RIVM report 773301001 / NRP report 410 200 051

Applications of EDGAR

Including a description of EDGAR 3.2:
reference database with trend data for 1970-1995

Jos G.J. Olivier[1], Jan J.M. Berdowski[2], Jeroen A.H.W. Peters[1], Joost Bakker[1], Antoon J.H. Visschedijk[2] and JanPieter J. Bloos[2]

2001/2002

[1] National Institute for Public Health and the Environment (RIVM)
Phone +31-30-274 3035/2759; Fax +31-30-274 4417; Email: Jos.Olivier@rivm.nl

[2] Netherlands Organisation for Applied Scientific Research (TNO)
TNO-MEP, P.O. Box 342, NL-7300 AH Apeldoorn
Phone +31-55-549 3732; Fax +31-55-549 3252; Email: A.J.H.Visschedijk@mep.tno.nl

This project was carried out in the framework of the Dutch National Research Programme on Global Air Pollution and Climate Change; registered under no. 954222, entitled: ‘Applications of EDGAR: the Emission Database for Global Atmospheric Research’.

This research is part of the Global Emissions Inventory Activity (GEIA), a component of the International Global Atmospheric Chemistry (IGAC) Core Project of the International Geosphere-Biosphere Programme (IGBP).

This investigation has been performed by order and for the account of the Directorate-General for Environmental Protection, Department of Air and Energy, of the Netherlands' Ministry of Housing, Spatial Planning and the Environment, within the framework of project 773301, entitled ‘International emission sources’.

Abstract

EDGAR 2.0 (*Emission Database for Global Atmospheric Research*) provided global annual emissions for 1990 of greenhouse gases CO_2, CH_4 and N_2O and precursor gases CO, NO_x, NMVOC and SO_2, both per region and on a 1^ox1^o grid. Similar inventories were compiled for a number of CFCs, halons and methyl bromide, methyl chloroform. This report discusses the applications of EDGAR 2.0 over the last couple of years as well as the validation and uncertainty analysis carried out. About 700 users have downloaded EDGAR 2.0 data during the last 2½ year. In addition, the approach taken to compile EDGAR 3.0 is discussed: update and extension from 1990 to 1995 for all gases and extended time series for direct greenhouse gases to 1970-1995 and inclusion of the new 'Kyoto' greenhouse gases HFCs, PFCs and SF_6. Selected time profiles for the seasonality of anthropogenic sources are also discussed. This work is linked into and part of the *Global Emissions Inventory Activity* (GEIA) of IGBP/IGAC.

Contents

Table captions

Box captions

Figure captions

Summary

EDGAR 2.0 provided global annual emissions for 1990 of greenhouse gases CO_2, CH_4 and N_2O and precursor gases CO, NO_x, NMVOC and SO_2, both per region and on a $1^o x 1^o$ grid. Similar inventories were compiled for a number of CFCs, halons and methyl bromide, methyl chloroform. This report discusses the applications of EDGAR 2.0 over the last couple of years as well as the validation and uncertainty analysis carried out. In addition, the approach taken to compile EDGAR 3.0 is discussed. This work is linked into and part of the *Global Emissions Inventory Activity* (GEIA) of the *International Global Atmospheric Chemistry Programme* (IGAC/IGBP).

Applications of EDGAR 2.0

The number of downloads from the FTP site increased from 50 per quarter in 1997 to nearly 100 in mid-1999. Of the 700 quarterly registered users in the logged 2½ year period, most reside in OECD countries. Most of these are modellers, but EDGAR data are also extensively used for policy applications for which emissions data on country level were calculated with the EDGAR information system.

Aim of EDGAR 3.0

The overall aim for Version 3.0 was to update the inventories from 1990 to 1995, and for direct greenhouse gases also to 1970, to include new greenhouse gases. After consultation of the users, the objectives have been somewhat changed and extended. Thus, specific aims were:

- update/extension from 1990 to 1995;
- extend time series for direct greenhouse gases to 1970-1995;
- include new 'Kyoto' greenhouse gases HFCs, PFCs, SF_6;
- greenhouse gas emissions also on per country basis using IPCC source categories;
- include NH_3;
- improve/include uncertainty estimates and time profiles.

For updating and extended time series different priorities were given for the following groups of gases:

- direct greenhouse gases CO_2, CH_4, N_2O and new gases HFCs, PFCs, SF_6: 1970-1995;
- ozone precursors CO, NO_x, NMVOC as well as SO_2 and NH_3: update 90 and 95;
- extend CFCs, halons, HCFCs to 1900-1995

Special attention was given to the compilation of a reference dataset for new gases as none was available. For the update of the current Version 2.0, we followed the following principles:

- *Activity data*: update by including relevant statistics for the period 1970-1995, after checking for possible changes of source categories; this implies the inclusion of the 'new' countries, e.g. for the former USSR.
- *Emission factors*: only to be changed for 1990 if validation showed major discrepancies; only to be changed for 1995 compared to 1990 if there are concrete indications that there major changes have occurred that cannot be neglected; the same holds for factors for 1970, in particular for direct greenhouse gases.
- *Grid maps*: only to be updated if maps available of better quality or better applicability.
- *Additional sources*: coal fires, oil fires, vegetation fires in temperate regions, domestic waste combustion and wastewater handling were added, based on the significance in some countries for specific emissions.

Validation

In order to judge whether update of methods or emission factors for 1990 is needed, a validation of V2.0 data for 1990 was performed: for greenhouse gases with National Communications submitted

under the UN Climate Convention and for other gases with data from CORINAIR, GEIA and others. In addition, inventories in National Communications were checked for the use of different emission factors for 1990 and 1995 in order to select sources and gases for which specific emission factors for 1995 in EDGAR V3.0 need to be determined. This has been done for the purpose of the update, but also as application of Version 2.0 as reference dataset for comparing with official national greenhouse gas inventories to flag possible inconsistencies in source allocation, incompleteness of sources, and areas of incomparability. In addition, for CO_2, NO_x and SO_2 a comparison was made with the present GEIA inventories, both on grid and per country, from which interesting conclusions could be drawn regarding the apparent uncertainty in international statistics, on emission factors, missing sources and on apparent strong emission trends in specific regions/sources.

Updating emission factors for 1990

As a result of the validation of EDGAR 2.0 with other global and regional emission inventories it was decided that several items should be modified for the reference year 1990. Compared to Version 2.0 the following amendments have been made for 1990:

- The emission factors for 1990 for direct greenhouse gases CO_2, CH_4 and N_2O have been brought more in line with the defaults recommended in the *Revised IPCC Guidelines for Greenhouse Gas Inventories* and for reference purposes any departures from them will be clearly identified. For CO_2 from fossil fuel use, emission factors per detailed fuel type will be used (in V2.0: one aggregated factor for coal, oil and gas). This also means that the agricultural emissions will be affected considerably by the inclusion of some ‘indirect’ emissions. Other examples of areas where emission factors will be updated are CH_4 from rice and landfills.
- Global default emission factors for NO_x, CO and NMVOC for the following non-road transport activities are updated: Rail transport, Inland water, Other land - non-road and Non-specified transport. Emission factors are entered for coal, diesel oil and gasoline when applicable.
- Global default emission factors for NO_x and SO_2 for sea ships have been updated; in particular the emission factor for NO_x has increased significantly.

Activity data 1970-1995

Next, activity data were collected for the period 1970-1995. A major part could be drawn from IEA (energy), UN (supplementary energy, industrial production) and FAO (agriculture) databases. But for some source like biofuels and specific industrial production of commodities like adipic acid, nitric acid and fluorinated carbons country statistics are not readily available. For each of these latter compounds additional data sources were found and used.

In the process of updating 1990 activity data with more recent statistical datasets, these levels are often changed to a lesser or larger degree. This is caused by the phenomenon that statistics of activity data of the most recent years tend to change during a couple of years after the first compilation. This happens in particular in non-OECD countries, however, also in industrialised countries this phenomenon can be observed, although in these countries the changes are often only minor. In addition, data for the former USSR have become rather weak due to inconsistencies between the sum of the new countries and the 1990 data for the former USSR.

For biofuels we use the previous V2.0 dataset for less developed countries and FAO fuelwood plus IEA data for OECD countries. In addition, for the IPCC sources ‘Land-use change and forestry’ (LUCF) and ‘Waste’ there is no readily available data in time-series per country. Here, in line with the approach taken for the compilation of the GEIA NH_3 inventory, biomass burning data (vegetation fires) for LUCF were based on FAO reports providing 10 year averaged estimates. For agricultural waste burning too the activity data were essentially based on the methodology used for NH_3, however using updated fractions for the amount of agricultural waste per unit of net crop production, and using much lower fractions burned in OECD countries. For waste, the activity data per country are based on a fit with of international waste generation figures per capita with per capita income per country.

Emission factors for 1995

For the update of the 1990 EDGAR 3.0 emission factors to 1995 the following three sectors have been selected: large combustion plants, mobile sources and solvent use. Updated emission factors, or another mix of sub-activities, for 1995 were required for sources such as coal mining, gasoline cars, shifting type of rice cultivation, landfills with gas recovery. In addition, also for power plants and some industries in countries where additional control technology e.g. for SO_2 and NO_x has been installed updated emission factors have been considered. For extension of emission factors for CH_4 and N_2O towards 1970 similar considerations have been made. Given the limited resources available for the 1995 update it was decided to focus only on the most important developments and changes which might influence emission factors. There are many sectors in which important emission reduction measures have been implemented.

