves shows typical national differences. The morning peak is reached at 8 am in Yugoslavia, France and Austria, 9 am in Italy, Belgium, and Poland, but at 11 am in Germany, Switzerland and Portugal. Strong minima occur between 12 am and 4 pm especially in Mediterranean countries and in Hungary, probably due to the 'siesta', though most distinct in Hungary, Italy, Portugal, and Greece, and not in Spain.

Figure 3: Total hourly loads for a Wednesday in May 1990 for Germany (left) and Italy (right) (Source: UCPTE).



In Poland the average daily loads on Sundays only reach 55%, on Saturdays 67%, and on Mondays 88% of average daily loads in the remaining weekdays. Hourly maximum loads in working-days in Poland are not reached during the day, but at 8 pm due to high energy consumption of households (Fudala 1995). For Hungarian power plants hourly load curves are available for all power plants for the whole years. Evaluations of these curves show that average hourly loads in different weekdays also show considerable differences (Török 1995).

c. Shortcomings of the power plant model

Estimations of the temporal variation of emissions heavily depend on the availability of indicator data and of the quality of the indicator. In the case of power plants the availability of data is comparably good. In most countries monthly fuel use data and grid loads are available, in some Central and Eastern European countries much more detailed data can be found. Within GENEMIS the most detailed data base exists for Hungary.

Fuel use data and load curves can be considered an excellent indicator for the temporal variation of emissions. National totals only provide a basis for the estimation of average national behaviour and hide regional differences and different behaviour of individual power plants. The operation of individual power plant blocks may reflect considerable differences from average operation times due to different operation modes and shut down times. Therefore, regional investigations with high spatial resolution would require more detailed data, which are in many countries available from regional statistical offices, or from regional utilities or power plants.

3.2 Snap Sector 2 - Small consumer combustion

a. Indicator data and simulation models for small consumers

The small consumer combustion category includes households as well as institutional and commercial fuel consumers such as public buildings, public and other institutions, workshops, farms, etc. Data about fuel use of small consumers are only available for a few countries and a few sectors, e.g. households. Different types of small consumers, however, usually have different temporal behaviour.

The fuel consumption of households is mainly used for space heating (about 80-90%) and to a smaller extent for hot water production (about 10-20%), as investigations in Germany and Hungary have shown (Fahl 1989, Barna 1995). Commercial small consumers' fuel consumption is partly dedicated to heating purposes and partly to production processes. It has been assumed that the production dependant fuel use is directly related to working-times. So the following modelling equation is suggested for the simulation of monthly or daily small consumer fuel use:

$$E_r = s_0 + (s_1 * D_r * H_r * n_d) + (s_2 * A_r * n_a)$$

where
- E_r: small consumers relative fuel consumption in the region r;
- D_r: degree-day of the region r;
- H_r: heating-season index for the region r;
- A_r: working-time index for the region r
- n_d, n_a: normalization factors for degree-days and working-time indices
- s_0: contribution of constant base load of small consumer fuel use
- s_1, s_2: share-factor describing the contribution of fuel use for heating and production related fuel use.

The heating-season index only has to be used for regions or countries, where heat is available for a limited season (e.g. 15. October - 15. April in Hungary). Days without limitation of heating are characterized by the value H = 1. For non-heating days the value for H has to include the information about the share of heating plants only working in a limited period (district heating plants) and the share of heating plants without limitation (single stove heatings, central heatings). In the case of 20% share of energy produced by district heating plants, non-heating days are characterized by the value H = 0.8. This is a reasonable estimate for many regions in Central and Eastern Europe.

The normalization factors guarantee that $\int(D_r * H_r * n_d) = \int(A_r * n_a) = 1$ over the whole year under investigation. This normalization allows to simply choose appropriate percentages for the share-factors. According to estimations from national experts within GENEMIS it is suggested to distinguish Western and Eastern European countries and define share-factors and heating season-indices as given in the following table:

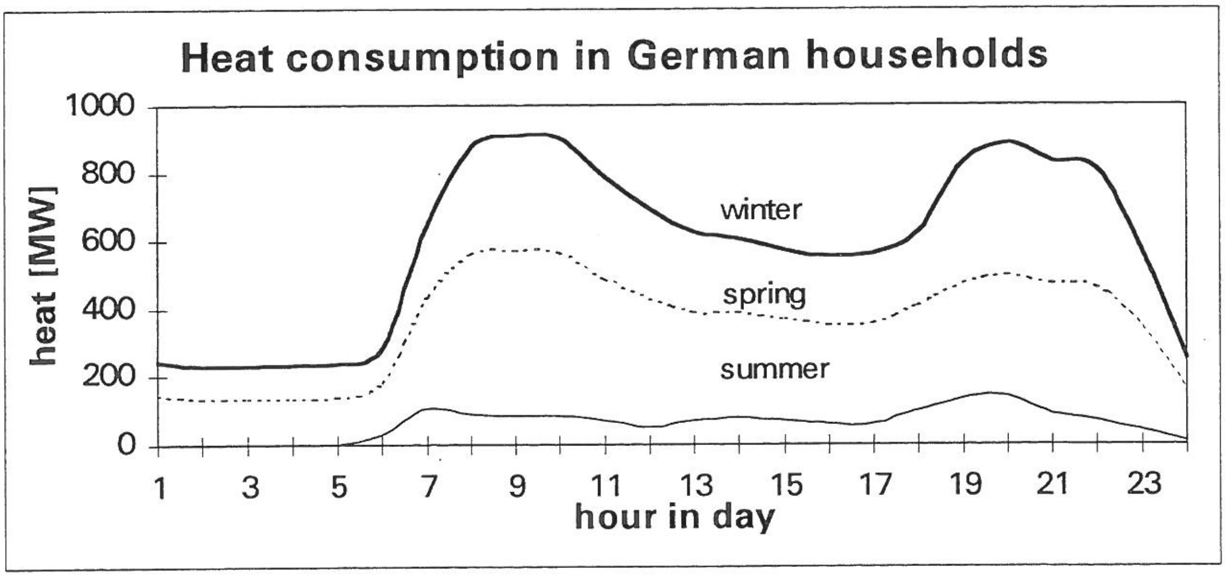
Countries	s_0	s_1	s_2	H (non-heating day)
European Union, EFTA member states	10%	60%	30%	always H = 1
Central and Eastern European countries	25%	50%	25%	0.6 - 0.8
Turkey, Albania	25%	50%	25%	always H = 1

In Central and Eastern European a rather high share of constant base fuel consumption is assumed, as a large amount of fuel is used for hot water and cooking. This is especially true for households with single coal or wood stoves that contribute a considerable share to total small consumer emissions. The share-factors given in the table represent default-factors, which can be used as long as no better information is available.

For the hourly distribution of small consumer emissions hourly patterns of fuel use for heating purposes and hourly patterns of production related fuel use have to be estimated. Within GENEMIS production related fuel use had been assumed to correspond to typical daily working times. The hourly variation of heating related fuel use, however, depends very much on the heating technology, climatic conditions and on isolation standards.

For central-heating it can be assumed a correlation to outside temperature with a reduction at night-time. For single coal or wood stoves a very strong morning and a very strong late-afternoon or evening peak can be observed. This pattern is due to fueling the stoves in the early morning and after returning home from work. Hourly patterns for households from an evaluation of a comprehensive survey in Germany are shown in figure 6.

Figure 4: Hourly fuel consumption of households in Germany (Source: VDI /2067,5/)



b. The variation of emissions from small consumer combustion

The strong dependency on degree-days leads to strong seasonal variations of small consumer emissions, while the dependency on working-times contributes to a strong hourly variation. In figure 7 the relative daily variation of total small consumer NO_x-emissions is shown for the United Kingdom and for Spain in the year 1990.

Figure 5: Relative daily small consumer NOx-emissions in the United Kingdom, in Spain and LOTOS-factors for 1990 (Source: GENEMIS, LOTOS)

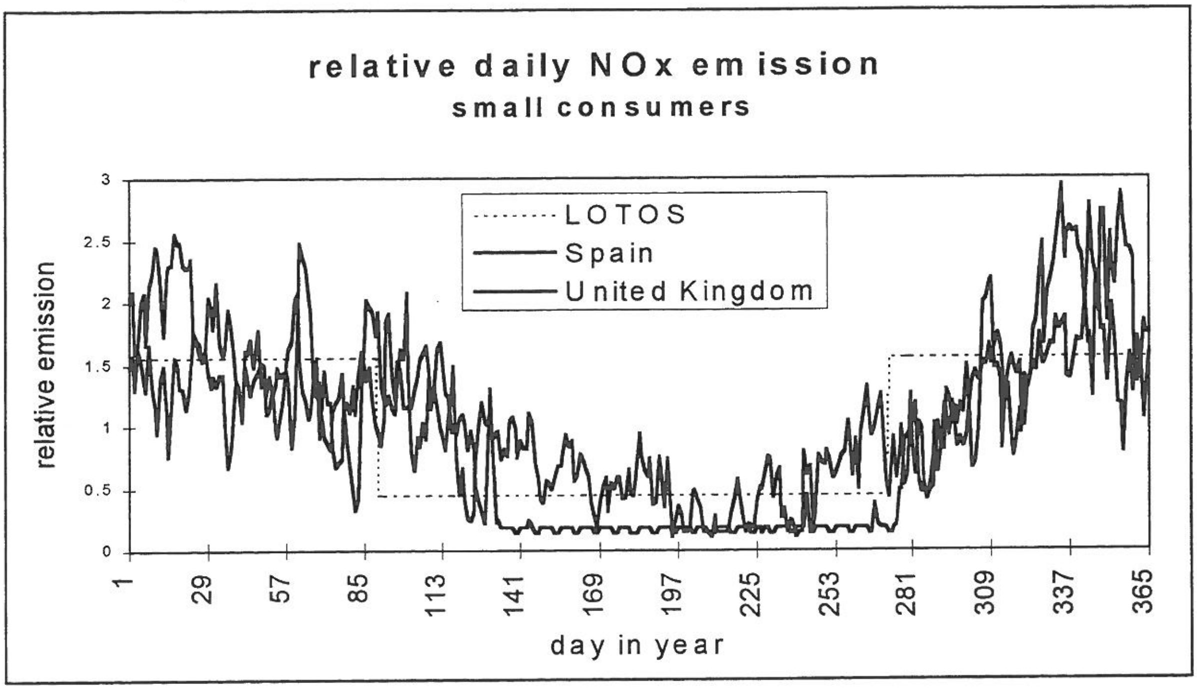
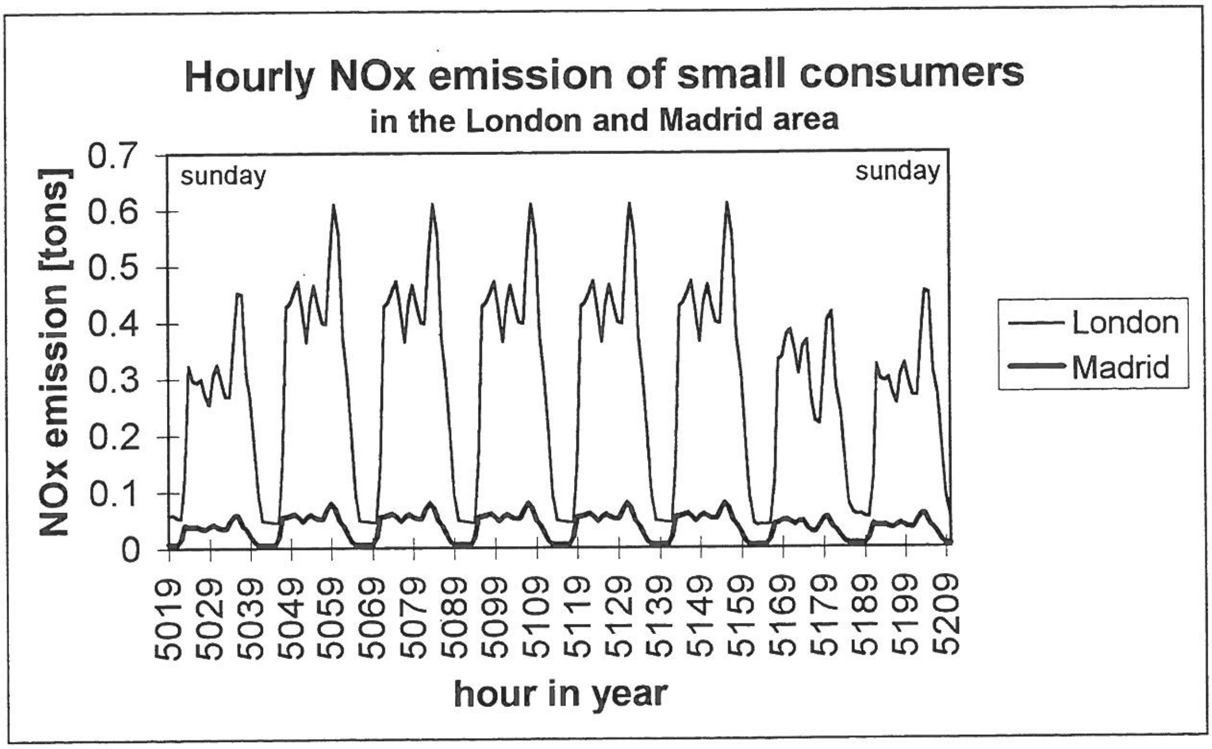


Figure 6: Total hourly small consumer NOx-emissions in the London and Madrid area for the TOR-episode in 1990 (Source: GENEMIS)



The resulting variation of total hourly emissions from small consumer combustion is shown for the London and Madrid area in figure 8. Both curves show a considerable variation of hourly emissions.

c. Shortcomings of the small consumer combustion model

The small consumer combustion model renders reasonable results for the temporal variation of emissions. Uncertainties, however, are assumed to be large. In the case of small consumers the assumption of a linear relation between total fuel use and emissions may lead to errors, as a large variety of very different small consumers with different heating technologies, different fuels, and different behaviours exist. As the availability of fuel consumption data with high temporal resolution is very limited, it is not possible to verify the modelling approach and the choice of constants in the model equation.

3.3 Snap section 3 - Industrial combustion

a. Indicator data and simulation models for industrial combustion

Emissions of industrial combustion are dependant on fossil fuel burning. Hence, it is reasonable to assume that the temporal variation of emissions follows the variation of fuel use. Data on fuel use with monthly resolution are available for some countries, but missing for many other countries. Monthly and daily fuel use, therefore, has to be simulated. The hourly energy consumption of industrial burners depends on parameters such as:

- production rates controlling energy consumption for production processes
- outside temperature controlling energy consumption for space heating
- production times, working times

Taking into account these parameters as variables, a modelling equation can be set up with regression coefficients describing the relative contribution of production dependant and temperature dependant fuel use. The value of the coefficients can be determined for different industrial sectors by reproducing measured fuel use data by a multidimensional regression analysis. Such a regression analysis can be performed for all countries or regions for which appropriate fuel use data are available. The result of the regression analyses is a model equation for the simulation of fuel use data with high temporal resolution. With such a model equation up to daily fuel use can be simulated based on actual production and temperature data.