Update of grid maps

Although no specific effort has been made to improve the current grid maps used for allocating country emissions of specific sources to the 1^ox1^o grid, the following new maps have been included:

- human population distribution, based on a new GEIA population map by Li, also split into an urban and rural population map;
- steel production plants by process type, which covers a large fraction of coal/coke use in the industry sector (also used for coke production locations);
- cement production plants;
- nitric acid production plants;
- aluminium smelters;
- rice production in Asia, based on NOP-MLK results by Denier van der Gon;
- coal fire map for China.

New sources

In EDGAR 3.0 the following new sources have been added:

- *Wildfires/vegetation fires in non-tropical regions:* Recognising the importance of emissions related to biomass burning, temperate vegetation fires have been added as an emission source based on the UN/ECE forest fire statistics for 1990 and 1995.
- *Waste handling:* Recognising the possible importance of this source category, wastewater treatment and domestic waste combustion were added as sources.
- *Coal fires:* Unintentional coal fires at shallow coal deposits have been added in EDGAR as an emission source category for China. This source appeared to be considerable and was so far lacking in EDGAR 2.0. Only for China this emission source has been taken into account, although these fires are known also to occur in other countries (e.g. USA, India, Indonesia).
- *Oil fires:* The Kuwait oil fires in 1992 due to the Gulf war have been included as separate source.

EDGAR 3.0 data

The largest differences with EDGAR 2.0 emissions are in the following sources:

- wastewater treatment has been added, which is a substantial source of CH_4;
- indirect emissions of N_2O from agriculture have been added;
- agricultural waste burning emissions have been decreased substantially, in particular for CO;
- temperate forest fires show considerable emissions, though highly variable between years;

NMVOC from *Domestic waste burning*, in version 2.0 called *Uncontrolled waste burning*, have decreased substantially; the same holds for *Miscellaneous industrial processes* (i.e. non-combustion);

fossil fuel fires have been added, increasing fuel-related emissions in China considerably;

NO_x from international shipping has increased substantially;

the spatial distribution of sources allocated with the population maps has changed substantially, due to the introduction of another base map and applying urban and rural maps where appropriate;

the use of other vegetation maps for allocating deforestation and savanna burning on the grid.

The 1990 emissions have not only changed due to updates of emission factors, but also since international statistics of activity data of the most recent years tend to change during a couple of years after the first compilation. This happens in particular in non-OECD countries, however, also in industrialised countries this phenomenon can be observed, although in these countries the changes are often only minor. In addition, data for the former USSR have become rather weak due to inconsistencies between the sum of the new countries and the 1990 data for the former USSR.

The new inventory data will be available through anonymous FTP as well as the EDGAR website, both as grid files on 1x1 degree as well as per country.

Samenvatting

EDGAR 2.0 (*Emission Database for Global Atmospheric Research*) geeft schattingen van de jaarlijkse mondiale emissies van directe broeikasgassen CO_2, CH_4 en N_2O en van de zgn. precursors CO, NO_x, NMVOC and SO_2 voor 1990, zowel per regio/land en op een $1^o x 1^o$ grid. Soortgelijke inventarisaties zijn gemaakt voor een aantal CFK's, halonen, methylbromide en methylchloroform. In dit rapport worden de toepassingen van EDGAR 2.0 in de afgelopen jaren beschreven, alsmede de validatie en onzekerheidsanalyses die uitgevoerd zijn. Ongeveer 700 gebruikers hebben de laatste 2½ jaar EDGAR-data gedownload. Daarnaast wordt de aanpak besproken die gevolgd is om EDGAR 3.0 te construeren: update en uitbreiding van 1990 naar 1995 voor alle stoffen en uitbreiding tot een tijdreeks 1970-1995 voor de directe broeikasgassen; en toevoeging van de nieuwe 'Kyoto-stoffen' HFK's, PFK's en SF_6. Ook worden tijdprofielen voor de seizoensvariatie van emissies van menselijke oorsprong besproken. Het onderzoek maakt onderdeel uit van de *Global Emissions Inventory Activity* (GEIA) van het *International Global Atmospheric Chemistry Programm*e (IGAC/IGBP).

Introduction

This report describes the activities carried out within the NRP-MLK project 'Applications of EDGAR'. These activities focus around the following topics:

- Validation and uncertainty assessment of the existing EDGAR 2.0 dataset;
- Monitoring and analysis of trends in emissions and use in integrated assessments such as RIVM's annual Environmental Balances and the background reports (Environmental Compendium);
- Applications of EDGAR data;
- Update of the database to EDGAR 3.0 (3.2 as publish at the website).

The validation activities provide input into the uncertainty assessment as well as for the update activities to Version 3.0 (Version 3.2 as presented for public access at the EDGAR homepage http://www.rivm.nl/env/int/coredata/edgar/). Although uncertainty assessments are an integral part of most activities, quantitative uncertainty estimates per source category could not made for the EDGAR 2.0 dataset. Therefore, focus was on analysing the differences, also in spatial patterns, with other similar GEIA datasets (CO_2, SO_2, NO_x). However, through participation in IPCC activities on Good Practice Guidance and Uncertainty Management and by comparing EDGAR estimates with official national figures reported in National Communications, a better knowledge base of the order of magnitude of the uncertainty per source category has been created. These topics are discussed in Chapter 1.

EDGAR data, supplemented with recent trend data are used in integrated assessments, are used for trend analysis of global emissions. To illustrate this we provide in Chapter 2 a background analysis carried out for the Environmental Balance 1997.

The applications of EDGAR data world-wide are discussed in Chapter 3 by presenting information about downloads of EDGAR files and concrete examples of scientific and policy applications. An important in-house application was the provision of data for the update of the IMAGE 2 model.

Finally, we summarise the approach taken to compile EDGAR 3.0 in Chapter 4. This report does not provide the results of Version 3.0; these are presented in separate reports. Here we build on the conclusions drawn in Chapters 1 and 2 (validation and user's survey) and summarise key differences with respect to Version 2.0. Specific issues dealt with are:

- update of emission factors for 1990;
- selection of emission factors for 1995;
- construction of 1970-1990 emissions estimates for CO_2, CH_4 and N_2O (notably for CH_4);
- addition of new source categories;
- update of grid maps used for the spatial distribution to 1x1 degree grid;
- largest changes compare with Version 2.0.

We hope that the appreciation of EDGAR 3.0 will be similar to the type of reactions we received in our user's survey of EDGAR 2.0:

I appreciate the effort very much.
Units and spatial resolution are very appropriate.
I am very glad to have the ammonia emissions inventory.
The EDGAR data are streets ahead of anything else I've seen!!!!!
I did appreciate to find an elaborate and comfortable database.
Thank you for the work of the EDGAR-team.
EDGAR database is very useful because it includes many kinds of NMVOC.
I am looking forward to releasing EDGAR V3.0!
Whilst the coding system for sources and sectors is very good, it is not very easy to understand.
Very nice dataset.
Good that the emissions are all spatially coherent with emission sources.

1. Validation of EDGAR V2.0 & uncertainty analysis

1.1 Introduction

Validation is used here in the meaning of comparing own estimates with those of others either alternative bottom-up emission estimates or top-down emission estimates based on 'reverse' calculations with models calibrated to observed atmospheric concentrations. Therefore, validation provides insight in the degree in which EDGAR data comply with and differ from major alternative inventories or budgets, all with different status and background. It flags the characteristic differences of the EDGAR inventories and possible errors or departures from commonly used emission figures. Thus, the conclusions from a validation exercise will assist:

1) users in providing a summary with key differences with other inventory data sets;
2) developers in identifying areas for checking and possible improvements, or when proven to be OK, of clear departures from often used emission estimates. The latter information is, obviously, also of importance to data users.

In addition, the latter results were also very useful for prioritising efforts for improvement of 1990 emissions data in the new EDGAR 3.0. Only when significant improvements are expected, emission factors for 1990 have been updated in Version 3.0.

In general validation has been done on aggregated sectoral levels, focussing on main source categories which have more or less the same definition as used in other datasets. Because of large differences in source definitions, more detailed comparisons are often not useful. Besides differences in source definitions, also differences in reference years have to be taken into account when comparing inventories. Comparing the spatial characteristics of gridded inventories is a relatively new activity for emission inventories. Here we apply methods recently used at RIVM for comparison of spatial patterns of other datasets.

1.2 Validation of EDGAR V2.0

When EDGAR 2.0 was completed in the previous NOP-MLK project, validation had been done only to a limited extent (Olivier *et al*., 1996; 1999). Within the follow-up project a number of more detailed validation activities have been executed of different types. At national total and/or sectoral level comparisons were made with European inventories compiled within the CORINAIR framework, with GEIA inventories (if available), and to national greenhouse gas inventories submitted to the UN Framework Convention on Climate Change (UNFCCC). In addition, validation of the spatial distribution of the gridded inventory was possible by comparison with independently developed gridded inventories of GEIA (only if available). Furthermore, the EDGAR 2.0 inventories have been used by various modelers, which also provides a validation of the gridded inventories, since these will provide feedback if they come across unlikely values based on their model experience or knowledge of alternative datasets.

1.2.1 Comparison with other regional sectoral emission estimates

Most inventories were validated by comparing total *global* estimates per source with other published estimates. This was done, for instance with the CO_2, CH_4 and N_2O inventories, which were compared with IPCC sector totals (Olivier *et al*., 1999a). The inventories of CO, NO_x, NMVOC and SO_2 were also compared that way (Olivier *et al*., 1996). In addition, *more detailed sectoral* inventories of NO_x and SO_2 were also compared for a number of regions in Europe and Asia; NMVOC only for European regions: OECD Europe, Eastern Europe, Former USSR, China region, India region, East Asia and Japan (Olivier *et al*., 1996). However, the EDGAR inventories of N_2O, NH_3 and CO, which are also GEIA inventories, have been validated in more detail be comparison with other references presenting emission estimates at various spatial and source levels (Bouwman et al., 1995; 1998; Olivier *et al*., 1999b).

1.2.1.1 Comparison with GEIA inventories: NO_x and SO_2

Within the framework of the the Global Emissions Inventory Activity (GEIA) global emission inventories of SO_2 and NO_x for 1985 have been compiled (Benkovitz *et al.,* 1996, Version 1A.1). These inventories consist of a compilation of several regional and one global emission inventory.

For SO_2 an inventory compiled by Spiro *et al.* (1992) was selected to provide the default emissions data for the GEIA SO_2 inventories. The Dignon 1992 inventory for NO_x emissions (Dignon, 1992) was selected to provide the default emissions data for the GEIA NO_x inventories. Data for the United States and Canada has been compiled by the National Acid Precipitation Assessment Program (NAPAP), Version 2 (Wagner *et al.,* 1986; Saeger *et al.,* 1989). Emissions for western Europe have been taken from the CORINAIR emission inventories Bouscaren (1990); the EMEP inventories described in Sandnes and Styve (1992) supplied the data for areas in Europe not covered by CORINAIR. Anthropogenic emissions of SO_2 and NO_x for Australia were obtained from Carnovale (1992) and the Australian Environment Protection Authority (AEPA, 1992). Anthropogenic emissions of SO_2 and NO_x for South Africa were obtained from Lloyd (1993). Kato and Akimoto (1992) developed inventories of anthropogenic emissions of SO_2 and NO_x for 25 Asian countries east of Afghanistan and Pakistan. For five Asian countries, being Japan, China, North and South Korea and Taiwan, emission estimates were available from Tonooka (1993).

Simple comparison GEIA versus EDGAR 2.0

Although the reference years for the EDGAR 2.0 and the GEIA 1A.1 inventories differ five years (1990 vs. 1985), provided that major changes during this period are taken into account, simple quantitative comparisons can still be made since emission factors are not expected to have changed drastically during this period.

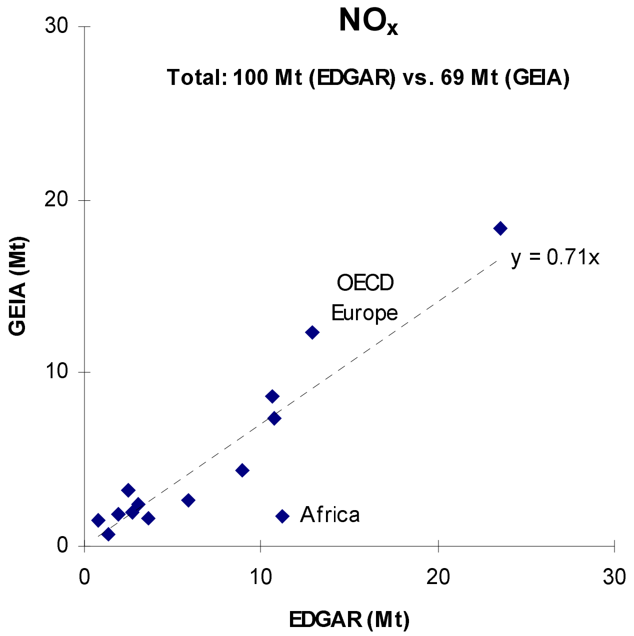


Fig. 1.1. Plot of the GEIA regional emission totals for NO_x against the EDGAR 2.0 results.

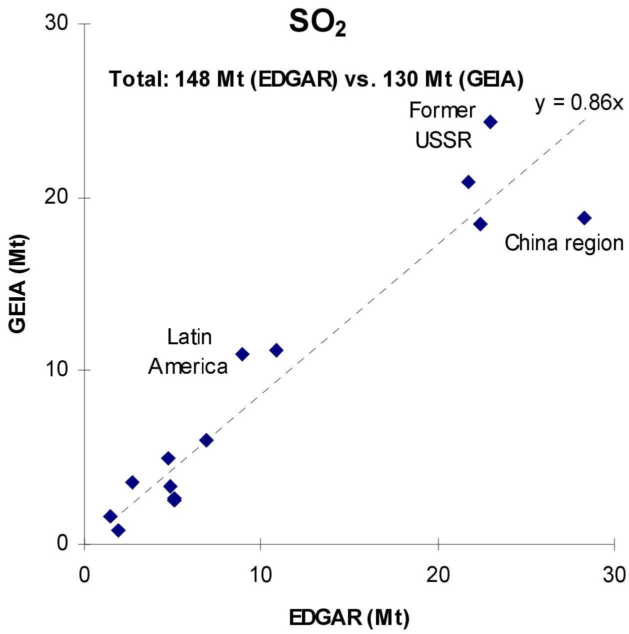


Fig. 1.2. Plot of the GEIA regional emission totals of SO_2 against the EDGAR 2.0 results.

In order to obtain a first impression of any structural or systematic differences between the EDGAR and GEIA inventories, the total regional emissions of NO_x and SO_2 where plotted against each other (Fig. 1.1 and 1.2). Also shown in the figure is the result of a linear regression. From the figures it can be observed that for both substances the EDGAR and GEIA results show structural as well as more random differences. On average EDGAR reports higher emissions (compare global totals) for both NO_x and SO_2. This is less pronounced for the latter substance, as can be concluded from the regression results. For SO_2, of which emissions are primarily the result of the combustion of fossil fuels, the average difference is about 10%. This approximately corresponds to the growth in the global energy consumption during 1985 to 1990. For NO_x the average difference is about 30% which would imply that for this substance other factors play an at least equally important role. There are a number of possible explanations for this, for instance certain source categories are covered by one inventory, however excluded in the other. Also NO_x emission factors are in general more uncertain compared to SO_2. In Section 1.2.1.3 structural inconsistencies will be analysed in more detail.

Figures 1.1 and 1.2 also highlight a few important regions for which differences seem higher than average. For Africa for instance the EDGAR results for NO_x are significantly higher than GEIA. As will be clarified later this is caused by the high biomass related emissions in EDGAR for this region. The earlier mentioned growth of the energy consumption between 1985 and 1990 has not been uniform across the world. Growth was very high in the China region whereas an economic decline has taken place in the former Soviet Union. These facts at least partly explain the differences found for these regions for SO_2.

GEIA versus EDGAR 2.0: a more detailed analysis

There are some important differences in starting points that should be taken into account when comparing the EDGAR and GEIA emission inventories. First, the reference years of the inventories differ five years. During 1985 to 1990 both an overall increase in energy consumption and an increase in industrial production has taken place. The second major difference between EDGAR and GEIA is that EDGAR is set up consistently whereas the GEIA work comprises a compilation of different inventories. Known emission sources are in the EDGAR inventories included whenever available information permits. In the GEIA inventories sources like biomass combustion and landuse activities are most often only partly or not included.

In Table 1.1 below the results of a quantitative comparison on a regional basis between GEIA and EDGAR has been presented. EDGAR results are listed in six ways: the fifth column of Table 1.1 represents the quotient of the unmodified emissions of GEIA and EDGAR. The results in the sixth column are comparable to the fifth however the changes in energy use between 1985 and 1990 are taken into account for certain regions: China region, India region, East Asia, Japan, Eastern Europe, Canada. These regions have been selected based on whether it was expected that differences between GEIA and EDGAR results could be for a large part explained by the increasing trend of energy consumption in 1985 to 1990. This correction for changes in energy consumption has been made using aggregated emission factors per major fuel type (solid, liquid and gaseous) and energy data from the IEA. In the seventh column landuse activities have been excluded from the EDGAR results without the energy correction for 1985 to 1990. The eighth column represents the same but here also the mentioned energy correction is included. Finally, the ninth and tenth column are comparable with the seventh and eighth except EDGAR estimates for biofuels are excluded. The regions presented in Table 1.1 are sorted in descending order of contribution to the global emission total (see second column).