Different model equation have been set up and tested with regression analyses. The quality of the regression and thus the quality of the model equation was described by the correlation coefficients. The best results have been achieved with a linear model equation including a constant base load (a_s) production (P_{sr}), temperature (T_{sr}), and degree-days (D_{sr}) as parameters

(Seier 1994).[4] The resulting model equation for the industrial combustion has the following general structure:

$$E_{sr} = a_s + (b_s * T_{sr}) + (c_s * D_{sr}) + (d_s * P_{sr} * A_{sr})$$

where	E_{sr}:	fuel consumption of the sector s in the region r
	T_{sr}:	mean temperature of the sector s in the region r
	D_{sr}:	(mean) degree-day of the sector s in the region r
	P_{sr}:	monthly production index of the sector s in the region r
	A_{sr} :	daily working time index of the sector s in the region r
	a_s, b_s, c_s, d_s:	Regression coefficients

This model equation allows to simulate monthly, weekly, or daily fuel use in industrial sectors. The model parameters have to be provided with the appropriate temporal resolution. Temperature data with high temporal resolution are available from national weather services, from the European Centre for Medium Range Weather Forecast (ECMWF) in Reading, or from EMEP Meteorological Synthesizing Centres in Oslo and Moscow. Production indices are available with monthly resolution from international sources like the UN, OECD, and EUROSTAT, or from national statistical offices.

In order to provide a daily estimate of relative production, a working time index has additionally been defined. This working time index A describes the total workforce at all days in the year and considers reduced working times on Saturdays and Sundays and on national or regional holidays. In GENEMIS a working time index has been defined for all European countries for the years 1986 to 1992 based on calendars and information from national experts. This index considers different holidays in different countries and different national traditions like bridge-holidays and work at weekends in Eastern European countries (Bogdanov 1995, Török 1995).[5]

It is much more difficult to provide reliable estimates for hourly emissions from industrial combustion sources. If no data on production times during the week and the day exist, it seems to be the most reasonable assumption to relate fuel use and emissions to working times and working shifts. In some countries data on working times and shifts are available from statistics or from industrial surveys. In other countries the calculations have to be based on experts estimates of common working times.

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[4] The temperature dependant contribution to fuel use was best described by considering both, temperature and degree-days. Degree-days is a parameter defined by heating engineers, which describes the heating energy consumption. It is defined as follows:

$$D = T_0 - T_d, \quad \text{if } T_d \leq T_0$$
$$= 0, \quad \text{if Td > T0}$$

where, T_d represents daily average temperature and T_0 the temperature limit for heating. According to most experts T_0 is assumed to be 15°C for countries in Western Europe and 12°C for countries in Eastern Europe.

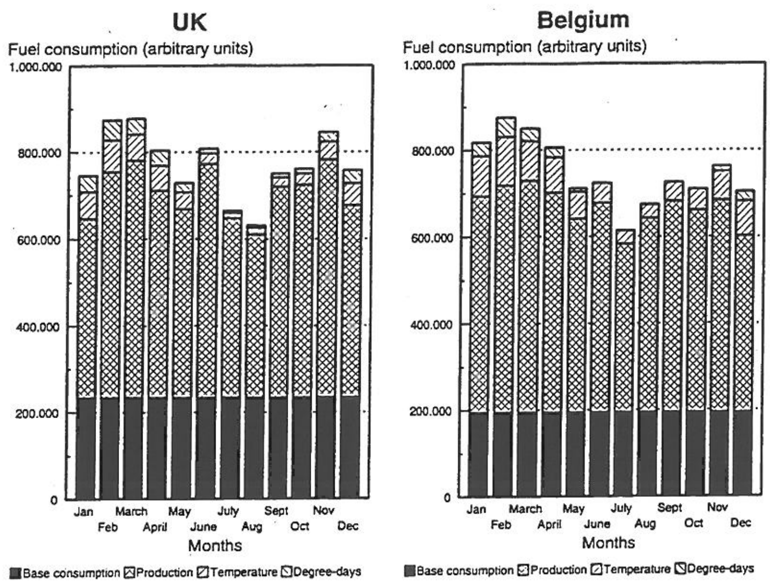
[5] If a national holiday falls on a Tuesday or a Thursday in many European countries (e.g.: Belgium, Hungary, Bulgaria) the preceding Monday or the subsequent Friday respectively are free and in some cases as a compensation a Saturday or a Sunday in the same week are working-days.

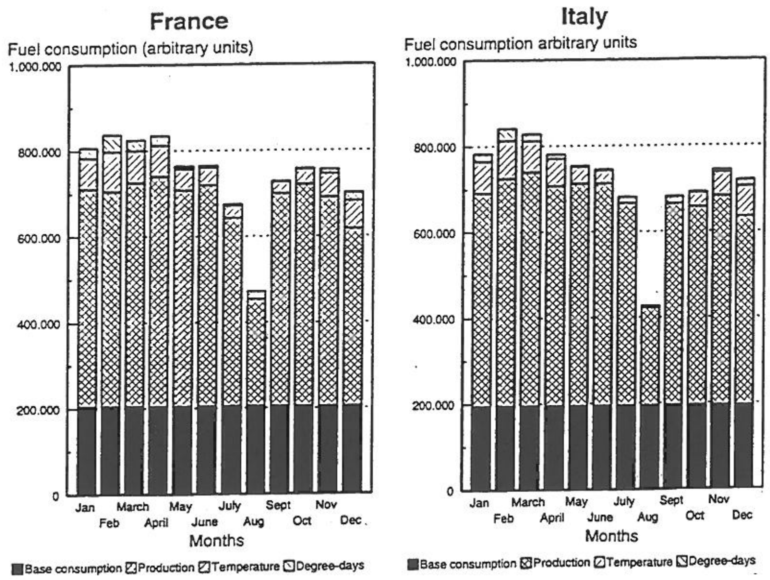
b. The variation of emissions from industrial combustion

The simulation of fuel use in industry has been performed individually for the iron and steel industry, non-ferrous metal industry, chemical industry, and paper industry. Additionally, total industrial fuel use has been simulated. The correlation coefficient, which describes the quality of the regression, ranged between 70% for the iron and steel industry and for total industrial fuel use, and more than 90% for the remaining sectors. The unsatisfactory correlation for the iron and steel industry and for total industry clearly indicates that other factors than production and temperature also have an important influence on fuel use. As such factors could not be isolated and properly described by other indicator data, they had to be neglected.

Model simulations with the present regression model clearly show that the major part of industrial combustion emissions is caused by fuel use for production purposes. A significant contribution is caused by a constant base load. The temperature dependant emissions usually ranges between 10-15% and can reach up to 25% depending on sector and climatic conditions.

Figure 7: Total monthly fuel consumption of the industry 1986 in the UK, Belgium, France, and Italy in relative units (Source: GENEMIS).





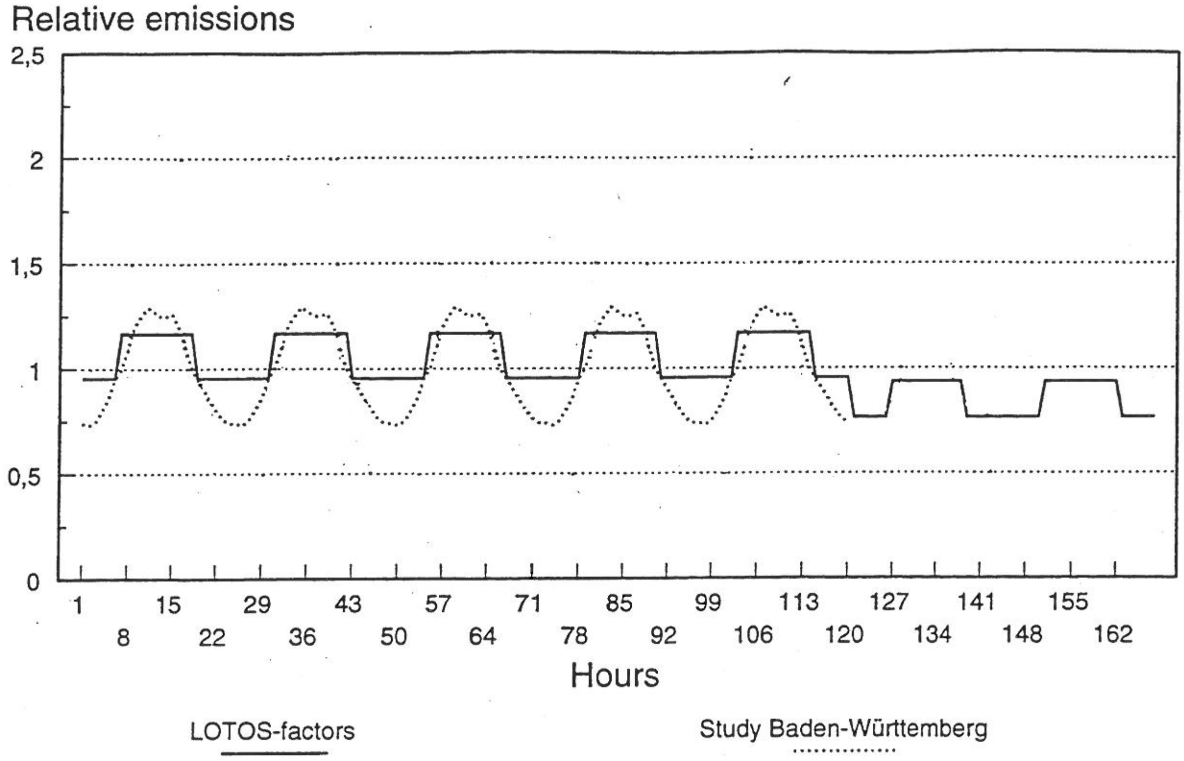
In figure 4 relative fuel consumption is presented for total industrial fuel consumption in the UK, Belgium, France, and Italy. The vertical bars show the relative share of the base load (full black), the load caused by fuel consumption for production purposes (cross-hatched), and the temperature-dependant fuel use (right- and left-hatched). The production dependant fuel consumption contributes the major share of about 50-65% to total fuel use. The base-load contributes about 20-25% of total load, while the temperature dependant part covers 5-25% of total fuel use. For most sectors a similar result can be observed.

The temporal variation of industrial combustion emissions is dominated by changes of production. In most countries summer emissions are lower than winter emissions due to vacation times. In countries like Belgium, Germany, Poland, and the UK the summer reduction reaches not more than 20-25% and is distributed over the summer months from June to August. In some countries like France and Italy, however, vacation times are concentrated in August and have a very strong effect on the reduction of production, fuel use, and emissions. Whole factories and plants are shut for two or three weeks and lead to a monthly fuel use reduction of 40-50%.

A comparison shows, that the effects of holiday-times and temperature are not taken into consideration by other available time-factors. This can lead to overestimated summer emissions of about 10 to 20% for countries like Germany and Belgium in July and August and about 40% for Italy and France. This overestimation is related to an underestimation of emissions in the winter time. So, similar as for power plant emissions, the seasonal variation of industrial combustion seems to be stronger than assumed by older patterns.

It is much more difficult to find reliable information on hourly emissions from industrial combustion. A survey of industrial plants in the German federal state of Baden-Württemberg suggests that hourly emissions during the day and during a week are mainly characterized by a strong ground load and a production dependant variation of about ±20% with a minimum at night-time. The results of this survey fit quite well to LOTOS hourly factors (see figure 5), which assume a smaller day and night variation of approximately 10%.

Figure 8: Hourly industrial fuel consumption during a week according to a survey in Baden-Württemberg and LOTOS hourly time-factors for industrial combustion (Source: IER, Stuttgart; LOTOS).



c. Shortcomings of the industrial combustion model

The simulations of monthly and daily fuel use in the industry can be considered much more reliable and nearer to reality than other approaches, because the most important parameters influencing the temporal variation of emissions (production, temperature, working times) are explicitly taken into account. With this approach, differences from region to region and from year to year due to economic changes or changed climatic conditions are considered. Problems of this approach are caused by the fact that fuel use data of industrial sectors are not available from international statistical offices or institutions. They have to be collected from national and regional authorities and institutes, which causes considerable efforts.

The simulation of fuel use data still produces some uncertainty. The quality of the simulations can hardly be assessed, because fuel use data of industrial sectors or individual industrial plants are only available for a few countries. Simulation results can in most cases not be verified by comparison with real fuel consumption.

3.4 Snap Sector 4 and 6 - Industrial production and solvent use

a. Indicator data and simulation models for industrial production and solvent use

The industrial production and solvent use categories pose severe problems for emission inventorying, as they are both characterized by a large number of small and heterogenuous emission sources. It is difficult to collect appropriate and reliable data for emission estimates of individual production processes or solvent using activities (e.g. VOC-Kommission 1994). The same is true for the estimation of the temporal variation of emissions from these sources.

It is a reasonable assumption that emissions of both emission from production processes and from solvent use are closely related to production figures of relevant production activities. Useful indicator data, therefore, are production data describing the activity of individual production processes and solvent using activities. In the case of solvent use, solvent consumption data with higher resolution than annual would provide the best indicator for the temporal variation of solvent using activities. However, such data are usually very hard to find or to estimate.

Due to the lack of detailed production data with high temporal resolution for individual processes in most countries, aggregated monthly production indices have to be applied to estimate a seasonal variation of emissions.[6] For private solvent use, assumptions about the user behaviour have to be made. Higher emissions of private solvent users can be assumed to occur in the summer and at weekends, lower emissions in the winter and at working days. Hourly emissions of production processes and solvent use can be estimated according to working times and total workforce per hour.

b. The variation of emissions from production processes and solvent use

The temporal variation of emissions from production processes and solvent use show variations according to economic cycles and working times. The seasonal variations are characterized by a reduction of emissions in summer months due to vacation times. The weekly, daily, and hourly variations are controlled by working times. Seasonal as well as hourly variations range in the order of magnitude of about 30%. LOTOS time-factors, instead, assume continuous activity all over the year and, therefore, overestimate summer emissions for most countries.

c. Shortcomings of the simulation model for production processes and solvent use

The estimations of the temporal variation of emissions from production processes and from solvent use have to be regarded as uncertain due to the lack of detailed statistical data. It has to be assumed that aggregated production data give an estimate for the temporal variation of individual production processes. But this simplification is likely to lead to estimation errors. Nevertheless, within GENEMIS it has been considered more appropriate to consider temporal variations in the way described than to neglect them completely.

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[6] E.g. for sectors like nitric acid production or paint use in the metal industry production indices for the chemical industry of the metal industry respectively have to be taken.

3.5 Snap Sector 7 - Road traffic

a. Indicator data and simulation models for road traffic

Road traffic belongs to the most important emission sources in Europe and contributes the major share of NO_x and VOC emissions. Additionally, it displays very strong temporal variations of emissions. While different vehicle types show a similar temporal behaviour, different road types like motorways, rural roads, and urban roads show a different course of road traffic densities and thus emissions.

The course of road traffic emissions in time is dependant on a variety of factors like time and day in the season, day in the week, weather conditions, working times, etc. Road traffic emissions can assumed to be directly related to total traffic density.[7] Traffic density data are usually available in form of traffic counts, which represent an excellent empirical base for the estimation of the temporal variation of emissions, because all external factors are implicitly considered. However, traffic count data are not available from international statistical offices, but only from national authorities. In some countries it is extremely difficult to obtain appropriate traffic counts or traffic density data.

Traffic count data can be available in different states of evaluation and data processing. In some countries original data from counting stations are available (e.g. in Austria, Winiwarter 1993). Due to a high number of counting stations and a big amount of data for every single station, such data require a further evaluation that causes considerable efforts. In other countries (e.g. in Germany) counting data are associated to characteristic monthly, daily, and hourly traffic density curves annually calculated with cluster analyses (e.g. Bundesanstalt für Straßenwesen 1991). In case of Austria and Germany an average traffic density has to be calculated. In other cases a monthly traffic density index is available for different road types (e.g. in France, INSEE 1990). This index gives an average road traffic density for all motorways and rural roads and can assumed to be a good indicator for the monthly variation of traffic emissions.

b. The temporal variation of road traffic emissions

Road traffic emissions show strong seasonal as well as strong hourly variations. They display a stronger seasonal variation for motorways than for rural and urban roads, and a stronger seasonal variation in rural areas than in urban areas. Hourly variation, instead, are quite similar for different road types and regions. In figure 9 weekly average traffic densities are shown for motorways, rural roads, and urban roads for the German federal state of Schleswig-Holstein in 1986. Schleswig-Holstein represents a rather rural area with a lower population density than the average in Germany. It is strongly affected by holiday traffic to the North Sea and the Baltic Sea, and from and to the Scandinavian countries.