The global totals of NO_x of both inventories seem to be in reasonable agreement with each other, provided that landuse activities and biofuels are excluded (column 9). As can be expected, substantial differences are revealed when comparing the raw results for regions in which biofuels and landuse activities are important. After exclusion of these activities results are in reasonable agreement. Also for the China and India region and East Asia this correction apparently leads to more comparable results. However these regions are known to have experienced a considerable economic growth during 1985 to 1990. A simple correction for the increase of energy consumption in these regions shows that the GEIA results are now higher than the EDGAR results for these regions. Naturally, the applied correction is rough and furthermore the GEIA estimates include several fuel types that are not regarded in EDGAR. In spite of this, the differences are such that major differences in emission factors can not be ruled out.

Table 1.1 Quantitative comparison of GEIA and EDGAR 2.0 emission inventory results for (a) NO_x and (b) SO_2..

Region	*Cumulative contribution to total (%)*	*NO_x EDGAR (Mt)*	*NO_x GEIA (Mt)*	*GEIA/ EDGAR [5]*	*GEIA/ EDGAR [a] [6]*	*GEIA/ EDGAR [b] [7]*	*GEIA/ EDGAR [c] [8]*	*GEIA/ EDGAR [d] [9]*	*GEIA/ EDGAR [e] [10]*
USA	24	24	18	0.8		0.8		0.8	
OECD Europe	37	13	12	1.0		1.0		1.0	
Africa	48	11	1.7	0.2		0.7		1.1	
China region	59	11	7.4	0.7	1.0	0.8	1.1	0.9	1.3
Former USSR	69	11	8.7	0.8		0.9		0.9	
Latin America	78	8.9	4.3	0.5		1.0		1.0	
India Region	84	5.9	2.7	0.5	0.8	0.7	1.2	1.0	1.6
East Asia	88	3.6	1.6	0.5	0.7	0.6	0.9	0.7	1.1
Middle East	91	3.1	2.4	0.8		1.0		1.0	
Japan	94	2.7	1.9	0.7	0.9	0.7	0.9	0.7	0.9
Eastern Europe	96	2.4	3.2	1.3	1.2	1.4	1.3	1.4	1.3
Canada	98	1.9	1.9	1.0	1.1	1.1	1.2	1.1	1.2
Oceania	99	1.3	0.7	0.6		0.6		0.6	
Sea (oceans)	100	0.8	1.5	1.9		1.9		1.9	
Total	100	100	69	0.7		0.9		0.9	

Table 1.1 Continued: (b) SO_2

Region	*Cumulative contribution to total (%)*	*SO_2 EDGAR (Mt)*	*SO_2 GEIA (Mt)*	*GEIA/ EDGAR [5]*	*GEIA/ EDGAR [a] [6]*	*GEIA/ EDGAR [b] [7]*	*GEIA/ EDGAR [c] [8]*	*GEIA/ EDGAR [d] [9]*	*GEIA/ EDGAR [e] [10]*
China region	19	28	19	0.7	0.9	0.7	0.9	0.7	1.0
Former USSR	35	23	24	1.1		1.1		1.1	
OECD Europe	50	22	18	0.8		0.8		0.8	
USA	64	22	21	1.0		1.0		1.0	
Eastern Europe	72	11	11	1.0	0.9	1.0	0.9	1.0	0.9
Latin America	78	9.0	11	1.2		1.4		1.4	
Africa	82	6.9	6.0	0.9		1.2		1.2	
East Asia	86	5.1	2.6	0.5	0.7	0.5	0.8	0.5	0.8
Sea (oceans)	89	5.1	2.6	0.5		0.5		0.5	
India Region	93	4.9	3.3	0.7	1.0	0.7	1.1	0.8	1.1
Middle East	96	4.7	5.0	1.0		1.1		1.1	
Canada	98	2.7	3.5	1.3	1.3	1.3	1.3	1.5	1.5
Japan	99	1.9	0.8	0.4	0.5	0.4	0.5	0.4	0.5
Oceania	100	1.5	1.7	1.1		1.1		1.1	
Total	100	148	130	0.9		0.9		0.9	

[a] *GEIA / EDGAR, corrected for 85-90 increase in energy consumption*
[b] *GEIA / EDGAR minus EDGAR LANDUSE*
[c] *GEIA / EDGAR minus EDGAR LANDUSE, roughly corrected for 85-90 increase in energy consumption*
[d] *GEIA / EDGAR minus EDGAR LANDUSE minus EDGAR BIOFUELS*
[e] *GEIA / EDGAR minus EDGAR LANDUSE minus EDGAR BIOFUELS, corrected for 85-90 increase in energy consumption*

In Table 1.2 a comparison is made between the NO_x emission factors from the GEIA and EDGAR inventories used for China and India for stationary combustion of fossil fuels. Both for China and for India hard coal makes the highest contribution to the total fossil fuel based energy use, although in India natural gas and oil products are used in significant quantities as well. In Table 1.2 the emission factors used for hard coal have been printed in bold. From the table can be concluded that NO_x emission factors for hard coal are 20-30% higher in the GEIA inventories. The emission factors used in EDGAR have a considerable uncertainty and moreover the quality of underlying information to the GEIA emission factors is not known at this moment. The differences found have been regarded as acceptable and factors have not been changed. Larger differences can be noted for brown coal and liquid fuel in several cases, where the GEIA factors seem in some cases quite high. These fuel types play however a relatively minor role in the energy balance of these countries. In both India and China biofuels such as vegetable oils and fuel wood make a very large contribution to the energy supply. Administration of the used quantities for these fuel types is limited and the EDGAR and GEIA data are both estimates with a sometimes high uncertainty and different covering of fuel types. This might also be a cause for differences.

In EDGAR emission data for Europe are based on the TNO LOTOS emission database whereas for the USA data from the NAPAP are used. For other countries default factors are used. Since these countries comprise a considerable part of the world, the EDGAR factors have been compared to emission factors from the EMEP-CORINAIR Emission Inventory Guidebook (EMEP-CORINAIR, 1999). In case primary measures for emission reduction are disregarded a reasonable consistency is found for most fuel types in case emission factors for a full load operating modus are selected. Only for hard coal and brown coal the CORINAIR factors seem on average higher: 481 vs 390 g/GJ (hard coal) and 483 vs. 250 g/GJ (brown coal) for CORINAIR and EDGAR, respectively. In case simple primary emission reduction measures are taken into account the EDGAR factors are higher. From Table 1.1 it can be noted that emissions for Eastern Europe are in EDGAR lower than in GEIA. Probably this can partly also brought back to lower EDGAR emission factors. For Eastern Europe the GEIA estimates are taken from the CORINAIR'85 inventories of which no emission factors are available. Differences with CORINAIR90 are discussed in Section 1.2.1.3.

Table 1.2 Comparison of the global default emission factors for NO_x between EDGAR and GEIA as used for China and India for stationary combustion (emission factors of minor importance are between brackets)

Sector - fuel type	Emission factors EDGAR 2.0	Emission factors GEIA for China[a]	Emission factors GEIA for India[a]
Power generation			
Hard coal	**390**	**474**	**498**
Brown coal	250	-	(863)
Heavy fuel oil	260	(243)	243
Light fuel oil	-	(668)	(668)
Natural gas	210	(105)	105
Industrial combustion			
Hard coal	**270**	357	**375**
Brown coal	150	-	(651)
Heavy fuel oil	175	(655)	655
Light fuel oil	80	(235)	235
Coal products	140	321	321
Natural gas	120	(53)	53
Small combustion sources			
Hard coal	**85**	**90**	**94**
Brown coal	60	(191)	(195)
Heavy fuel oil	175	(48)	(48)
Light fuel oil	50	(78)	78
Coal products	85	(80)	80
Natural gas	50	(37)	37

[a] Kato *et al.* (1992)

Another source category for which differences were found is international shipping (see region "Sea (Oceans)"). Comparison with various literature sources has lead to the conclusion that the EDGAR emission factors need updating for this source (see Section 1.4).

For SO_2 it can be concluded from Table 1.1 that the non-corrected global emission totals are in reasonable agreement with each other. Regionally, the differences found can be for a large part explained by the increase in energy consumption during 1985 to 1990. This can be seen for China and East Asia, for which emission estimates show considerably more consistency after a rough correction for energy use. The GEIA estimates for East Asia are still somewhat lower after this correction. However, comparison of the emission factors shows that these are in good agreement. The differences possibly originate from differences in underlying fuel consumption data but this is difficult to verify. Since SO_2 emission is primarily determined by fossil fuel combustion, correction for landuse and biomass activities has only a slight effect. For other regions differences can not be so easily explained. The GEIA emission estimates are considerably higher for Latin America, Africa and Canada. These all comprise regions with a high production of non-ferrous metals (e.g. copper) which can give rise to a considerable sulphur release. For this source emission factors as well as activity rates might differ. OECD Europe will be discussed in the next chapter on validation of EDGAR with CORINAIR. Emission reported in GEIA for Japan seems low compared to EDGAR. In the EDGAR emission factors sulphur removal technologies as applied in Japan are taken into account. Also sulphur contents of fuels (including diesel fuels) are comparable between EDGAR and GEIA. It is not exactly clear what causes these differences.

In conclusion, the comparison of the EDGAR 2.0 NO_x and SO_2 estimates for 1990 with the GEIA inventories for 1885 shows a reasonable agreement provided that changes in energy consumption are taken into account. For NO_x the importance of anthropogenic sources other that fossil fuel combustion such as landuse activities and the use of biofuels can be noted. For SO_2 these sources are not of such importance. These sources are difficult to quantify and activity rates vary considerably between studies. Emission factors for coal combustion as used in GEIA and CORINAIR are within the uncertainty range of the EDGAR factors but tend to be somewhat higher on average. SO_2

emissions show a better consistency between EDGAR and GEIA than for NO_x. Emission factors generally agree but fuel consumption data might, also after correction for 1985 to 1990, still differ significantly. Emission factors for international shipping have been updated in EDGAR, since very large differences were found for 'Sea (Oceans)', which was also observed and communicated to us by some EDGAR users.

1.2.1.2 Comparison with GEIA inventories: CO_2

A detailed comparison has been made between the EDGAR and ORNL/CDIAC (GEIA) datasets for CO_2, which are based on energy statistics of the IEA and the UN, respectively (Marland *et al*., 1999). This was done both at country and at grid level. Here we summarise the conclusions of the comparison made at country (region) level for 1990 (Marland *et al*., 1998).

EDGAR 2.0 adopted the emission factors of CDIAC for comparable source types (Table 1.3) and global total emissions differ only 1%. The largest difference in global total emissions was found in solid fuels (16%) (see Table 1.4). However, emissions for specific countries were found to differ significantly for many countries, e.g. 8% for the former USSR, 50% for North Korea, 25% for South Korea, 10% for India, 1% for USA and China and 3 to 25% for Japan, Venezuela, Canada, China and Taiwan. In general, the largest relative differences occur in countries with small total emissions and weaker national energy statistics systems (see Fig. 1.3). For more details we refer to Marland *et al.* (1999).

Table 1.3 Summary of variables used in EDGAR 2.0 and GEIA CO_2 emissions datasets.

Variable	EDGAR	ORNL
Energy data		
- data source	IEA	UN
- fuel consumption	detailed fuel types by end-use sector	primary solids, liquids, gases
- units of primary data	TJ (LHV) (converted using country-specific conversion factors)	ton, TJ
- emission sources	all domestic use for combustion (on grid: minus domestic aircraft)	similar
- emission factor	3 uniform aggregated values	essentially the same values
- correction for unoxidised part	no	yes
Cement data		
- data source	UN	USGS (former US-BoM)
- activity explanatory variable	cement production	cement production
- emission factor	uniform factor	same value
Gas flaring data		
- data source	IEA	UN
- emission factor	uniform factor	same value

Table 1.4 Comparison of ORNL and EDGAR estimates of national CO_2 emissions for different fuel types and three country groups; data refer to the natural logarithm of (ORNL value/EDGAR value)

Ln (ORNL/EDGAR)	Mean	Standard deviation	Number of countries	% of global total emissions
All countries				
- Total emissions	0.011	0.449	173	
- Solids combustion	-0.161	0.921	92	
- Liquids combustion	0.107	0.391	170	
- Gases combustion	-0.042	0.621	74	
- Cement production	0.016	0.207	123	
- Flaring	0.027	0.050	40	
Total emissions, grouped				
- Highest emitting countries	0.010	0.115	48	94%
- Medium emitting countries	0.093	0.259	41	5%
- Least emitting countries	-0.028	0.611	84	1%

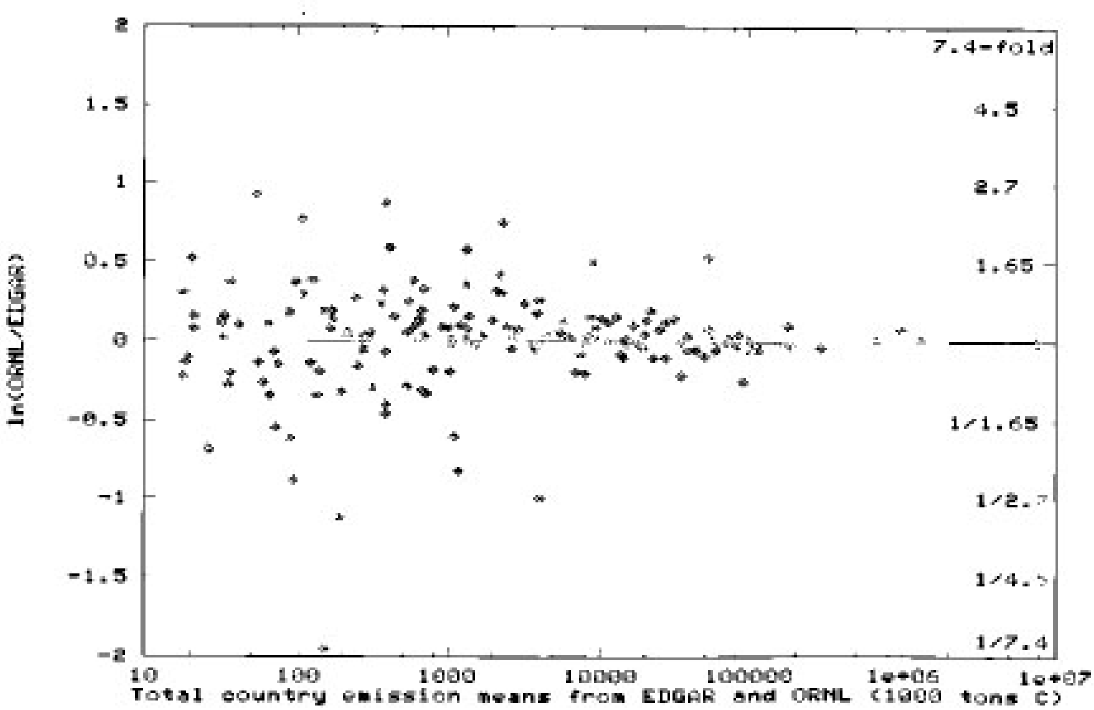


Fig. 1.3. The log of the ORNL/EDGAR-country total CO_2 emission values against the log of the mean of the two values.

1.2.1.3 Comparison with European countries in CORINAIR'90

For Europe the CORINAIR emission inventories are available. CORINAIR comprises a European framework within which country submissions of emission inventories are collected. In CORINAIR, 5-year advancing emission estimates by source category are stored. It holds inventories for all substances that are included in EDGAR. CORINAIR inventories have three levels of sector detail, which are called 'SNAP 1, 2 and 3-levels', respectively. The EDGAR inventories have been compared with CORINAIR at the first level. In order to link the EDGAR source categories to the CORINAIR sectors the conversion table has been used as presented in Table 1.5.

Basically every country is free to use its own methodology in order to prepare their submission to CORINAIR. There are comprehensive guidelines such as the Atmospheric Emission Inventory Guidebook available for making default estimates of emissions but in practise a variety of unique methods are used. The uncertainty of the CORINAIR estimates varies by country, source category and substance.

Comparison of CO_2

The first step in the validation of EDGAR with CORINAIR has been the comparison of national total emissions of CO_2. Table 1.6 lists the results of the EDGAR inventory vs. CORINAIR. Provided that emission factors do not differ significantly this comparison can give insight in the consistency of the underlying activity data of EDGAR and CORINAIR. Moreover it can be tested whether the links between the EDGAR and CORINAIR sectors have been correctly defined. In the second and third column the unmodified CORINAIR and EDGAR results are presented. The fourth column lists the ratio. In the CORINAIR inventories the use biofuels is often excluded for various reasons. In some cases CO_2 emission due to the use of fossil fuels for non-energy purposes and as feed stocks is also omitted in CORINAIR. Therefore the EDGAR estimates have been corrected for these sources and the ratios are listed in the last two columns.

Table 1.5 Link between the EDGAR 2.0 and CORINAIR SNAP1 source categories.

EDGAR main sector	EDGAR sub-sector	CORINAIR SNAP1 category *
Fossil fuel	Air (domestic and international)	8
Fossil fuel	Industry	3
Fossil fuel	International shipping	8
Fossil fuel	Non-road land transport	8
Fossil fuel	Other transformation sector	3
Fossil fuel	Power generation	1
Fossil fuel	Residentials etc.	2
Fossil fuel	Road transport	7
Fossil fuel: combustion	Air (domestic and international)	8
Fossil fuel: combustion	Industry	3
Fossil fuel: combustion	International shipping	8
Fossil fuel: combustion	Non-road land transport	8
Fossil fuel: combustion	Other transformation sector	3
Fossil fuel: combustion	Power generation	1
Fossil fuel: combustion	Residentials etc.	2
Fossil fuel: combustion	Road transport	7
Fossil fuel: non-combustion	Feedstock use of energy carriers	4
Fossil fuel: non-combustion	Gas flaring	5
Fossil fuel: non-combustion	Gas production	5
Fossil fuel: non-combustion	Gas transmission	5
Fossil fuel: non-combustion	Non-energy use	4
Fossil fuel: non-combustion	Oil handling	5
Fossil fuel: non-combustion	Oil production	5
Fossil fuel: production/transm.	Coal production	5
Fossil fuel: production/transm.	Gas production	5
Fossil fuel: production/transm.	Gas transmission	5
Fossil fuel: production/transm.	Oil handling	5
Fossil fuel: production/transm.	Oil production	5
Biofuel	Industry	3
Biofuel	Other transformation sector	3
Biofuel	Residentials etc.	2
Industrial processes	Adipic Acid	4
Industrial processes	Aluminium	4
Industrial processes	Cement	4
Industrial processes	Chemicals	4
Industrial processes	Iron & steel	4
Industrial processes	Nitric Acid	4
Industrial processes	Non-ferro: Copper	4
Industrial processes	Non-ferro: Lead	4
Industrial processes	Non-ferro: Zinc	4
Industrial processes/solvents	Chemicals	4
Industrial processes/solvents	Iron & steel	4
Industrial processes/solvents	Miscellaneous industry	4
Industrial processes/solvents	Solvents	6
Landuse/waste treatment	Agricultural waste burning	9
Landuse/waste treatment	Animals	10
Landuse/waste treatment	Arable land	10
Landuse/waste treatment	Biomass burning	10
Landuse/waste treatment	Deforestation	11
Landuse/waste treatment	Enteric fermentation	10
Landuse/waste treatment	Landfills	9
Landuse/waste treatment	Post-burn effects deforestation	11
Landuse/waste treatment	Rice cultivation	10
Landuse/waste treatment	Savanna burning	11
Landuse/waste treatment	Uncontrolled waste burning	9