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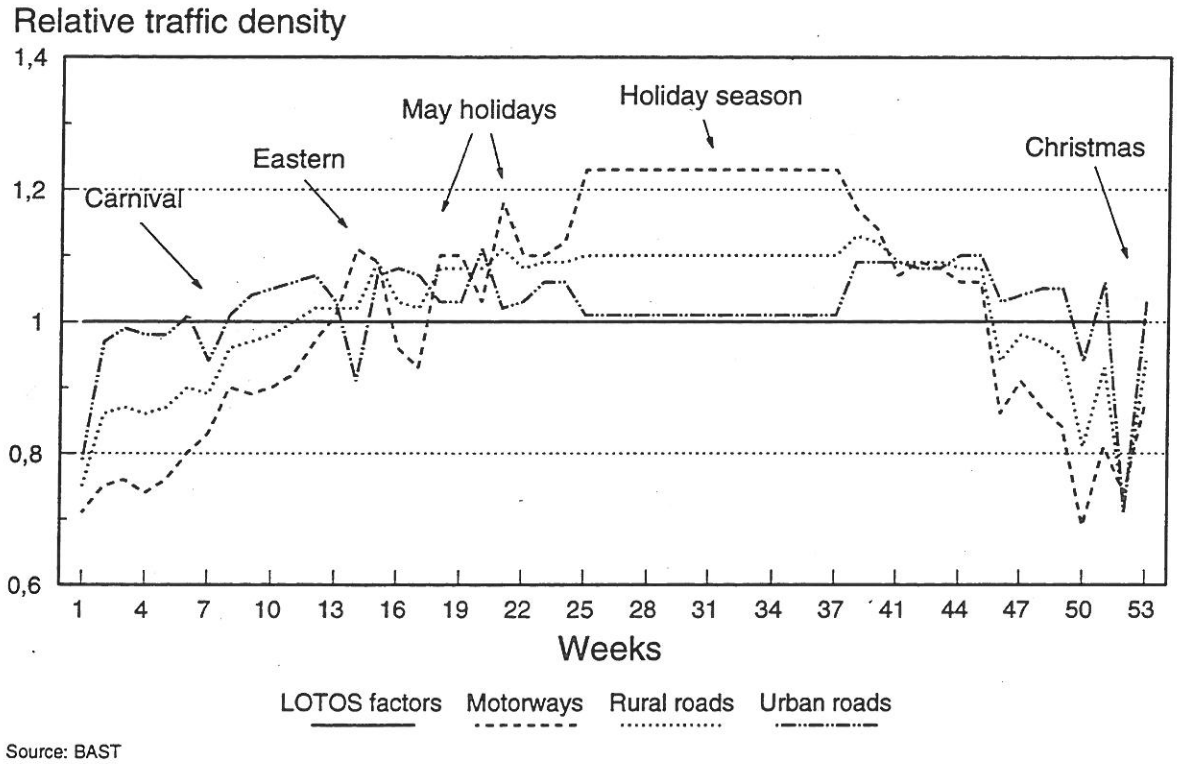
7 This, of course, is a simplification, as vehicle velocity is of major importance. The assumptiom has to be made that a similar velocity distribution can be assumed for different motorways, different rural roads, and different urban roads.

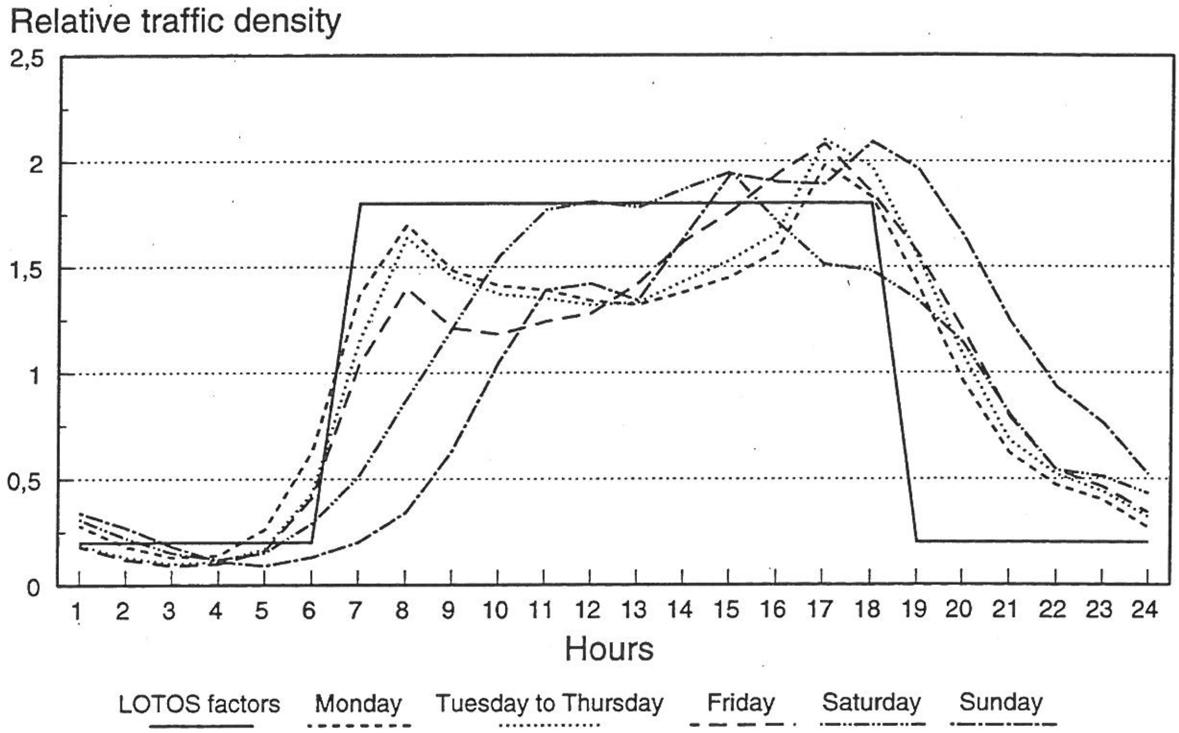
Figure 9: Weekly average traffic densities for motorways, rural roads, and urban roads for the German federal state of Schleswig-Holstein in 1986 (Source: Bundesanstalt für Straßenwesen, GENEMIS)



The influence of holiday traffic can clearly be seen especially on weekly motorway traffic density, which shows characteristic peaks at spring and summer holidays and strong minima at winter holidays. During the summer holiday season, traffic density and thus road traffic emissions on motorways were more than 50% higher than traffic density and emissions in the winter. Similar results hold for other years and other regions. Weekly rural and urban traffic density is more continuous. In spring and summer holidays, urban traffic is partly shifted from urban roads to motorways and from urban regions to rural areas, as can clearly be observed for Eastern 1986.

Road traffic is also characterized by very strong hourly variations. Emission peaks at day-time are 6-7 times as high as the lowest emissions at night-time. This feature can clearly be observed in figure 10, where hourly road traffic densities are presented for Monday to Sunday in the federal state of Schleswig-Holstein. Average hourly road traffic counts for the Greek city of Thessaloniki show even stronger emissions in the evening than load patterns for Germany. This condition is typical for Mediterranean countries.

Figure 10: Hourly road traffic densities for Monday to Sunday in Schleswig-Holstein, and according to LOTOS time-factors (Source: Bundesanstalt für Straßenwesen, GENEMIS; LOTOS)



Source: BAST

c. Shortcomings of the road traffic model

The availability of road traffic counts poses one of the main problems. Within GENEMIS traffic counts have as yet only been available for Germany, Austria, France, and Greece. More data are to be expected from Central and Eastern European countries within 1995. Moreover, it is hard to assess the representativity and reliability of the data available.

A major problem is often caused by the large amount of road traffic data with unsatisfactory homogeinity and quality caused by different data structures, missing data, or errors, which hampers automatic processing. The examination and evaluation of such data, therefore, causes enormous efforts.

Regions and countries without any traffic count data available have to be treated with the temporal patterns based on data from other regions. For sure, this generalization causes big errors and reduces the reliability of the data calculated. However, more sophisticated simulations for such regions are not possible, as road traffic density is a very complex function of many parameters.

3.6 Snap Sector 8 - Other mobile sources

The Other mobile sources category comprises air traffic, ship traffic, railway traffic, and off-road vehicles. Emissions of other mobile sources can assumed to be proportional to total traffic activity of these sources. The estimation of the temporal variation of emissions, therefore, requires data on traffic activity with high temporal resolution.

For the estimation of aircraft-emissions with high temporal resolution at airports, landing-take-off cycles (LTO cycles), passenger numbers, and freight statistics, which are available from airports or from the International Air Traffic Association (IATA), provide the best information available. The hourly emissions from airtraffic can usually assumed to be distributed over the day without strong variations, while no emission occur during night-time (usually between 23 pm and 6 am).

For the estimation of ship traffic emissions with high temporal resolution the number of passing ships per hour, day, week, or months in harbours or ship routes is related to the temporal distribution of ship emissions and provides a reasonable indicator, though different ship types show different emission behaviours. However, it is usually hard to find appropriate data. In the case of complete lack of data it seems reasonable to assume an equal distribution over the year and over the day.

Within GENEMIS ship traffic, railway traffic, and off-road vehicle traffic has not been treated due to a lack of data. According to new studies a more detailed treatment may be needed for off-road-vehicles, which seem to be responsible for a considerable contribution to total emissions and also are likely to show important temporal variations of emissions (Zierock 1994, see also chapter 3.5 of this handbook). As a first estimate it could be assumed that off-road vehicle emissions are higher in the summer and at day-time and lower in the winter and at night-time.

As the temporal variation of emissions from other mobile sources has not been treated within GENEMIS or other projects, no results calculated with these approaches can be presented. Shortcomings of these approaches are likely to be caused mainly by a lack of reliable data.

3.7 Snap Sector 10 - Agriculture

Only little information is available about the temporal variation of emissions from agricultural sources. Agriculture contributes a large share of ammonia emissions in Europe. Ammonia emissions are caused by animal manure and very dependant on climatic conditions, conditions of animal breeding, behaviour of the farmers, etc. It is very hard to simulate these conditions in order to estimate the variation of emissions.

From investigations of the RIVM in The Netherlands and of the National Environmental Research Institute in Denmark some information about the temporal course of ammonia emissions are available from measurements (Asman 1992, Asman 1992a). In figure 11 and 12 the averaged course of ammonia emissions over the year and over the day is presented. Actual emissions for single days and hours, however, can show a completely different pattern due to the conditions described above.

Figure 11: Monthly ammonia emissions derived from measurements (Source: Asman 1992).

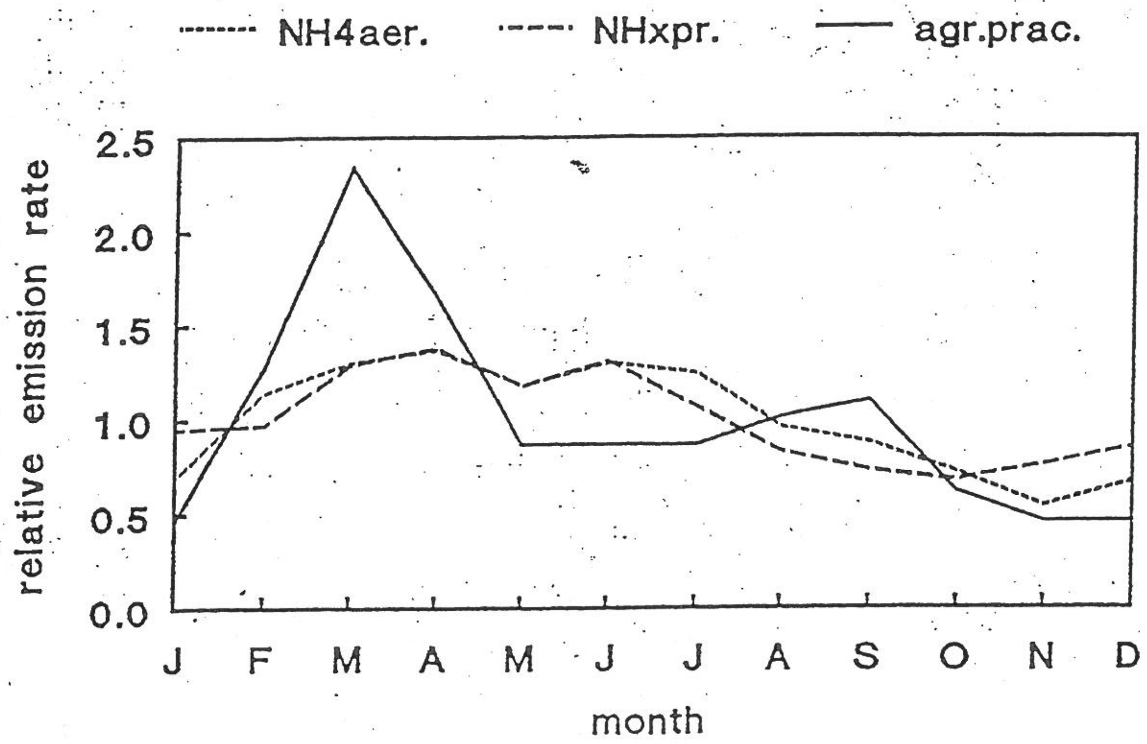
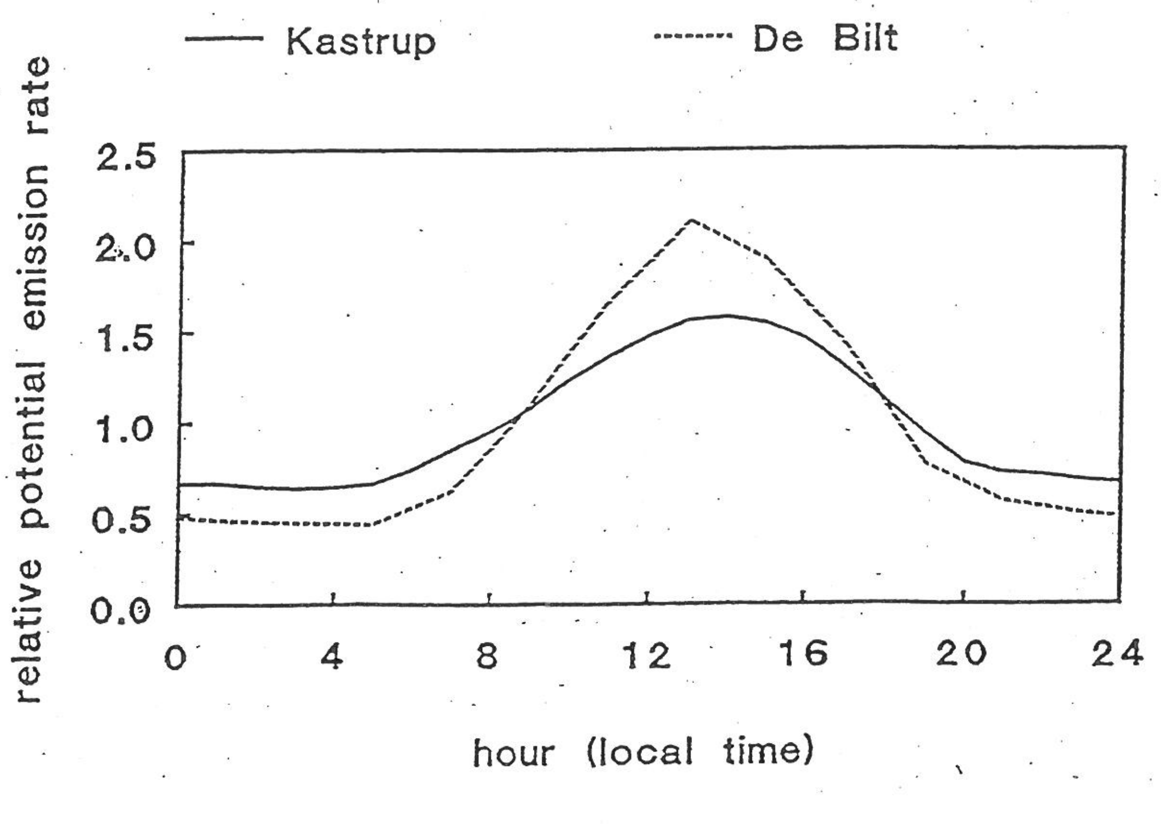


Figure 12: Hourly ammonia emissions derived from measurements (Source: Asman 1992)



At present, a more detailed investigation including a large number of measurements and careful surveys of farmers to account for the farmer behaviour is being carried through by the National Environmental Research Institute in Denmark. The goal of this project is the improvement of ammonia emission simulation.

3.8 Snap Sector 5 + 9 - Other anthropogenic sources

A number of other sectors not mentioned contribute to total emissions in Europe. To these sectors belong activities like waste disposal, gas distribution, coal mining, etc. For these sources no information on the temporal variation of emissions is available to the GENEMI project. Within the GENEMIS project these sources have been considered of minor importance. Partly, they contribute mainly to methane emissions, which are not important for short-term tropospheric pollution phenomena, partly they are assumed to show no important variation of emissions in time, and partly they only contribute a minor share to total emissions.

3.9 Snap Sector 11 - Biogenic emissions

a. Indicator data and simulation models for biogenic emissions

Biogenic VOC emissions vary from species to species and from region to region for individual species. The largest contribution to biogenic emissions is caused by trees, which emit 10 times as much as smaller plants. For an estimation of the temporal resolution of biogenic emissions it, therefore, seems reasonable to focus on tree emissions and assume a similar temporal behaviour of other species. This approach is justified, as for most other species much less information is available (Veldt 1991, Steinbrecher 1994).

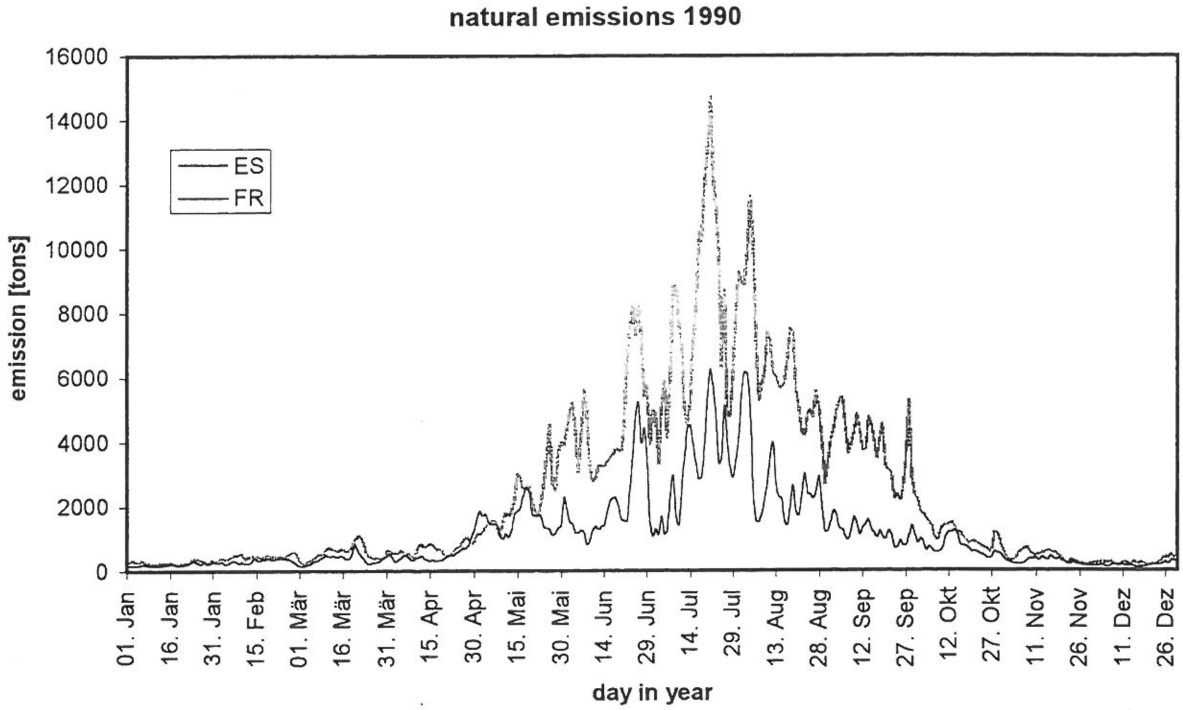
Biogenic emissions show a strong dependency on temperature, on radiation, and on the state of plant growth. Mathematical expressions for the temperature- and the radiation-dependencies are available from emission factors currently used in Europe. With the help of these emission factors emission data with high temporal resolution can be calculated (e.g. Winiwarter 1992, Moussiopoulos 1993).

As on the one hand the emission factors available are very uncertain, and on the other hand the collection and evalutation of temperature and radiation data requires considerable effort, reasonable simplifications have been introduced in the LOTOS inventory by Chris Veldt. LOTOS considered medium radiation intensities and gave general factors for the temperature dependency of coniferous, isoprene, and non-isoprene biogenic emissions (Veldt 1991). This approach can be considered sufficient as long as no better data are available.

b. The temporal variation of biogenic emissions

Due to a strong dependency on temperature, radiation, and plant growth, biogenic emission show very strong seasonal variations. In winter-times biogenic emissions are of minor importance, while they provide in summer times a major contribution to total VOC-emissions. During day-time biogenic emissions are much higher than at night-time. In the GENEMIS-project the LOTOS methodology has been adopted to calculate the temporal variation of biogenic emissions. As an example daily biogenic emissions for France and Spain are presented in figure 13 for the year 1990.

Figure 13: Daily natural emissions of France and Spain in 1990 (Source: GENEMIS)



c. Shortcomings of the biogenic emissions model

The estimation of biogenic emissions in Europe is very uncertain, because emission factors exist only for few species and existing emission factors are not very reliable.

Due to the lack of appropriate measurements in Europe, American emission factors had to be used in the past years, though it has been shown in several studies that these emission factors do not adequately represent the vegetation classes and climatic and geological conditions in Europe (Janson 1993, Steinbrecher 1994).

Moreover, the processes controlling biogenic emissions are not yet completely understood and additional factors like blossoming, stress behaviour, etc. are likely to have a major influence on emissions. Many species emit discontinuously and show different behaviours in different regions. Consequently, strong uncertainties have to be taken into consideration both for the calculation of annual VOC-emissions as well as for the temporal variations of emissions.

More detailed emission factors for biogenic emissions in Europe are being prepared in a cooperation project between EUROTRAC-BIATEX and GENEMIS. These emission factors are based on measurements performed in BIATEX and other projects in Europe and will be available in late 1995.

3.10 Temporal variations of VOC-profiles

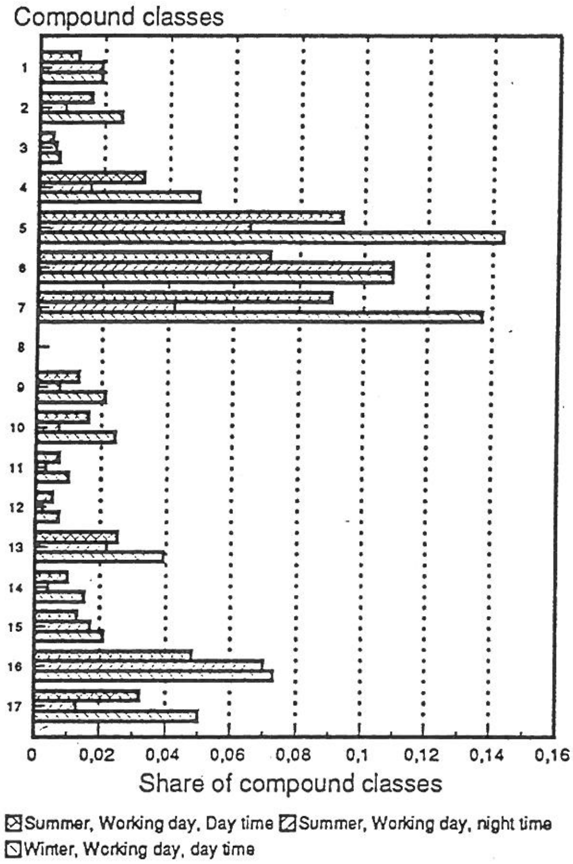
Atmospheric simulation models require detailed information on individual organic compounds or compound classes, while emission inventories currently only provide total VOC-emissions or NMVOC plus methane emissions. In the past standard VOC-profiles have been used by most modellers, assuming that total VOC-emission can be split into individual compounds or appropriate compound classes by generalized profiles. Such profiles have usually been applied for all countries and regions and for all periods.

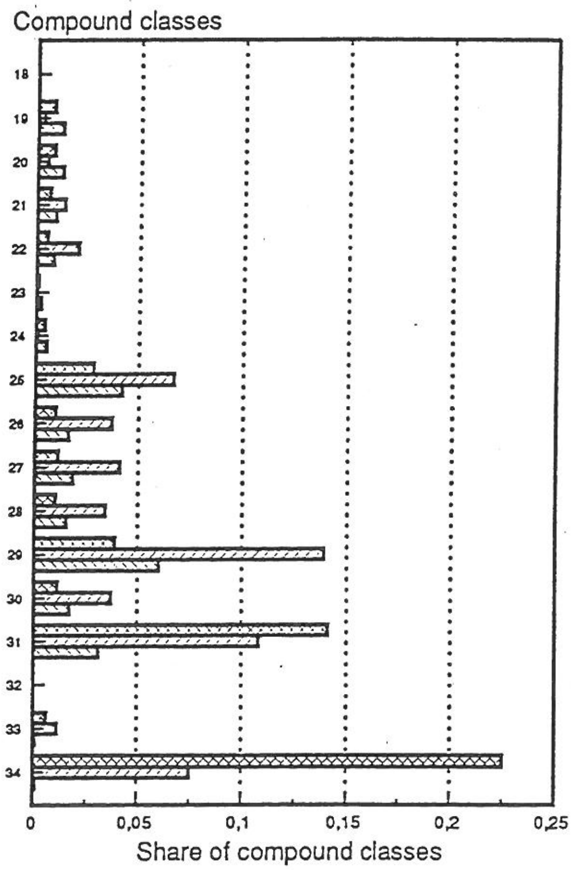
This assumption appeared to be unsatisfactory. Investigations in GENEMIS clearly showed that the varying composition of emissions from country to country and from hour to hour may lead to fundamentally different VOC-profiles. All sectors emit VOC-species in different shares and amounts. As individual sectors contribute different shares of emissions in different regions and contribute emissions according to very different temporal patterns, the resulting total speciation for the VOC-classes looks different from region to region and hour to hour.

An example of this effect is shown in figure 14 for RADM-2 VOC-profiles for a summer working-day at day-time, a summer working-day at night-time and a winter working-day at day-time in Germany. The relative share of compound classes to total VOC-emissions changes considerably at different times. These changes affect all compound classes and reach up to 300% for some classes. Some classes contribute much more at day-time, while others contribute stronger at night time. Therefore, at every hour a different mix of VOC-compounds is emitted.

These variations are likely to have an important impact on atmospheric chemistry. As all RADM2-classes reflect different chemical behaviour of the compounds assigned to these classes, different reaction chains and different reaction velocities will have to be considered and may lead to important effects in atmospheric transport and chemistry modelling. Certainly, it has to be considered that information about VOC-profiles is far from being satisfactory for many processes and regions in Europe. Uncertainties, therefore, are expected to be high. Nevertheless, it seems reasonable to recommend at least a distinction of day and night profiles for atmospheric modelling.

Figure 14: RADM-2 VOC-profiles for a summer working-day at day-time, a summer working-day at night-time and a winter working-day at day-time in Germany (Source: GENEMIS)





1: Methane
2: Ethane
3: Propane
4: Alkanes (r=0.25-0.50*10000*1/(ppm*min))
5: Alkanes (r=0.50-1.00*10000*1/(ppm*min))
6: Alkanes (r=1.00-2.00*10000*1/(ppm*min))
7: Alkanes (r>2.00*10000*1/(ppm*min))
8: Alkane/Aromatic Mix
9: Ethene
10: Propene
11: Alkenes (Primary)
12: Alkenes (Internal)
13: Alkenes (Prim/Int. Mix)
14: Benzene
15: Aromatics (r<2.00*10000*1/(ppm*min))
16: Aromatics (r>2.00*10000*1/(ppm*min))
17: Phenols and Cresols
18: Styrenes
19: Formaldehyde
20: Higher Aldehydes
21: Acetone
22: Higher Ketones
23: Organic Acids
24: Acetylene
25: Haloalkanes
26: Unreaktive VOC
27: other VOC (r<0.25*10000*1/(ppm*min))
28: other VOC (r=0.25-0.50*10000*1/(ppm*min))
29: other VOC (r=0.50-1.00*10000*1/(ppm*min))
30: other VOC (r>1.00*10000*1/(ppm*min))
31: Unidentified VOC
32: Unassigned VOC
33: Isoprenes
34: Terpenes

4 THE VARIATION OF TOTAL EMISSIONS IN EUROPE

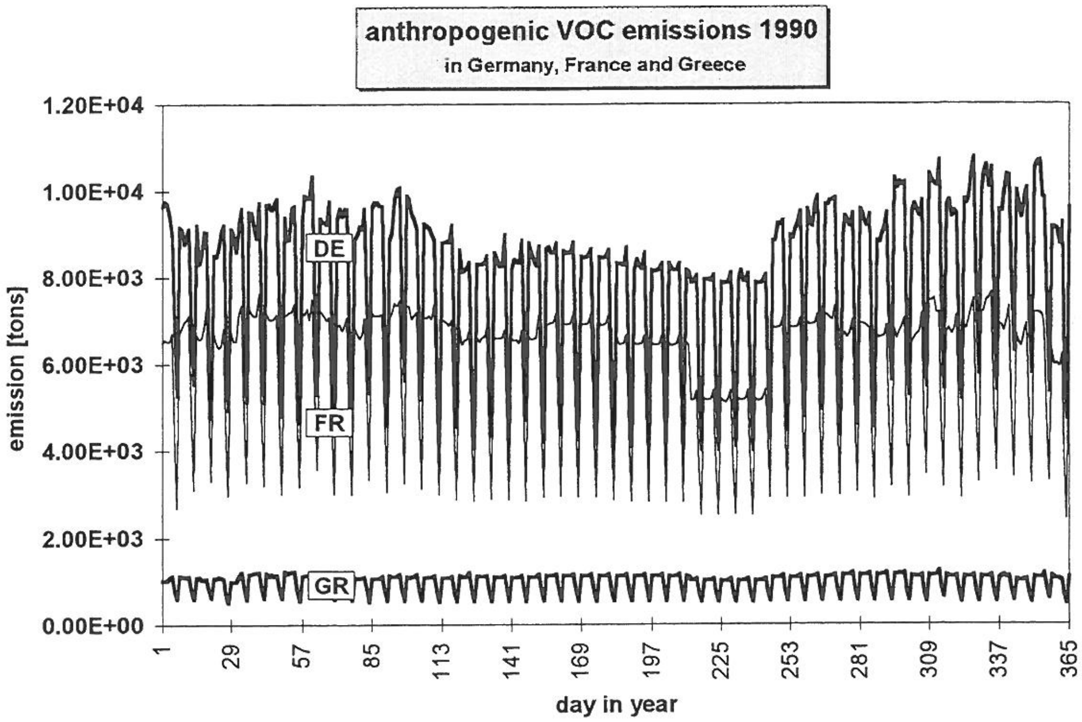
The temporal behaviour of emissions for each sector and the contribution of these sectors to total emissions differ for each country. Therefore, the temporal pattern of total emissions also show considerable differences for different countries and regions. In figure 15 total daily NO_x- and total daily VOC-emissions are shown for France, Germany, and Greece in 1990.