* 1= Power generation etc.; 2 = Residential etc. combustion; 3 = Industrial combustion; 4 = Industrial process emissions; 5 = Fossil fuel production etc.; 6 = Solvent use; 7 = Road transport; 8 = Other mobile sources; 9 = Waste handling; 10 = Agriculture; 11 = Nature, incl. forest fires.

Table 1.6 Comparison of 1990 CO_2 emissions for European countries of CORINAIR'90 (excl. 'nature') and EDGAR 2.0, by country (Mton/year)

Country	CORINAIR (excl. nature)	EDGAR 2.0	CORINAIR/ EDGAR 2.0	CORINAIR/ EDGAR 2.0, excl. biofuels	CORINAIR/EDGAR 2.0, excl. biofuels and non-enery use and chemical feedstocks
Total	**4371**	**4614**	**0.9**	**1.0**	**1.1**
Austria	53	78	0.7	0.8	0.9
Belgium	103	121	0.9	0.9	0.9
Bulgaria	91	76	1.2	1.2	1.2
former Czechoslovakia	206	226	0.9	0.9	0.9
Denmark	55	64	0.9	1.1	1.1
Finland	55	88	0.6	1.0	1.1
France	373	429	0.9	0.9	1.1
Germany (former DDR)	303	305	1.0	1.0	1.0
Germany (former BRD)	708	754	0.9	1.0	1.0
Greece	74	79	0.9	1.0	1.0
Hungary	60	75	0.8	0.8	0.9
Ireland	32	37	0.9	0.9	0.9
Italy	441	456	1.0	1.0	1.1
Luxembourg	11	10	1.1	1.1	1.1
Netherlands	159	177	0.9	0.9	1.1
Norway	34	42	0.8	1.0	1.2
Poland	402	386	1.0	1.1	1.1
Portugal	47	52	0.9	1.0	1.1
Romania	171	171	1.0	1.0	1.0
Spain	279	236	1.2	1.2	1.3
Sweden	86	110	0.8	1.4	1.6
Switzerland	47	48	1.0	1.1	1.1
United Kingdom	580	596	1.0	1.0	1.0

In Table 1.6 differences larger than 10% have been underlined. As can be concluded the unmodified emission estimates sometimes vary considerably between EDGAR and CORINAIR. A correction for biofuel use (which is usually but not always excluded in the CORINAIR inventories) leads to more consistent results: the European totals deviate less than 5%. Still differences remain for several countries that might be partly caused by different CO_2 emission factors for non-energy use and use as feed stock of fossil fuels. In order to verify this CO_2 emission due to non-energy uses of fuels have been excluded from the EDGAR results and the result is listed in sixth column. Although for some countries this leads to an improvement, overall consistency is less with the exclusion of non-energy uses. As in CORINAIR methodologies and sector coverage with respect to biofuels and non-energy uses vary between countries, incidental differences with consistent inventories like EDGAR are likely. Overall, results are in reasonable to good agreement with each other and no major inconsistencies in the underlying energy data seem to exist.

Comparison of other compounds

The second validation step comprises a more detailed comparison of the CORINAIR and EDGAR results for CH_4, CO, CO_2, N_2O, NMVOC, NO_x and SO_2. In this comparison the link between the sectors is analogous to Table 1.4. Basically this comparison has been made by sector and by country and aggregated results are listed in Table 1.7. Here results are aggregated for three regions being Western and Eastern Europe separately and Europe as a whole. There are several different sub-totals given in the tables. In the second column is indicated which CORINAIR SNAP1 sectors are included in the sub-totals. These sub-totals are listed because in some cases the apportioning of emissions to SNAP sectors is not always consistent in CORINAIR. This applies for example to small differences in what a country considers SNAP01 ‘Public Power, cogeneration and district heating’, SNAP02

'Commercial, institutional and residential combustion' and SNAP03 'Industrial combustion'. Furthermore the combustion-related sources in industry (SNAP03 'Industrial combustion') are sometimes listed under SNAP04, 'Process emissions' and vice versa. In several cases waste which is incinerated for heat production is listed under SNAP01 or SNAP03, whereas waste incineration would normally fall under SNAP09 'Waste treatment and disposal'. For SNAP 11, 'Nature', no emissions are reported in CORINAIR while in EDGAR there are emissions for this source category. Therefore for each substance the totals minus 'Nature' are also listed. In the section following, it will be evaluated whether all differences between CORINAIR and EDGAR can be explained.

Differences per compound

The CO_2 emission estimates of EDGAR and CORINAIR show a good consistency. As has been mentioned above possible causes for differences are process emission factors (for instance cement production) and non-energy uses, for which emission factors have a higher uncertainty compared to combustion sources. This results in differences for SNAP 04, process emissions.

The sub-totals (total excluding 'Nature') for CH_4 agree very well. Also for the individual major sources results are consistent. For SNAP 09, EDGAR gives higher values for Eastern Europe. This is caused by including the EDGAR estimate for Agricultural Waste Burning (some 300 kton), whereas this source is lacking in CORINAIR. For combustion processes (SNAP 10, 02, 03) which are a minor source of CH_4 though, emissions differ more. The emission factors proposed in the CORINAIR handbook have a very broad range, which might imply that these are fairly uncertain and highly variable.

For N_2O large differences are found. Of the seven substances discussed here the N_2O emission factors probably have the largest uncertainty. The very broad range of the emission factors in the CORINAIR handbook can for instance illustrate this. It is therefore not unexpected that results differ so remarkably. On average the CORINAIR figures are about a factor 3 higher than the EDGAR estimates, and similar ratios in the values of the emission factors are observed. Given the large uncertainties in these factors however, it is difficult to assess which inventory gives the best results in this case. For SNAP 10, CORINAIR sometimes includes emission estimates for crops and grasslands whereas these are estimated according to different methodologies in EDGAR.

For CO the differences are somewhat larger than for CH_4. The emission estimates for the main contributing sources, road transport, small combustion sources, show a reasonable agreement. Differences are higher for SNAP 03, industrial combustion. Partly this is caused by the fact that emissions from processes with contact such as ore sintering (a major CO source) are in CORINAIR categorised under SNAP 03 while in EDGAR these emissions are marked as process emissions and thus would fall under SNAP 04, process emissions. This also partly causes the discrepancies found for SNAP 04. The sum of process emissions and industrial combustion compare better. But there still seem to exist notable differences in emission factors. For SNAP 08, non-road transport, EDGAR excludes air transport in the country totals. However, emission factors for other transport modes differ to such degree that revision of the EDGAR 2.0 factors has been necessary (see Section 4.2.3). Another major CO source in EDGAR is agricultural waste burning. Coverage of this source is only very limited in CORINAIR, hence the very large differences for SNAP 09, agriculture.

For NMVOC regional totals show a fair consistency. This is also observed for major contributing sectors separately such as solvent use, road transport and industrial processes. It should be noted that the distinction between emissions from processes and industrial combustion is not always consistent in CORINAIR. The sum of these emissions compare reasonably, the higher EDGAR estimate for industrial combustion is mainly caused by the inclusion of biofuels for this sector. Agricultural waste burning makes a very relevant contribution in the EDGAR inventories for NMVOC. In CORINAIR this activity is poorly covered, hence the differences for waste treatment and disposal (SNAP 09). CORINAIR includes NMVOC emission estimates for excretions and crops/grassland that are in turn lacking in EDGAR. Also for NMVOC, the large differences found for emission from non-road transport (SNAP 08) have led to a revision of the EDGAR factors for this compound (see Section 4.2.3).

Table 1.7 Quantitative comparison of the CORINAIR90 results on SNAP1 with EDGAR inventories for (a) CO_2, CH_4, N_2O; and (b) CO, NMVOC, NO_x and SO_2, by region and by sector (unit: kton, except CO_2: Mton).