It is also important to note that total NO_x- and VOC-emissions do not follow the same temporal pattern. This is of major important for the simulation of atmospheric photo-oxidants formation, which are strongly dependant on the proportion of NO_x- and VOC-emissions. Consequently, these results will have an impact on emission reduction strategies, as different reduction approaches are likely to be most efficient in different regions.

A similar result has been achieved for hourly emissions over one week. In figure 16 total hourly NO_x-emissions of all main sectors are shown within 8 days of the JWC for large urban regions (Greater London, Greater Athens) and for very rural and little industrialized regions (Northern Jutland in Denmark and Alto Alentejo in the East of Portugal). It can clearly be seen that road traffic emissions have a major influence on total NO_x emissions. The contributions of other sectors like power plants, industrial combustion, and industrial processes, however, varies considerably from region to region.

In Greater London and Greater Athens the share of public power plant emissions is very low, because power plants are located outside of the city areas. Power plant emissions, however, are extremely high in Northern Jutland due to large power plants located in this region. In Alto Alentejo NO_x emissions are almost only caused by road traffic. According to these graphs the day-night variation reaches 4:1 in Northern Jutland, 5:1 in Greater London, 8:1 in Greater Athens and 12:1 in Alto Alentejo. These differences may have an influence on short term photo-oxidants formation, destruction, and deposition.

Figure 15: Total daily NOx- and total daily VOC-emissions in France, Germany, and Greece in 1990 according to GENEMIS and to LOTOS time-factors (Source: GENEMIS, LOTOS)



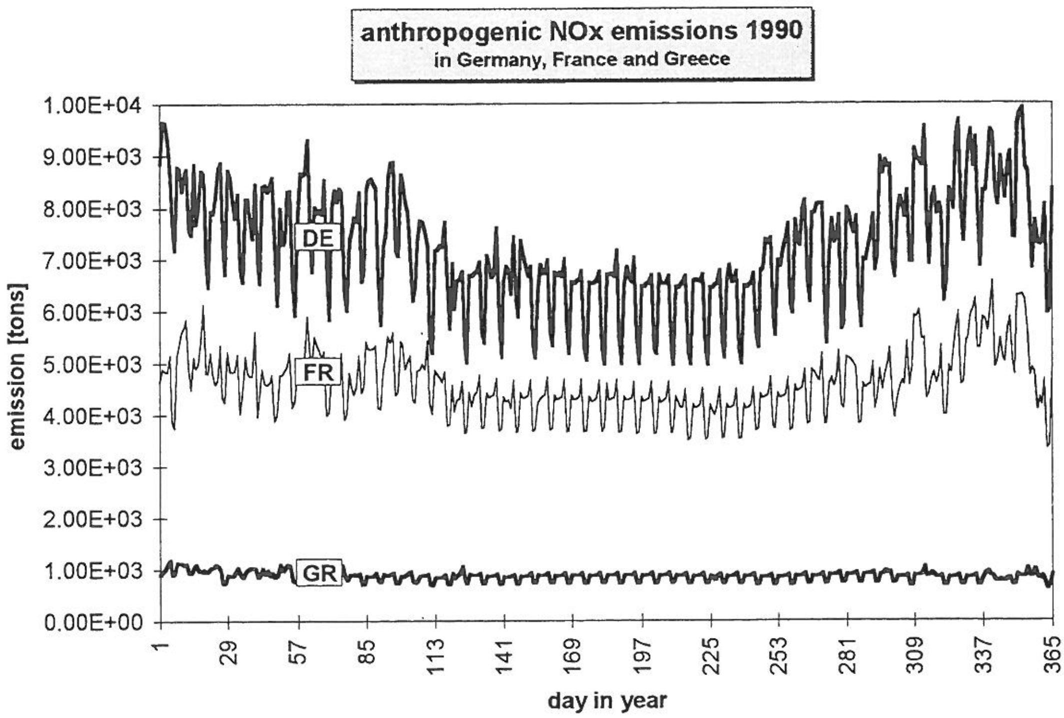
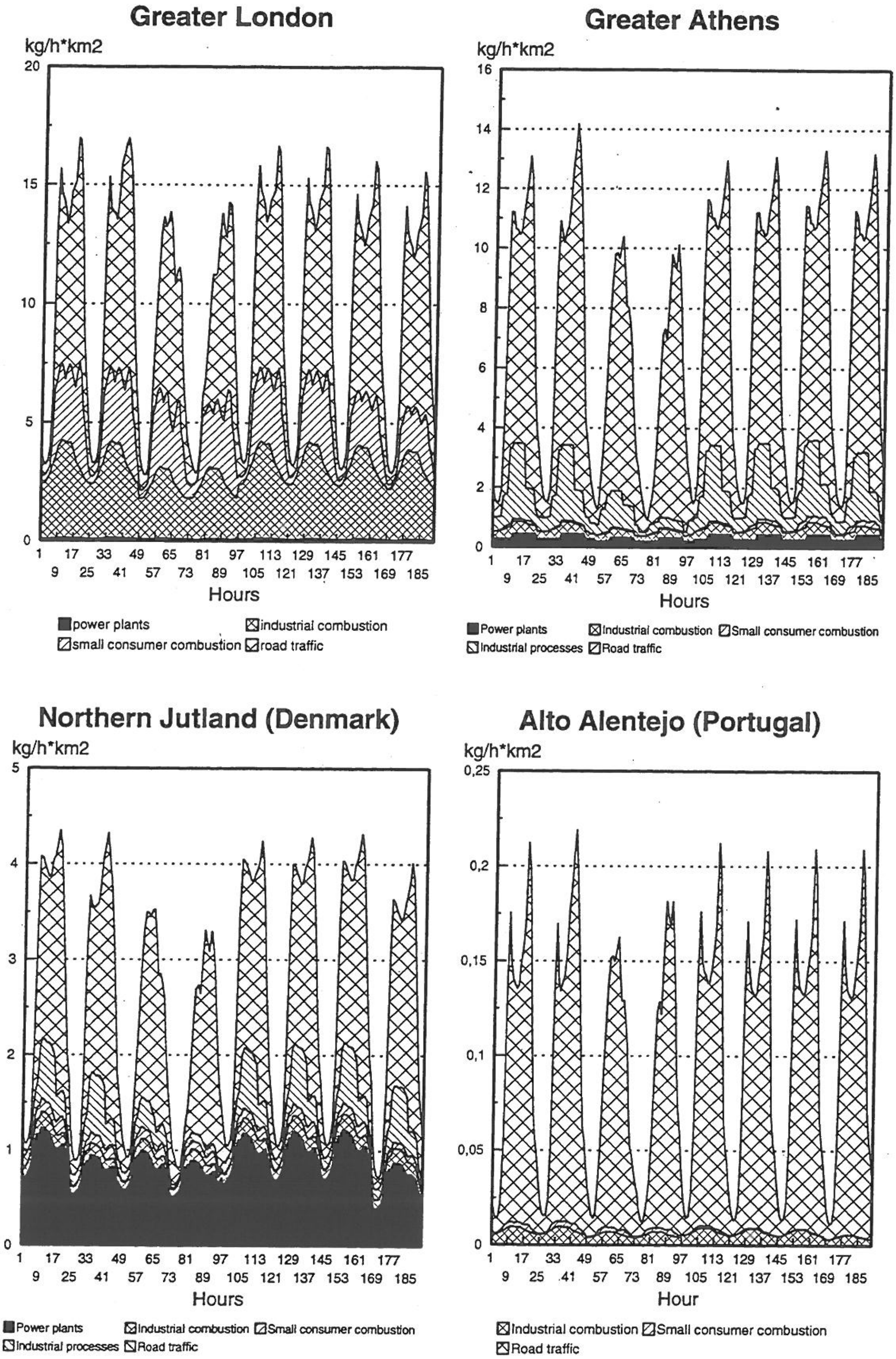


Figure 16: Total hourly NOx-emissions of all main sectors within 8 days of the JWC for big urban regions (Greater London, Greater Athens) and for rural and little industrialized regions (Northern Jutland in Denmark and Alto Alentejo in the East of Portugal; Source: GENEMIS)



5 CONCLUSION

Emissions from many major source sectors in Europe show strong temporal variations. Seasonal, daily and hourly variations often add up to several 100% deviation from average emissions. These variations should therefore be taken into consideration in atmospheric transport and transformation modelling. Though the availability of indicator data with high temporal resolution is limited and though large uncertainties are connected to the simulation of monthly, daily, and hourly emissions, the GENEMIS exercise has shown that:

- data and information describing the temporal variation of emissions are available for many countries for many sectors;
- models for the estimation of emission data with high temporal resolution have been developed and are available for many sectors;
- these models provide reasonable estimates of the temporal variation of emissions based on statistical and meteorological indicator data;
- these estimates can be considered more reliable and nearer to reality than simple and generalized temporal patterns as used in the PHOXA, LOTOS, EMEP, and other projects.

Furthermore, calculations within GENEMIS have shown that:

- the temporal variation of emissions varies considerably from sector to sector and region to region;
- the temporal variation of total emissions varies strongly from region to region and from country to country; generalized patterns applied to all European countries lead to considerable errors in many countries and periods;
- total emissions of different pollutants show very different temporal patterns and lead to changing proportions of NO_x- and VOC-emissions, which can affect photo-oxidant formation;
- the temporal variation of emissions strongly affects VOC-profiles; it is very likely that a variation of VOC-profiles will have an impact on atmospheric chemistry modelling.

The effect of these results on atmospheric modelling compared to modelling results based on less detailed data remains to be shown. It seems reasonable to assume that many atmospheric simulation models will only show limited sensitivity to the variation of emissions because of limited detail and limited resolution. However, more sophisticated models with high temporal, spatial, and vertical resolution, which have been developed and applied in the past years in several countries, are very likely to be sensitive to variations in the estimation of seasonal, daily, and hourly VOC and NO_x emissions. Therefore, it is reasonable to recommend the use of the best information available about the temporal variation of emissions to improve the quality and reliability of atmospheric modelling results.

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7 RELEASE VERSION, DATE AND SOURCE

Version: 1.0

Date: June 1995

Source: Lutz Lenhart, Matthias Heymann, Rainer Friedrich
Institute of Energy Economics and the Rational Use of Energy
Stuttgart University
Germany

PROCEDURES FOR VERIFICATION OF EMISSIONS INVENTORIES

BACKGROUND

An emissions inventory is the foundation for essentially all air quality management programs. Emissions inventories are used by air quality managers in assessments of the contributions of and interactions among air pollution sources in a region, as input data for air quality models, and in the development, implementation, and tracking of control strategies. The importance of emissions inventory data increases with advances in the sophistication of the models and other analysis tools used in air quality management, and as a result, the interest in emissions verification is widespread. The formation of the Task Force on Emissions Inventories and the Verification Expert Panel demonstrates the importance of these issues to U.S. and European programs. The principles of emissions verification are equally applicable to urban, regional and global scale analyses and verification issues and procedures apply on each of these scales.

It is recognized that within the context of the Verification Expert Panel, verification procedures represent those activities that can be applied to demonstrate the applicability and reliability of emissions inventory data for the specific air quality management projects they support. While routine quality assurance and quality control activities are verification procedures, it should be kept in mind that in the context of this chapter quality assurance and quality control do not cover all of the possible verification concepts. The overall quality, completeness and level of representativeness of emissions inventory data are, however, directly related to the verification concepts discussed here, and for that reason, planning and initial implementation activities related to quality assurance are discussed in some detail. Figure 1 is a simple diagram of the activities that are discussed in this chapter to promote inherent data quality and to facilitate emissions data verification exercises.

The objective of this work is to provide guidance related to the development of emissions inventory data and suggestions for procedures and techniques that can be used to assess the validity of the emissions data included in inventories. Since most emissions data are estimates, it is often difficult to derive statistically meaningful quantitative error bounds for inventory data. Frequently, it is possible, however, to provide ranges that bound the likely minimum and maximum for an emissions estimate or to develop a qualitative data quality parameter to assess the relative confidence that can be associated with various estimates.

Figure 1 **Simple Flow Diagram of Inventory Validation Programs**

It is useful to define some key terms relative to the inventory verification process that will be used throughout the remainder of this chapter. Often individual inventory developers and/or inventory users will define these terms in the context of their own applications or goals. Therefore, the following definitions of key terms are provided to promote common usage in the context of this chapter.

Accuracy — Accuracy is a measure of the truth of a measurement or estimate. The term accuracy is often used to describe data quality objectives for inventory data, however, accuracy is hard to establish in inventory development efforts since the truth for any specific emission rate or emissions magnitude is rarely known.

Precision — The term precision is used to express the repeatability of multiple measurements of the same event. In experimental applications a measurement or measurement technique could have high precision but low accuracy. The term precision is also used to describe the exactness of a measurement. The term precision is not well suited for use in emissions inventory development.

Confidence — The term confidence is used to represent trust in a measurement or estimate. Many of the activities discussed in this chapter are designed to increase the confidence that inventory developers and inventory users have in the databases. 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 applied to problem solving.

Reliability — Reliability is trustworthiness, authenticity or consistency. In the context of emissions inventories reliability and confidence are closely linked. If the approaches and data sources used in an inventory development project are considered reliable, then users will have an acceptable degree of confidence in the emissions data developed from those techniques.

Quality Control — Quality control activities are those procedures and tests that can be performed during the planning and development of an inventory to ensure that the data quality objectives are being met. These activities may include criteria tests for data on operations, completeness criteria, or averaging techniques for use in developing default parameters. Quality control activities are generally applied by the developers.

Quality Assurance — Quality assurance describes the activities that are completed after the development of a product, usually by an independent party to verify that data quality objectives were met and that the product conforms to specifications. In experimental programs, audits with standard instruments and standard measures are used to establish the reliability of the experimental procedures. In emissions inventory development, however, few such standards exist. One effective activity discussed in this chapter is the use of an independent review team of experts to monitor the developments as progress is made on the inventory. The review team can identify alternate approaches and further documentation to enhance the credibility and reliability of the emissions estimates developed.

In the context of emissions inventory development, and in general use in this chapter, quality assurance is used to represent the sum of activities that are implemented to ensure the collection and presentation of high quality data.

Uncertainty

Uncertainty is a statistical term that is used to represent the degree of accuracy and precision of data. It often expresses the range of possible values of a parameter or a measurement around a mean or preferred value.

In some applications involving emissions inventory preparation, it is possible to describe in statistical terms the relative accuracy of an estimate and ultimately provide a preferred estimate or central value and a percent range that bounds the actual value. Such opportunities are frequently limited to sources that have requirements for extensive monitoring, through continuous emissions monitors, to verify emissions rates. More often, however, the data that is available is insufficient to develop statistically based quantitative measures of the data accuracy. In these cases, subjective rating schemes are often used to describe the relative confidence that is associated with specific estimates.