	CORINAIR	Western Europe			Eastern Europe			Europe (total)		
Subst.	SNAP 01 *	EDGAR	COR.	COR/EDG	EDGAR	COR.	COR/EDG	EDGAR	COR.	COR/EDG
CO_2 (Mt)	1	946	936	1.0	444	397	0.9	1390	1332	1.0
	2	662	655	1.0	151	194	1.3	813	850	1.0
	3	833	835	1.0	329	306	0.9	1162	1141	1.0
	4	343	162	0.5	45	17	0.4	388	180	0.5
	3+4	*1176*	*997*	*0.8*	*374*	*324*	*0.9*	*1550*	*1321*	*0.9*
	1+3+4	*2122*	*1933*	*0.9*	*818*	*720*	*0.9*	*2940*	*2653*	*0.9*
	1+3+4+9+10	*2122*	*2031*	*1.0*	*818*	*727*	*0.9*	*2940*	*2758*	*0.9*
	5	25	15	0.6	1	12	11.3	26	27	1.0
	6		0			0		0	0	
	7	660	632	1.0	68	63	0.9	728	695	1.0
	8	124	111	0.9	10	28	2.8	134	139	1.0
	9		77			6		0	83	
	10		21			1		0	22	
	All except 11	***3593***	***3445***	***1.0***	***1049***	***1025***	***1.0***	***4642***	***4470***	***1.0***
	11	0	278		0	16		0	295	
	TOTAL	**3593**	**3723**	**1.0**	**1049**	**1041**	**1.0**	**4642**	**4764**	**1.0**
CH4 (kt)	1	14	28	2.0	6	15	2.3	21	43	2.1
	2	403	383	0.9	299	236	0.8	702	619	0.9
	3	122	53	0.4	37	39	1.0	160	92	0.6
	4	151	50	0.3	46	26	0.6	197	76	0.4
	3+4	*273*	*104*	*0.4*	*83*	*64*	*0.8*	*357*	*168*	*0.5*
	1+3+4	*288*	*132*	*0.5*	*90*	*79*	*0.9*	*378*	*211*	*0.6*
	1+3+4+9+10	*18094*	*18430*	*1.0*	*5182*	*5327*	*1.0*	*23276*	*23757*	*1.0*
	5	4751	4874	1.0	5295	5534	1.0	10046	10408	1.0
	6	0	0		0	0		0	0	
	7	141	186	1.3	17	14	0.8	159	200	1.3
	8	12	22	1.9	1	3	3.0	13	25	2.0
	9	7281	7580	1.0	1726	1173	0.7	9007	8752	1.0
	10	10525	10718	1.0	3366	4075	1.2	13891	14793	1.1
	All except 11	***23401***	***23896***	***1.0***	***10794***	***11113***	***1.0***	***34195***	***35009***	***1.0***
	11	0	9062		0	1344		0	10406	
	TOTAL	**23401**	**32958**	**1.4**	**10794**	**12457**	**1.2**	**34195**	**45415**	**1.3**
N_2O (kt)	1	8	56	7.3	4	41	10.9	11	97	8.5
	2	3	28	8.8	1	17	16.0	4	45	10.7
	3	6	37	5.8	2	17	9.4	8	54	6.6
	4	123	325	2.7	40	30	0.8	163	356	2.2
	3+4	*129*	*362*	*2.8*	*42*	*48*	*1.1*	*171*	*409*	*2.4*
	1+3+4	*137*	*418*	*3.1*	*46*	*89*	*1.9*	*182*	*506*	*2.8*
	1+3+4+9+10	*274*	*914*	*3.3*	*90*	*332*	*3.7*	*364*	*1246*	*3.4*
	5		0			0		0	0	
	6		0			0		0	0	
	7	5	27	5.9	0	3	7.7	5	30	6.0
	8	1	5	7.8	0	1	17.8	1	6	8.6
	9	8	10	1.3	2	3	1.7	10	13	1.4
	10	130	486	3.7	42	240	5.7	172	726	4.2
	All except 11	***283***	***974***	***3.4***	***91***	***353***	***3.9***	***374***	***1327***	***3.6***
	11	84	451	5.4	32	102	3.2	115	553	4.8
	TOTAL	**366**	**1425**	**3.9**	**123**	**455**	**3.7**	**489**	**1880**	**3.8**

* 1= Power generation etc.; 2 = Residential etc. combustion; 3 = Industrial combustion; 4 = Industrial process emissions; 5 = Fossil fuel production etc.; 6 = Solvent use; 7 = Road transport; 8 = Other mobile sources; 9 = Waste handling; 10 = Agriculture; 11 = Nature, incl. forest fires.

Table 1.7 Continued: (b) CO, NMVOC, NO_x and SO_2

	CORINAIR	Western Europe			Eastern Europe			Europe (total)		
Subst.	SNAP 01 *	EDGAR	COR.	COR/EDG	EDGAR	COR.	COR/EDG	EDGAR	COR.	COR/EDG
CO (kt)	1	156	652	4.2	75	156	2.1	231	807	3.5
	2	6245	6965	1.1	3771	2981	0.8	10016	9947	1.0
	3	1919	3426	1.8	343	4774	13.9	2261	8200	3.6
	4	6086	2695	0.4	2255	493	0.2	8341	3188	0.4
	3+4	*8005*	*6121*	*0.8*	*2598*	*5267*	*2.0*	*10602*	*11388*	*1.1*
	1+3+4	*8161*	*6772*	*0.8*	*2673*	*5423*	*2.0*	*10834*	*12195*	*1.1*
	1+3+4+9+10	*25359*	*10120*	*0.4*	*6842*	*7081*	*1.0*	*32202*	*17201*	*0.5*
	5	0	61		0	2		0	63	
	6	0	1		0	0		0	1	
	7	36658	34081	0.9	6285	4839	0.8	42944	38919	0.9
	8	249	2051	8.2	14	172	12.5	263	2223	8.4
	9	17198	2769	0.2	4170	1657	0.4	21368	4427	0.2
	10	0	579		0	1		0	579	
	All except 11	***68512***	***53279***	***0.8***	***16912***	***15075***	***0.9***	***85424***	***68354***	***0.8***
	11	0	1329		0	29		0	1358	
	TOTAL	**68512**	**54608**	**0.8**	**16912**	**15104**	**0.9**	**85424**	**69712**	**0.8**
NMV (kt)	1	25	41	1.6	14	14	1.0	40	55	1.4
	2	343	741	2.2	148	249	1.7	491	989	2.0
	3	512	77	0.2	127	77	0.6	639	154	0.2
	4	1112	977	0.9	280	243	0.9	1391	1220	0.9
	3+4	*1624*	*1054*	*0.6*	*406*	*320*	*0.8*	*2030*	*1374*	*0.7*
	1+3+4	*1649*	*1095*	*0.7*	*421*	*334*	*0.8*	*2070*	*1429*	*0.7*
	1+3+4+9+10	*3358*	*1981*	*0.6*	*885*	*713*	*0.8*	*4243*	*2694*	*0.6*
	5	1803	1166	0.6	298	210	0.7	2101	1376	0.7
	6	4771	4260	0.9	751	660	0.9	5522	4920	0.9
	7	7385	6072	0.8	1005	694	0.7	8390	6766	0.8
	8	4	564	160.0	0	112	228.2	4	677	168.3
	9	1709	244	0.1	464	261	0.6	2173	506	0.2
	10	0	641		0	117		0	759	
	All except 11	***17664***	***14784***	***0.8***	***3086***	***2638***	***0.9***	***20750***	***17422***	***0.8***
	11	0	3547		0	800		0	4347	
	TOTAL	**17664**	**18332**	**1.0**	**3086**	**3438**	**1.1**	**20750**	**21770**	**1.0**
NO_x (kt)	1	2186	2485	1.1	765	1273	1.7	2951	3759	1.3
	2	664	518	0.8	113	236	2.1	778	754	1.0
	3	1732	1698	1.0	453	741	1.6	2185	2439	1.1
	4	851	229	0.3	247	163	0.7	1098	392	0.4
	3+4	*2583*	*1927*	*0.7*	*700*	*903*	*1.3*	*3283*	*2830*	*0.9*
	1+3+4	*4770*	*4412*	*0.9*	*1465*	*2177*	*1.5*	*6234*	*6589*	*1.1*
	1+3+4+9+10	*5373*	*4583*	*0.9*	*1611*	*2297*	*1.4*	*6984*	*6880*	*1.0*
	5		76			6		0	82	
	6		1			0		0	1	
	7	6701	6970	1.0	675	876	1.3	7376	7846	1.1
	8	433	1800	4.2	33	509	15.4	466	2310	5.0
	9	604	134	0.2	146	108	0.7	750	241	0.3
	10		37			12		0	50	
	All except 11	***13171***	***13949***	***1.1***	***2432***	***3924***	***1.6***	***15603***	***17873***	***1.1***
	11	0	49		0	1		0	50	
	TOTAL	**13171**	**13998**	**1.1**	**2432**	**3925**	**1.6**	**15603**	**17923**	**1.1**
SO_2 (kt)	1	8814	8605	1.0	6812	6343	0.9	15626	14948	1.0
	2	2246	1288	0.6	1066	1758	1.6	3312	3046	0.9
	3	5700	4967	0.9	1250	2001	1.6	6949	6968	1.0
	4	4793	623	0.1	1578	299	0.2	6371	923	0.1
	3+4	*10492*	*5590*	*0.5*	*2828*	*2301*	*0.8*	*13320*	*7891*	*0.6*
	1+3+4	*19306*	*14195*	*0.7*	*9639*	*8643*	*0.9*	*28946*	*22838*	*0.8*
	1+3+4+9+10	*19411*	*14278*	*0.7*	*9665*	*8648*	*0.9*	*29076*	*22926*	*0.8*
	5	0	44		0	1		0	45	
	6	0	0		0	0		0	0	
	7	808	547	0.7	87	172	2.0	895	718	0.8
	8	40	432	10.7	13	133	10.1	54	565	10.6
	9	105	82	0.8	25	5	0.2	130	87	0.7
	10	0	1		0	0		0	1	
	All except 11	***22506***	***16589***	***0.7***	***10831***	***10711***	***1.0***	***33337***	***27300***	***0.8***
	11	0	573		0	0		0	573	
	TOTAL	**22506**	**17162**	**0.8**	**10831**	**10711**	**1.0**	**33337**	**27874**	**0.8**