In the context of this emissions verification chapter, uncertainty is used to represent any of several techniques or procedures that can be applied to establish a ranking or numerical scale to compare the reliability of and confidence in the emissions estimates. In their simplest forms, such ranking procedures are subjective evaluations that reflect the accuracy or reliability of estimates based on the opinion of the developer. In other applications the evaluation is guided to a specific attribute of the data. For example, the completeness, coverage, or specificity may be of special importance and developers may be asked to rate the final emissions estimates relative to one or more of these components that can affect the quality of the estimates.

Validation

Validation is the establishment of sound approach and foundation. The legal use of validation is to give an official confirmation or approval of an act or product. Validation is an alternate term for the concept of verification as used in this context.

Verification

The term verification is used to indicate truth or to confirm accuracy and is used in this chapter to represent the ultimate reliability and credibility of the data reported.

In the context of this chapter verification refers to the collection of activities and procedures that can be followed during the planning and development, or after completion of an inventory that can help to establish the reliability of the inventory for the intended applications of that inventory. In this context, the representativeness of the final data for the intended applications is of more importance than the absolute accuracy of the final emissions estimates. The procedures identified as verification activities will be applied to establish confidence that the data are sufficient in terms of coverage, completeness and reliability to guide decision makers to effective policy options.

These verification approaches can be used to understand the strengths and weaknesses of completed inventories relative to the desired applications of the data. In this context, verification procedures should be useful in directing research to improve the underlying data or procedures used to develop emissions estimates in future programs.

Transparency — In the context of this chapter, transparency is used to represent the condition of being clear and free from pretense. The use of the term implies that data collected and reported by different agencies will be similar and, therefore, easily understood by other parties and comparable to the data presented by the other parties.

Compliance — Compliance is the act of conforming or yielding to a specified norm or protocol. In the inventory development process, compliance may indicate conformity to development protocols or international agreements. In this sense the compliance issue can be thought of as verification of adherence to these established and agreed norms. The concepts of verification discussed in this chapter, however, are not intended to support the idea of compliance to norms or international protocol.

In the context of the Task Force on Emissions Inventories, the concepts of verification can be applied on two distinct levels characteristics of two different kinds of applications. One is for analytical applications, where accuracy and small uncertainty bounds are preferred to establish credibility in modeling results and in calculations of emission reductions and cost analyses. The second is for political applications, where adherence to agreed protocol and justification of the methodologies applied in a national effort are important to satisfy international agreements. The intent of this chapter is provide guidance and suggestions that will help inventory developers prepare high quality data for analytical pursuits and, therefore, the discussions favor the scientific applications over the political applications. The reader should, however, consider and be sensitive to all of the possible ramifications of emissions inventory data when constructing the inventory.

Table 1 presents a summary of the importance of the terms defined above as they relate to the analytical and political applications of inventories and the verification process. Table 1 is presented as a general summary and the reader is cautioned that in specific programs the importance of any of these terms may be more or less stringent than that presented.

Organization of the Chapter

The chapter begins with a background discussion of the approaches for emissions inventory development and the role of emissions inventory data in air quality management activities. Considerations applicable in the planning phases of inventory development efforts that can improve the reliability of inventory data are discussed. The remainder of the chapter discusses specific analyses that can be performed to assist in validating emissions inventories. All of the activities that comprise emissions inventory verification concepts can be categorized in one of the major groupings listed below.

- Documentation of Data and Procedures
- Application of the Data
- Comparison of Alternative Estimates
- Uncertainty Estimates
- Ground Truth Verification

This discussion presents an overview of the verification procedures that can be implemented before, during, and after an emissions inventory is prepared. The success of these procedures is dependent on the overall quality of the data used in the development of the inventory and the procedures used to construct and maintain the inventory data.

TABLE 1. IMPORTANCE OF TERMS IN MAJOR APPLICATIONS

TERM	ANALYTICAL APPLICATIONS	POLITICAL APPLICATIONS
Accuracy	Very important, inaccurate data can lead to erroneous scientific conclusions; can affect credibility of policy decisions and cost/benefit analyses	Accurate data is always preferred for any application, however in some political applications adherence to protocol could be more important; accuracy of data should be within the constraints of the proposed control programs
Precision	Very important for comparative analyses and for repeatability	Numbers generated with accepted protocol should be comparable and repeatable, but for applications it is not so important
Confidence	Not important for scientific purposes if all quality control and quality assurance standards were achieved	Important in terms of following established protocol, empowers the developer and users in international programs
Reliability	Important in that it implies usefulness and credibility	More important as a reflection of method followed than for accuracy of specific numbers
Quality Control	Very important, this is a necessary part of data gathering and processing	Important as it relates to ensuring the adherence to accepted procedures and methods
Quality Assurance	Very important, in the scientific arena QA defines technique and qualifies results	Important as it relates to ensuring the adherence to accepted procedures and methods
Uncertainty	Important, the error inherent in the databases used to generate emissions data should be known to understand the error in final numbers	Important, uncertainty in policy applications translates directly to confidence and reliability concerns,
Validation	Not important for scientific applications, but is needed when data or analyses are used in policy applications	Very important, official acceptance is the critical test in the political arena
Verification	Very important, if the scientific applications of the inventory are satisfied then the effort was a success	Important only in a relative sense that data can be repeated and that two data sets can be compared
Transparency	Only important if analyses extend into neighboring countries	Very important to demonstrate adherence to common protocol
Compliance	Important if no standard procedures exist, but is relatively unimportant if methods followed are trusted	Very important in terms of adherence to agreed protocol or methods

DOCUMENTATION OF DATA AND PROCEDURES

The activities discussed in this section are related primarily to the planning stages of an inventory development program to ensure that the resulting inventory and quality assurance program applied to the inventory will be properly documented. These activities are completed to ensure that the finished inventory will be useful for the intended projects that depend on the inventory and to facilitate the application of the inventory in future programs. These records establish the strengths and weaknesses of the inventory and can be assessed at later times to determine whether the current inventory is suitable for other applications or whether major revisions or modifications are needed to support these other applications. The major considerations discussed are itemized below:

- defining data quality objectives (DQOs)
- selecting inventory development procedures and assumptions
- defining quality assurance procedures
- planning and conducting an independent review
- conducting QA/QC, documentation

The principal objective of the planning phases is to define the needs of the users of the final inventories and to develop a set of data requirements and data quality objectives that are consistent with those needs. Data quality objectives (DQOs) can be presented as a formal written component of the inventory research plan or developed informally through consideration of the project objectives. The DQOs specify the geographic scope, the spatial and temporal resolution, and the pollutant and source coverage, and, in some cases, the accuracy criteria to be applied to inventory components. The primary purpose of DQOs is to guide the inventory development team in the completion of a final inventory database that will fill the needs of the intended user community.

The development of DQOs is directly related to the specificities of procedures and assumptions applied in the specific effort. The specific development effort, however, is also influenced by the resources and time constraints of the project. In some cases, some of the needs of the user community may not be achievable. In these cases, coordination and cooperation between the inventory development team and the intended users is required to agree on compromises and other procedures to ensure the best possible inventory to support the application program.

Another important part of the inventory development planning process is to specify quality assurance procedures.[1] The QA plan specifies the types of data that will be collected, the procedures that will be used to assess the applicability of those data to the program, the steps that will be taken to correct or modify questionable or incorrect data, the procedures for documenting data corrections or modifications, and the procedures that will be applied to process the data into formats that are consistent with the inventory applications. This QA plan must address implementation and documentation approaches that are consistent with the DQOs and the resources that are available. The QA plan must also contain a contingency plan that describes an alternate approach in the event that the specified approach can not be completed. When resources permit, an independent review panel or third party review may be useful for large, complex, and high visibility programs. Such a procedure can be used as an audit, with a purpose similar to that of an laboratory or systems audit in experimental programs. The findings of a well respected panel of experts can add credibility to a well organized inventory development effort. The selection of participants, and the direction for their activities must also be considered with the DQOs established in the early phases. It is often helpful to have this independent panel available throughout the inventory development process, from planning phases through completion and delivery of the final product.

APPLICATION OF THE DATA

The intended application of the completed inventory is the principal consideration when preparing and implementing an inventory verification exercise. The two primary uses of emissions data and emissions inventories are listed below:

- assessments of the specific air quality problems in an area and identification of the most important sources and source categories that influence those air quality problems;
- input for regulatory activities associated with policy-making, including air quality modeling activities and the design, implementation, and tracking of the effects of air quality control strategies.

These major uses of emissions inventory data and the specific needs for inventory verification programs related to each of these uses are summarized. In some cases, it is possible to use data and analyses developed while conducting these activities for emissions verification exercises. The ultimate test of the quality and reliability of an emissions inventory is an appraisal of how well it has supported the goals of the program or programs to which it was applied.

Assessment Studies

The requirements for specificity and accuracy of inventory data are less stringent for assessment studies than for the other applications of inventories. Top-down inventory development methodologies are usually suitable for application to assessment studies and annual emissions estimates for an entire industrial sector are often adequate for these purposes. Assessment studies, are generally intended to provide the background understanding of the primary causes of the air quality problems being evaluated. One example of an assessment type inventory is the preparation of annual trends inventories. In these applications, it is not necessary to develop estimates for specific sources; it is usually more suitable to develop estimates for large industrial sectors such as electric power production and chemical manufacturing operations.[2] Another example is an assessment study to define the ten largest source categories of VOC and NO_x emissions in an urban area. For example, estimates of total emissions of NO_x resulting from fuel combustion can be estimated from total energy demand estimates, and VOC emissions can be estimated from raw material feed rates. In this type of study it would not be necessary to represent the emissions for specific sources. Similarly, total emissions of VOC, CO, and NO_x from mobile sources could be estimated from vehicle registration records, total regional fuel sales data, and assumptions about the fleet average fuel economy and would not require specific information on road type and speed classifications. These types of analyses are useful to confirm that the largest or otherwise most significant sources have been identified.

Regulatory Activities and Policy Making

Regulatory activities are performed by environmental agencies to define programs and policy options to reduce the negative impacts caused by air pollutants. The development of an air quality control policy usually uses an emissions inventory to estimate the potential for mitigating those problems and the costs that are associated with the control options. For example, emissions inventories facilitate the understanding of the following regulatory issues:

- relative importance of local/regional/national emissions and the impact of air contaminants that are transported from other regions
- the relative importance of biogenic or other naturally occurring sources to the anthropogenic sources in an area
- the contribution of various anthropogenic source categories to the overall controllable emissions burden

In some cases, regulatory actions and policy options are derived from model results. The requirements for emissions inventories in air quality modeling applications, and the methodologies and activities required to validate these inventories are significantly more demanding than for assessment inventories. Air quality models require meteorological and emissions input data and are used to simulate actual atmospheric conditions that result in air quality problems. Thus, for application to air quality modeling programs, representative inventories of the appropriate chemical species are needed at spatial and temporal scales consistent with the model formulation. It is necessary to develop the baseline inventory data at source-specific detail to represent the species, spatial, and temporal variability associated with the emissions.

Air quality problems, such as urban ozone formation, are influenced by local meteorological factors including wind speed, wind direction, temperature, and sunlight intensity. These factors are variable on hourly time scales, and therefore, emissions data is required at hourly intervals to adequately simulate these processes. The emissions input data must also be resolved spatially to represent a regular grid pattern covering the modeling region. Since emissions data are commonly estimated at the annual-level, and at a convenient geopolitical distribution, techniques must be applied to convert the emissions estimates into the appropriate spatial and temporal resolution. VOC, NO_x, and particulate emissions data must also be resolved to represent the source specific chemical distribution, to adequately track the complex chemistry that occurs throughout an urban area or other larger regional area.

Examples of regulatory programs that rely directly on emissions inventories are the Acid Rain Control System in the United States, permit fees and emissions trading concepts, and emissions offsets programs to compensate for the influence of new sources in areas with air quality problems. The Acid Rain Control Program established a maximum emissions allowance for all of the major sources of SO_2 and requires continuous emissions monitoring to demonstrate that each source is in compliance with its limit. Permit fees and emissions trading need a base from which to conduct transactions, and emissions offsets programs are dependent on consistent emissions inventory processes over different source types.

The use of an inventory as a component of a major research program or in response to a requirement of an international convention can benefit from these types of analyses in a verification context. Again the purpose of the resulting inventory is an important consideration in the design and implementation of such a verification exercise.

Examples of Data Applications for Emissions Verification

Some examples of data applications that can be used in the emissions verification process are discussed in the following paragraphs. This discussion does not include all possible activities related to the applications of inventory data that could be used in the verification process.

Frequently, whether the inventory is being used for an assessment or modeling purpose the largest sources of a particular pollutant are summarized. This source list can be reviewed to see if it is reasonable. That is, is it possible that the sources on the list are the largest sources. These types of reviews can sometimes identify coding errors, or otherwise incorrect emission factors, activity data units or other correctable data errors.

Some actual examples that were identified during the review and assessment of the 1985 NAPAP inventory are summarized here, but other examples from other programs are widespread. During a review of the largest SO_2 sources, one source with incorrect fuel use units was identified. Use of the incorrectly coded units resulted in orders of magnitude error in the final emissions estimate. Review of the largest NO_x sources indicated that orchard heaters were one of the most serious sources in the southeast and Florida. This problem resulted from the use of an inappropriate emission factor. Cattle feedlots were found to be one of the largest sources of VOC emissions when these approaches were applied to the VOC database. Identification of these anomalies and proper review based on expert knowledge can help to prevent inappropriate policy decisions.

Another good example of using these kinds of application based data reviews is to calculate a rule effectiveness value from existing data. The rule effectiveness value can be used to describe the amount of control that is actual realized through the adoption of an emissions limitation regulation. Sometimes small sources within a regulated source category are exempted from a rule to avoid an unrealistic economic burden or simply because the emissions are so low that control would result in negligible affects. The overall uncontrolled emissions based on the total production of the source type can be compared to the actual emissions reported in the inventory to calculate the rule effectiveness. If that number is too high the analyst can assume that the inventory represents an unrealistic emissions total.

Although modeling results often do not match monitoring data exactly in either temporal or spatial performance, they do frequently provide a result that is conceptually similar to the observed monitoring data. In other words, a model can predict that the pollutant maxima is in the same area as the monitored maxima, and that the general distribution of the pollutant under many scenarios is similar to the measured distributions of the pollutant. Whenever general agreement between model results and monitoring data cannot be shown, the researcher should be concerned that the emissions of meteorology are not representative of the system.

Further modeling related activities can be reviewed under an emissions inventory verification program. Spatial distributions of emissions can be reviewed to verify that high source densities are in and near cities, that sources are not located over water bodies, and that emissions patterns reflect the population and transportation patterns. Temporal variations can be reviewed in this way as well. Checks can be performed to see that higher emissions occur during weekdays, and during normal working hours to help identify potential anomalies. Sometimes spatial or temporal distributions are selected as surrogates for a particular source and after application the combination will result in inappropriate emissions distributions.

Various regulatory activities require emissions inventories of different levels of specificity and accuracy. Many of the same approaches mentioned for assessment and modeling studies can be applied in regulatory applications. The primary concern in regulatory programs for application to policy making is to establish a solid base line of data and develop analytical results that are specific and suitable for the regulatory issue. The specificity and detail represented in data need to be targeted to the process covered by and the scale of the regulatory application. For example, regional and global policy issues can be treated with relatively aggregated data, whereas population exposure and risk analysis require more detailed and specific data.

COMPARISON OF ALTERNATE ESTIMATES

Various alternate approaches that exist for estimating emissions magnitudes from selected source categories can also be used to derive independent estimates of emissions. These estimates can then be compared to each other to infer the validity of the data based on the degree of agreement among the estimates. Such a process can be used to facilitate transparency among databases developed through different approaches. For example, statistical comparisons of aggregate emissions totals may be applied among countries or regions of countries that have similar population and economic status. The convergence of estimates derived through alternate emission development procedures adds reliability and validity to the final reported estimates. Table 2 lists some of the opportunities for data comparison studies that can provide a basis for determining the overall quality of emissions estimates.

The following discussion summarizes information on the requirements of spatial, temporal, and species resolution of inventory data for modeling applications and provides some approaches that can be used to evaluate the quality of resolved inventory data. The verification needs for modeling inventories are dependent on the physical domain of the modeling exercise, the chemistry simulated by the model, and the specific science and policy applications that the model results will support. Specifically, these verification needs must address the data sources and methodologies that are available to transform annual and regional estimates into the detail required to support the modeling exercise. Table 3 summarizes some of the issues related to inventory allocation procedures and of modeling inventories.

TABLE 2. SUMMARY OF DATA COMPARISON OPPORTUNITIES IN EMISSIONS INVENTORY APPLICATIONS

DATA COMPARISON TYPE	EXAMPLES
Alternate estimation methods	• Emissions magnitudes based on raw material feed versus product • Emissions magnitudes based on alternate measures of the inherent activity
Top-down versus bottom-up methodologies	• National- or regional-level estimates versus source-specific totals within source categories
Emission density comparisons	• Aggregate estimates for per-capita, per-employee or per-area compared to total emissions from all facilities in a source category • Aggregate emissions densities compared to similar estimates from other countries or regions
Emission factor comparisons	• Source-specific emission factors compared to default or average factors • Uncontrolled emission factors with average level of control to controlled emission factors • Emission factors based on alternate measures of the inherent activity
Control total comparisons	• National totals compared to sum of all source categories or facilities within source categories • Summed emissions totals from detailed inventories compared to national totals in trends analyses • National totals compared to national totals of nearby countries corrected for population and economic status
Completeness checks	• Comparison to earlier inventories to check that all significant sources are considered • Checks that all important source categories are considered • Checks that all important data elements are included for facility records
Consistency checks	• Internal consistency for facility data records • Consistency of methodology for source categories • Consistency of methodologies between countries in multiple country inventory development

UNCERTAINTY ESTIMATES

Experimental measurement data is commonly reported as average or preferred values with an associated error bound expressed in either absolute units or as a percentage of the preferred values. The standard techniques for estimating experimental uncertainty depend on the known accuracy and precision of the measurement methods employed in the experiments. Since the accuracy and precision specifications of the data elements associated with emissions estimates are rarely known, the application of these standard approaches for developing uncertainty are, in general, less straightforward than for experimental analyses.

There is a need, however, for reporting quantitative error bounds associated with emissions estimates. Uncertainty estimates for emissions data are important for assessing both the inherent uncertainty of the emissions estimates for individual facilities and the range of emissions magnitude represented by all sources in a study area. The uncertainty estimates for individual facilities help to understand the likely impacts of source-specific control options while uncertainty estimates for a collection of sources covering larger areas help to assess the overall quality of the emissions data and the relative quality between the estimates of specific pollutants. While the uncertainty technique discussed here[3], and others that have been presented elsewhere,[4,5] are useful for application to well-characterized sources, they are not generally applicable to most sources of air pollutant emissions. Our current understanding of the effects of the estimation assumptions on individual facilities and the effects of assumptions inherent in the emissions allocation procedures has not yet advanced to the point that allows routine uncertainty analyses of completed inventories.

It is possible to apply the techniques for classical uncertainty analyses for essentially any emissions estimate for any source category, if the inventory developers are willing to assign a range or some other quantified assessment of the error in the input parameters used to estimate emissions. If the developers are comfortable with estimated error bounds for the activity parameters, feed rates, temperatures, control efficiency and other factors that affect the final emission rate, these estimates can be applied to derive a final uncertainty estimate in the emissions estimate. Efforts to improve the procedures for such analyses are continuing in Europe and the United States.

TABLE 3. VERIFICATION ISSUES FOR DIFFERENT ALLOCATION TYPES

Allocation Type	Examples of Verification Approach	Problems or Issues That Can Affect Verification
Spatial Allocation	• Comparison of alternate allocation file surrogates	• Lack of suitable alternate surrogates • Not quantitative
Temporal Allocation	• Comparison of actual or reported operating data to surrogate operating profiles • Matching allocation profiles to typical work schedules, or density schedules or seasons	• Limited options for comparison distributions • Not quantitative • Often neglects daily temperature effects
Species Allocation	• Measured species profiles • Engineering assumptions • Mass balance considerations	• Many potential species not measured or estimated • Specific sources can vary significantly in source makeup • Not quantitative

Sensitivity studies used to test model predictions over the likely range of emissions to require an estimate of the extremes of the actual emissions range. Ideally, the sensitivity of model predictions to emissions inputs would address the individual components that contribute to the variability of the emissions. These results would assist both modeling and inventory development researchers to target the most critical issues for further research and improvements. The ultimate value of sensitivity studies is in the analyses of regulatory and policy options. If the estimated spread in emissions is large, it can be difficult to identify the most efficient option. For example, analyses at one extreme of VOC and NO_x emissions estimates may suggest NO_x control while analyses at the other extreme may suggest VOC control. The lack of quantifiable uncertainty bounds often leaves policy decision makers with difficult choices and limited options.

Classical Uncertainty

An approach to estimate uncertainty that relies on simple statistics including the standard deviation, the coefficient of variation, and the 90 percent relative confidence interval has been applied in the NAPAP program.[3] The standard deviation (S.D.) is a commonly used statistic that describes, quantitatively, the spread of data points in a population of measurement data. The coefficient of variation (C.V.) is a measure of the standard deviation relative to the mean value (i.e., C.V. = S.D./mean). The 90 percent relative confidence interval is used to define the limits that include 90 percent of all possible measurements in a population assuming that the distribution of the measurements is a normal distribution. In a normal distribution, 90 percent of the possible measurement values lie within a range bounded by $\pm$ 1.64 times the standard deviation.

Simple statistical approaches based on standard deviations and confidence intervals are based on the assumptions that the spread of possible results can be represented by a normal distribution and that the parameters estimated do not vary significantly with time. Alternate approaches based on distribution free statistical procedures that do not require these assumptions have also been presented.[4,5,6,7]

In summary, procedures for estimating emissions uncertainty have only recently been made available for specific, well-understood emissions sources and the specific pollutants that are unmistakably associated with those sources. While these techniques are useful to assess the relative accuracy and validity of the aggregate emissions estimates, they have not yet evolved to the level where they can be rigorously applied to sensitivity studies of photochemical air quality models and other more detailed analyses associated with emissions control options and control strategy development. Further efforts are ongoing and opportunities are being explored for analyses that can be used to evaluate the validity of an emissions inventory in terms of its influence on air quality analyses.

Data Quality Ratings

Emissions inventory estimates are often calculated as functions of process rates, manufacturing units, control technologies, and factors for spatial, temporal, and species allocation. Estimates of each of these parameters are often based on a small number of measurements and the estimate is then universally applied to all sources within a given source category.

Differences in operating characteristics, maintenance and repair procedures, and in some cases climate and local weather conditions can affect the actual emission factor and control efficiency as applied to individual sources.

Spatial allocation of point sources is generally known with a great deal of accuracy from plant-specific location data, but the spatial allocation of area and mobile sources usually requires the application of spatial allocation surrogates that often do not reflect the variability in those activities resulting from personal lifestyles or other external influences. Similarly, surrogates of temporal operating characteristics are often applied to allocate emissions to seasonal, daily and hourly levels when specific operating data are not available. Species allocation factors are the largest source of uncertainty in these applications, and only limited information is available to assess these uncertainties. In general, uncertainty estimates based on the techniques discussed here have not been developed for highly resolved species inventories, because the information to complete these analyses is simply not available.

Therefore, a meaningful measure of the overall reliability of an emissions inventory can sometimes be developed by the application of a data rating scheme. Rating schemes can have different formats, but each sets up some arbitrary scale that is applied to score individual emissions estimates at the appropriate level of aggregation. Several rating schemes have been discussed in the context of the UNECE EMEP Task Force. Each of the schemes is briefly summarized below.

The U.S. EPA has long used a rating system for its preferred emission factor listings included in its AP-42 document.[8] This technique uses a letter rating system of A through E to represent the confidence in emission factors from best to worst. In this system A factors are based on several measurements of a large number of sources, and E factors are based on engineering or expert judgement. The U.S. EPA has recently expanded this approach to include a letter based rating of the emissions estimate as well as for the emission factor. While there are some guidelines for the assignment of the letter score, this approach is largely subjective.

A similar method has been used in the United Kingdom for assessing the overall quality of emissions estimates.[9] In this approach letter ratings are assigned to both emission factors and the activity data used in the emissions estimates. The combined ratings are reduced to a single overall score following an established schedule. The emission factor criteria for the letter scores are similar to those applied in the U.S. EPA's approach and scores for the activity data are based largely on the origin of the data. Published data either by a government agency or through an industry trade association are assigned C ratings and extrapolated data based on a surrogate would receive an E rating.

The IPCC has included a rating scheme in its guidelines for reporting of greenhouse gas emissions through international conventions.[10] This scheme uses a different approach. For each pollutant associated with major source categories a code is specified to indicate the coverage of the data included in the estimate. The codes indicate if the estimate includes full coverage of all sources or partial coverage due to incomplete data or other causes. Additional codes can be specified to indicate if the estimate was not performed, included in some other category, not occurring or not applicable. An additional rating is then applied to each pollutant for each source category to indicate the quality assessment of the estimate as either high, medium, or low quality. Two additional ratings are requested that apply to the source categories without reference to specific pollutants.

These ratings cover the quality of the documentation supporting the estimates, rated as either high, medium, or low; and a rating to indicate the level of aggregation represented in the estimate. The possible choices are 1 for total emissions estimated, 2 for sectoral split and 3 for a sub-sectoral split. This rating scheme has more detail but retains a simplicity that allows the analyst to quickly review the quality ratings and to compare the quality ratings to other estimates.

Another rating approach has been developed and is being used by researchers in the Netherlands.[11] This approach recognizes the difficulties in getting agreement from several organizations in international efforts on the specific needs of emissions data quality and on definitions of data acceptability criteria. In this approach two specific issues are addressed concurrently in the rating scheme. The first is an assessment of the accuracy or uncertainty in the emissions estimate, and the second is an assessment of whether decision makers have confidence in the application of the estimates for regulatory and policy activities.

In this approach two scaling indicators are applied to represent these two concerns. The first is a letter grade from A through E that indicates the inventory developers assessment of the overall quality of the estimate. A ratings imply the highest quality and accuracy and E ratings imply that the estimate is an educated guess. The second rating scale applies a letter code to indicate the purpose for which the estimate was prepared and offers the policy maker a quick assessment of the reliability of the estimate for a given application. These rating categories and their associated applicability are listed below.

Applicability Rating	Description
N	National Level
R	Regional Level
L	Local Level
I	Industry Level
P	Plant Level

This indicator is meant to provide information to the user to enable judgment of the level of aggregation put into the estimate. For example. when an emission factor is based on national averaged numbers and therefore aimed at estimating the national total emissions, it is assigned a rating of "N", and the user would be cautioned against the application of this factor for any specific plant, or for only one section of a country where conditions may be different. Likewise estimates based on plant level data, with a rating of "P", would not be used with high confidence to estimate the regional total emissions for an emission sector.

One more quantitative approach to address this need is being developed by the Office of Research and Development of the U.S. Environmental Protection Agency.[12] In this approach a numerical value is associated with the quality of the various components or attributes of an emissions inventory. This technique, called the Data Attribute Rating System (DARS), seeks to establish a list of attributes that can affect the quality or reliability of the emission factor and activity data associated with the emissions estimate for any given source category. A numerical scale is used to rank these attributes in a relative priority against a set of criteria selected to represent the reliability of each attribute estimate. This procedure will allow a comparative assessment of the overall quality of the alternate emissions estimates for a specific category or for a group of high priority source categories in an urban or regional inventory.

A detailed approach based on these concepts is currently being developed and further information will be available during 1994.

Systematic Error and Bias

There is also the potential for systematic error or bias in the emissions estimates. Bias results when one of the parameters used in the emissions estimation algorithm is based on unrepresentative data or does not consider some essential component of the emissions process. Bias in aggregate emissions estimates can also be caused by the failure to consider all of the sources or source categories that contribute emissions in an area. Systematic error in emissions estimates is difficult to predict and the effects of the bias introduced in emissions estimates as a result of systematic error can have significant effects on air quality analyses that rely on emissions inventories.[13]

GROUND TRUTH VERIFICATION

The implementation of the procedures and activities discussed in the preceding sections of this chapter will provide the basis for the development of a well-documented emissions inventory database. The application of techniques to establish a likely range for the final emissions estimates, and the methodologies for the estimation of uncertainty can assist in a qualitative assessment of the representation and relative accuracy of the inventory data.

Ground truth verification involves techniques that make direct comparisons between emissions estimates and some other known quantity that is related either directly to the emissions source or indirectly to the underlying process that results in emissions. While ground truth verification procedures can be resource intensive they will often provide the most powerful and quantitative method for data validation and should be incorporated into emissions inventory development programs whenever possible. Although this discussion of ground truth verification techniques concentrates on monitoring analyses, some survey procedures are also presented.

Survey Analyses

Some common methodologies for estimating emissions from area source emission categories rely on a per-capita, per-employee, or per-area emission factor. While these approaches may be adequate for estimating national or regional emissions, they may introduce bias when applied to specific locations or during specific time periods. Statistical sampling techniques can identify the population of establishments in a specific industry that need to be sampled in detail to provide useful statistical results on the regional and temporal characteristics of that activity. The results of a statistical sampling based on these principles could be applied to develop regionally specific emission or allocation factors that depend on population density, economic demographics, or the distribution of employment by major industrial and commercial sectors. Another possible survey approach could be implemented to evaluate the representation of emissions estimates applied in urban modeling analyses. In this approach, some of the grid cells that are thought to contribute significant emissions magnitudes could be surveyed in a methodical way. This would involve a detailed manual survey of all stationary activities in a given grid cell location that can result in emissions.

Monitoring Analyses

Monitoring analyses include three principal types of measurement activities: direct source testing, indirect source testing, and ambient measurements. All monitoring programs are expensive to implement and should be well planned and executed to maximize the data recovery and to ensure the collection of high-quality measurement data. It is possible, in some cases, to apply measurement data that is routinely collected as part of a government-sponsored air quality management program and data that is routinely collected by individual facilities related to process operation and efficiency, to an emissions verification exercise. Whenever a monitoring program is considered, a thorough review of all existing measurement data should be completed and the program should be designed to make use of these data whenever possible. Table 4 summarizes some of the monitoring activities that have been used to help verify emissions estimates.

Source Sampling. Direct measurement of stack gas emissions, using CEMs, is sometimes required to establish compliance with environmental regulations. Obviously, if such measurements are available to the agency responsible for the development of an emissions inventory, those data can be applied directly to the inventory. In these cases, there is no need for the application of an emissions estimation technique. More commonly, however, such compliance data are only available for limited periods of time, or for only a subset of the population of sources in a given area. However, compliance data collected for some specific facilities or over a limited time period, along with similar data collected specifically for application to an emissions verification program, can be used to evaluate emission factors and emissions estimation techniques.

Such direct source testing methods are primarily applied to large stationary sources where emissions are vented through a clearly identifiable stack or vent. Indirect source testing methods are used to estimate emissions from dispersed sources. These types of sources either are too numerous to consider individually, like residential space heating, or arise from unexpected sources, like leaks in chemical plants or petroleum refineries. Some examples of indirect source testing are described below.

Measurement of Operating Parameters. It is not always necessary to measure the direct emissions from a source to quantify the actual emissions. For sources that have relatively high-quality emission factors or emission estimation algorithms that have been demonstrated to predict emissions with a high degree of accuracy over the typical range of operating conditions, emissions can be monitored by collecting and processing these activity data. For example,accurate monitoring of the fuel use rate and the sulfur content of fossil fuels can be applied to make highly accurate estimates of the SO_2 emission rates as a function of time.

Random Sampling of Leak Sites. A well-organized leak detection and prevention program in chemical and petrochemical operations can be useful to estimate total fugitive emissions for a facility or group of facilities.

<u>Remote Measurement Techniques</u>. These are measurement methods that do not rely on the collection of a captive sample. Instead they make a determination of concentration or some other physical property in an undisturbed air parcel. Three specific examples of remote measurement technologies applicable to measure air quality parameters are Fourier Transform Infrared (FTIR), ultra violet spectroscopy (open path) and gas-filter radiometry.

TABLE 4. MONITORING TYPES, EXAMPLES, AND USES FOR EMISSIONS INVENTORIES

Monitoring Class	Examples of Monitoring Programs	Uses of the Data for Emissions Inventories
Direct Measurements	• Inprocess emissions measurements • Process operating parameters • Random sampling of process units or potential leak tests	• Comparison to estimated values • Identification of ranges of application estimates (operating parameters, emissions factors) • Specification of fugitive emissions or process leaks
Indirect Measurements	• Remote measurement systems: FTIR, UV, Gas Filter Correlation • Ambient VOC/NO_x ratio studies	• Comparison of estimated emission rates with near source concentrations • Estimation of emission factors for sources that do not have stacks or vents
Ambient Studies	• Tunnel Studies • Aircraft Studies • Upwind-downwind difference studies • Receptor Modeling	• Identification of obvious weaknesses in procedures or underestimation of emissions • Checking of ambient impacts of sources or mixtures of sources • Identification of principal emissions sources in a region

Each of these technologies can be used to measure the concentration of pollutants along a line of sight through the ambient atmosphere or at the mouth of an emissions source. An approach based on open path FTIR or UV Emissions Tests involves the measurement of a path averaged concentration along a line of sight that is immediately downwind of the subject source.[14,15,16] Adaptations to this basic approach could also be applied to measure emission rates from selected industrial activities such as fugitive emissions from process leaks, fugitive emissions from chemical storage facilities, and emissions from in-use motor vehicles.

The Gas-Filter Radiometer Emission Test system has been used to measure in-use motor vehicle emissions.[17,18,19] In this system, an infrared light source is mounted on one side of an on-ramp to a restricted access highway. As each car passes the detector, there is a drop in the reference signal caused by the car interfering with the light beam. This drop in the reference initiates a measurement. As the car exits the beam, a one-second voltage versus time trace is obtained and stored electronically in the device. These systems are primary examples of the use of indirect source measurements for inventory verification, and the studies suggest some cars have much larger emissions rates than are predicted by average vehicle emissions factors.

Ambient Ratio Studies. In the United States, ambient measurement programs are routinely operated in urban areas that are classified as nonattainment for the ambient ozone standard. Typically, these measurement programs include a rural measurement site in a location that is in the typical upwind sector, two or more sites in the downtown area near the urban core, and two or more sites in the downwind sector at locations that are thought to represent the location of the ozone maxima events. Both grid-based and trajectory modeling approaches are used to simulate the urban area and model predictions are compared to the observed concentrations of ozone and ozone precursors. The use of grid-based models allows the investigator to track the temporal distribution of ozone precursors in the urban center in addition to the ozone maxima. Frequently, these models are reasonably successful in predicting the ozone maximum in the downwind locations, but are less successful in tracking the concentrations of precursors in the downtown area.[20] These types of results have led researchers to question whether the underlying emissions inventories are adequately representing the actual emissions fields, and to question if control strategies based on these modeling predictions are valid.[21,22]

Several techniques have been developed and applied that seek to relate ambient measurement data to emissions source strengths. The studies using these techniques have been conducted to assess the reliability of general overall emissions estimation methods for use in regulatory applications. These studies can be categorized in one of three major groupings: tunnel studies, aircraft monitoring studies, and receptor modeling studies. The concepts of using these types of studies for emissions verification and some examples of each are discussed in the following paragraphs.

Tunnel Studies. Highway tunnels offer an excellent location to sample the contribution of emissions from in-use highway vehicles. Concentrations of VOC, CO, NO_x, and particulate matter (PM) can be measured at both the upwind and downwind portals of the tunnel and the emissions rate can be calculated by their difference. Air flow can be determined by simultaneously monitoring the exit concentration of an SF_6 tracer, which is introduced at the upwind portal at a known release rate.[23] Video images can be recorded to accurately assess the distribution of vehicles in the tunnel during the measurement periods. Average vehicle speed can be measured in each lane of the tunnel during each experiment. The measured concentration data may be used to estimate the mass emissions rate for the sampling periods.

Aircraft Monitoring Studies. An aircraft platform outfitted with air pollution instrumentation has been used to compare emissions inventory results to ambient monitoring results.[24] Aircraft measurements are made in both the upwind and downwind direction from a cluster of sources of specific VOC emissions. The measurements are obtained at various altitudes to define a flux of the selected pollutants in both locations and the difference is attributed to the combined emissions strength of all sources in the area between the measurement locations.

Receptor Modeling. Receptor modeling relies on the analysis of ambient measurement data along with the chemical characteristics of specific source types. If certain sources in an area have unique signatures their contribution to ambient samples can be inferred. This technique is often useful to determine the relative contribution of particulate sources to measured ambient concentrations.[25] These approaches are currently being evaluated to identify the potential for adaptation of these techniques for application to VOC and other sources.[26]

The U.S. EPA Office of Mobile Sources has recently completed a brief study that offers a critical assessment of 19 studies of receptor modeling approaches and 5 studies of ambient concentration ratios to evaluate emissions inventories in urban areas across the United States. This reference is a good summary of recent work in these areas and will lead emissions inventory developers to detailed descriptions of study designs and other useful information for planning and conducting such emissions verification studies.[27]

SUMMARY

This guideline chapter represents a comprehensive review of emissions inventory development procedures and those activities that can and should be applied before, during, and after the preparation of emissions inventories to promote high quality emissions data and to provide for verification of those data. Ideally, verification procedures should be applied by the inventory developers and the results of the verification efforts should be discussed along with the inventory. It is also equally useful for the users or a third party to conduct verification analyses. Ultimately, the true test of the utility and quality of the inventory data is how well it performs in the applications it is intended to support. Good planning, careful attention to procedures and analyses, and the judicious use of other data and other techniques are the foundation of a reliable verification effort.

A companion report that presents additional details of and selected results from activities that can be applied to emissions verification efforts is available through the U.S. EPA. That report does not recommend any specific techniques over any others and does not indicate a preferred combination of techniques for any individual program. The complexity of emissions development procedures and the variable activities these inventories support make it difficult to specify any universal recommendations for all applications.

For the purposes of this guidebook, however, it is desirable to promote a consistent approach for representing the overall quality of the databases. Therefore, it is suggested that a method be applied to develop a data quality estimate for all emissions data generated through the use of the guidebook. In all cases, the preferred approach is a formal uncertainty analysis. In some cases, it may be possible to apply Monte Carlo procedures in uncertainty analyses. When it is not possible to complete an uncertainty analysis the data quality rating procedure followed in Great Britain is recommended. This approach provides a simple assessment of the underlying confidence of the inventory developer in the data used to generate the emissions estimates. Each emission factor and activity data parameter is assigned a letter data quality rating according to the following definitions. For emission factors the following guidelines apply:

A An estimate based on a large number of measurements made at a large number of facilities that fully represent the sector.

B An estimate based on a large number of measurements made at a large number of facilities that represent a large part of the sector.

C An estimate based on a number of measurements made at a small number of representative facilities, or an engineering judgement based on a number of relevant facts.

D An estimate based on a single measurement or an engineering calculation derived from a number of relevant facts and some assumptions.

E An estimate based on an engineering calculation derived from assumptions only.

Similar ratings are then assigned to the activity or production data using the general guidance that a C rating is applied if the data are taken from a published source such as Government statistics or Industry Trade Association figures. Other possible ratings apply relative to the C rating. If activity was some how measured accurately and with high precision it would receive an A or a B rating and if the data were developed by extrapolation from some other measured activity or a nearby country they would be assigned rating of D or E. The overall quality rating would be determined by a combination following the schedule listed below:

Combination Factor	Final Factor	Combination Factors	Final Factor
E - E	E	C - C	C
E - D	D	D - A	C
E - C	D	C - B	B
D - D	D	C - A	B
E - B	D	B - B	B
E - A	C	B - A	A
D - C	C	A - A	A
D - B	C		

The proper emissions verification effort can be identified for each project through careful consideration of the needs of the project, the resources available to the project, and the collection of supporting data that is readily accessible. If more detailed analyses are possible,they are encouraged. It is suggested that the developer include the results of any verification procedures used in a summary of the inventory data and describe the implementation of the approach so that others may benefit in future projects from those efforts. Table 5 summarizes the verification techniques discussed in the chapter that have been or could be applied to specific source categories. The table is organized to follow the second level of aggregation included in the Selected Nomenclature for Air Pollution (SNAP90) adopted for application to the CORINAIR 1990 project. The summary represented in Table 5 is intended to define cases where specific techniques have actually been or are anticipated to be applied in actual emissions inventory development projects. Many of the verification techniques listed in the table could be applied to additional categories if specific requirements demanded special attention or if resources were adequate to fully plan for their application. This summary does not specify an absolute order of preference for the application of verification procedures; however, a brief summary of the relative priority ranking of the various approaches is presented to guide inventory developers in the selection of appropriate techniques.

Application

Table 6 represents an application of the concepts of qualitative data rating schemes for all pollutants of concern in the guidebook. The Table is organized by major SNAP code groupings. It is important to note that any such qualitative summary is subjective and individual opinions will differ. While the subjective nature of this approach is recognized, the data ratings summarized in Table 6 represent a general consensus among the members of the Expert Panel on Verification, given the current understanding of emissions inventory estimation methods. The inclusion of these ratings in the summary table does not suggest that the entire membership of the Expert Panel or the Emissions Inventory Task Force are in complete agreement with every entry. The letter grade ratings summarized in Table 6 are primarily applicable to the estimation approaches for emissions inventory preparation that rely on emission factors and estimates of activity indicators. In all cases, the application of more direct approaches based on measurement would receive higher quality ratings.

The application of these subjective ratings for the aggregated source category groupings represented by the major SNAP code groupings can be misleading in some specific cases. For example, the rating specified for heavy metals/persistent organic pollutants for road transport is listed as E to apply in general to the understanding of the contribution of these pollutants from mobile sources. In fact, for the specific case of lead from mobile sources, the emission factors and emissions estimates are known with significantly more confidence. In such an analysis at that level of disaggregation, lead from mobile sources would receive a B rating. Also at this level of aggregation several source category pollutant combinations are irrelevant in that emissions of the pollutant from that source category are zero or so minimal as to be of little or no importance (for example see chapter ACOR).

The value of a rating scheme such as that summarized in Table 6 is enhanced when applied in conjunction with a table of total emissions from each pollutant organized in the same matrix format. The researcher can then compare relative quality ratings in consideration of the overall contribution of that category to the total loadings of emissions of the specific pollutant species. The appearance of sources of significant amounts of pollutants with corresponding low quality ratings can serve to caution researchers on the applications of the inventory and direct efficient research efforts in future programs to improve the quality of the overall inventories.

TABLE 6. EMISSION INVENTORY UNCERTAINTY RATINGS

MAIN SNAP CATEGORY	SO_2	NO_x	VOC	CO	NH_3	HM/POP	CO_2	CH_4	N_2O
1 public power, cogeneration and district heating	A	B	C	B		D	A	C	E
2 commercial, institutional & residential combustion	B	C	C	C		E	B	C	E
3 industrial combustion	A	B	C	B		D	A	C	E
4 industrial processes	B	C	C	C	E	E	B	D	D
5 extraction & distribution of fossil fuels	C	C	C	C		E	D	D	
6 solvent use			B			E[1]			
7 road transport	C	C	C	C	E	E[2]	B	C	E
8 other mobile sources and machinery	C	D	D	D		E	C	D	D
9 waste treatment	B	B	B	C		D	B	C	E
disposal activities	C	C	C	C	E	E	C	D	E
10 agriculture activities		D	D	D	D	E	D	D	E
11 nature	D[3]	D	D	E	E	E[3]	D	E	E

1 In some cases, solvents may be toxic compounds
2 Rating representative of typical pollutant source category combination; some specific cases may have higher ratings
3 Natural sources could be contributed from volcanoes and other geothermal events

Highest Priority Methods

In all cases and whenever practical, a direct test or series of direct source testing is the preferred emissions validation technique. Direct source testing provides the obvious benefit of analytical data consistent with experimental method. In addition, direct source testing in combination with sampling and monitoring of operating parameters can be used in the development of a classical uncertainty estimate. The combination of direct source testing and statistical uncertainty estimates are always the most desirable and highest priority methods for emissions inventory validation.

Secondary Priority Methods

Some source categories are not suited to direct source testing and in many applications resources are insufficient to conduct extensive source testing in emissions inventory development projects. In these cases, the application of a data ranking system is the next highest priority. This type of approach provides a structured analysis that allows direct comparisons to be made between categories in the final inventory and among various suggested estimation approaches. Although the final result of such an approach can not provide an absolute assessment of accuracy, it can provide a consistent basis to assess the relative accuracy of the components of an inventory. In many applications, such an assessment can be of extreme value.

The use of two or more estimates of the magnitude of emissions from source categories using alternate estimation methodologies is often the most practical method for validation exercises. Often a second or third approach can be used to develop an estimate of the overall magnitude of emissions with limited or even minimal expense. Although an agreement of two independent estimates does not ensure accuracy of either estimate, it does provide confidence that the preferred estimate is reasonable.

If extensive source sampling is not possible, and data to support a statistical uncertainty estimate are not available some combination of a rigorous quality rating system and comparison of sector or source specific alternate estimates would be the desired approach to emissions validation.

Third Priority Methods

Survey analyses and indirect source sampling are included in the next level of priority for emissions inventory validation techniques. Survey analyses are not rated higher because they can be difficult and costly to implement, they can be affected by incomplete response or coverage, and are subject to the accuracy of the aggregate responses. Often if properly planned and implemented they can provide useful information; however, if participants have little incentive to respond, the results can be misleading. Indirect source tests can provide supportive information but are only useful as an emissions validation technique for selected sources that can be isolated and assumptions must be applied to relate the results to the overall emission rate of the source or source group. While these methods may offer reasonable approaches for some categories, in general, other approaches in higher priority classifications should be considered first.

Lowest Priority Methods

The validation method entries for ambient monitoring studies and assessments of modeling allocation factors in the matrix are listed here with the lowest priorities. The low priority ranking of these methods, however, should not be interpreted as a suggestion that these approaches are universally undesirable. In general, the application of ambient monitoring data and quick analyses of emissions distributions in inventory validation exercises require assumptions to relate the results of these studies to emissions rates and emissions factors for specific source categories. There are opportunities, such as tunnel studies that are used to evaluate mobile source emission factors and studies to relate emissions inventories to observed ambient VOC/NO_x ratios, that can provide significant information concerning the usefulness and reliability of emissions estimates for air quality management programs. These approaches are assigned the lowest priority ranking for two important reasons. First, the application of ambient monitoring techniques is expensive and requires the operation of a monitoring program designed specifically for the application or require additional technical analyses and model assessment activities. Secondly, neither of these approaches are applicable to a large number of source categories and, therefore, they have rather specialized applicability.

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RELEASE VERSION, DATA AND SOURCES

Version : 2.1

Date : January 1996

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