* 1= Power generation etc.; 2 = Residential etc. combustion; 3 = Industrial combustion; 4 = Industrial process emissions; 5 = Fossil fuel production etc.; 6 = Solvent use; 7 = Road transport; 8 = Other mobile sources; 9 = Waste handling; 10 = Agriculture; 11 = Nature, incl. forest fires.

Although the total NO_x emission for Europe of EDGAR is in reasonable agreement with CORINAIR, there are some noticeable regional and sectoral differences. Emission estimates for stationary combustion (SNAP 01, 02, 03) are for Eastern Europe somewhat lower in EDGAR compared to CORINAIR90. In the GEIA inventories CORINAIR'85 formed the basis, a similar difference was found in the validation with GEIA (see above). Yet, given the available background information on the emission factors it has been concluded that the EDGAR V2 factors for stationary combustion do not require adjustment (see validation with GEIA). As has been observed for other substances, in CORINAIR the distinction between emissions from processes and industrial combustion is not always consistent in practice. Furthermore, EDGAR uses higher NO_x emission factors for cement production (included under SNAP 04 in EDGAR). This could explain the differences found for Western and Eastern Europe for SNAP 04, process emissions. For road transport emission estimates agree. For non-road transport however, new emission factors for the different transport modes have been entered in EDGAR. The EDGAR emission estimate for SNAP 09, waste treatment and disposal, is dominated by the contribution of agricultural waste burning which is not included in CORINAIR. However, EDGAR does not include the source category controlled municipal waste incineration. This source represents some 200 kt of NO_x emission in CORINAIR.

For SO_2 differences between EDGAR and CORINAIR are sometimes unexpectedly high. The biggest difference can be noted for process emissions. For Western Europe, emissions for this sector are almost twice as high in EDGAR relative to CORINAIR. This can be brought back to the EDGAR estimates for sulphur emission from non-ferrous metals production, which amounts to more than 5000 kton for this region. In CORINAIR only 200 kton is reported for this source (which is listed under SNAP 03 in CORINAIR). Emission factors for non-ferrous metals production appear to differ significantly. EDGAR uses a global default value. In addition, EDGAR includes some 400 kton SO_2 originating from biofuel use in industry, which is not regarded in CORINAIR. The differences found for small combustion sources and road transport can be explained by the different assumptions of the sulphur content of coal and diesel fuel respectively.

In conclusion, validation of EDGAR V2 with the CORINAIR90 emission inventories has resulted in among others the following points of interest:

- EDGAR 2.0 contains rather inaccurate emission factors for non-road transport;
- EDGAR includes rather high emissions from agricultural waste burning;
- EDGAR does not contain emission estimates for controlled waste incineration;
- Separation of emissions from processes and combustion are in CORINAIR not always consistently distinguished which makes a detailed comparison difficult;
- For some combustion sources NO_x emission factors from EDGAR seem somewhat lower on average;
- Sulphur contents seem to vary for domestic and automotive fuels.

A number of these topics are addressed in Section 4.2.3.

1.2.1.4 Comparison with inventories in Second National Communications

Second in a series, Van Amstel *et al.* (1999) report on a more detailed analysis of differences between national emission inventories of CO_2, CH_4 and N_2O included in so-called second National Communications on Climate Policy of industrialised countries and global inventories such as EDGAR 2.0 and atmospheric concentration data. National inventories as reported to the Climate Convention Secretariat and compiled by the Secretariat in tables (UNFCCC/CP/1996/12/Add.2 and UNFCCC/CP/1998/11/Add.2) and country study results (as cited in Braatz *et al*., 1996) were compared with EDGAR 2.0 emission estimates. Relatively large differences were analysed. The study provided background information for IPCC expert meetings in 1999 on *Good Practice Guidance and Uncertainty Management* (IPCC, 2000). It also supports the review and synthesis process of national communications by the Climate Secretariat and the *Subsidiary Body on Scientific and Technological Advice* (SBSTA).

The report describes a number of ways to estimate the quality and uncertainty of national greenhouse gas emission inventories. It can be concluded that measuring concentrations of greenhouse gases in the atmosphere is not the only independent method to verify inventories because measurements and atmospheric models also contain errors and uncertainties. Comparisons with independent inventories on national, regional and global scales can provide more insight into the quality of the inventories. Analysis showed that national inventories from industrialised countries, as reported in the *National Communications,* are not transparent. Compliance to the Kyoto Protocol cannot be reviewed on the basis of this information alone. A more detailed standard reporting format is recommended for national inventories. A review for the Kyoto Protocol can thus be made on the basis of similar information from all industrialised countries. Precise and complete information on emissions from non-Annex-I countries is still missing. A lack of statistics on long-term trends and a lack of country-specific emission factors make national inventories from these countries incomplete and inaccurate, especially for agriculture, forestry and land-use change. Energy statistics could also be much improved.

From the viewpoint of validating the EDGAR 2.0 emissions, we summarise here the conclusions for each of the three greenhouse gases that were compared.

Carbon dioxide

For CO_2, the difference between the estimated global budget of fossil fuels and the sum of the available inventories is small (<10%) (Table 1.8). However, the IPCC global budget (1996) was obtained from a similar global database of emission estimates. Thus, the expected global budget and the sum of inventory data are expected to be similar. This makes the comparison for CO_2 less meaningful.

Table 1.8 Global totals for carbon dioxide in Pg CO_2/year

Source	Number of countries	NC1	NC2	Global budget[a]
Annex I countries[b]	NC1=34, NC2=35	13.7	14.3	-
Country studies[c]	31	5.1	5.1	-
Global database[d]	124	6.7	6.7	-
Total	190	25.4	26.1	26.0

[a] IPCC (1995) (7.1 Pg C x 44/12)
[b] UNFCCC (1997)
[c] Braatz *et al.* (1996)
[d] Olivier *et al.* (1996; 1999a)

Differences that were found between the estimates in the first and second National Communications (NC1 and NC2, respectively) are explained by the fact that countries have updated estimates using improved methodology. For some European countries differences between national reports and EDGAR estimates are also caused by the use of different base years. For EDGAR estimates of carbon dioxide emissions to become comparable – for instance within 5% - to country emissions, the IEA energy data for many countries (including conversion factors) as well as country-specific emission factors need a thorough evaluation. The activity data for industrial processes in EDGAR also need improvement for some countries. Clearer definitions are needed for the allocation of emissions from combined heat and power: to be reported within industry or within power generation? The confusion about allocation to process emissions or combustion emissions of coking coal use in the iron and steel industry should be dealt with in order to make national inventories comparable at the sector level.

Methane

For methane, the discrepancy between the global budget and the sum of national inventories is about 22% in the NC1 column, and 16% in the NC2 column with updated methane emissions for Annex I countries and the country study of India added (Table 1.9). The global budget was derived from atmospheric measurements and is therefore independent of the inventory data. The agreement between the two budgets is within the expected level of uncertainty, which is 30%, thus giving confidence in the Revised IPCC Guidelines.

Table 1.9 Global totals for methane in Tg CH_4 per year

Source	Number of countries	NC1	NC2	Global budget[a]
Annex I countries[b]	33	104	108	-
Country studies[c]	31	66	84	-
Global database[d]	125	121	121	-
Total	189	291	313	375 (300-450)

[a] IPCC (1995)
[b] UNFCCC (1997)
[c] Braatz *et al*. (1996) and Mitra and Battacharya (1998)
[d] Olivier *et al.* (1996; 1999a)

When comparing national inventories and EDGAR estimates for 1990, the net large differences for methane between national reports and EDGAR 2.0 are 30 Tg. This may be an indication for the uncertainty of the methane emission inventories. The global total methane emissions estimated from national data, country studies and EDGAR data to fill in the missing countries fall short of the middle estimate of the ranges in the IPCC budget as published in 1994. The aggregated world total anthropogenic methane emission of 320 Tg compares with the low end of the range of 300-450 Tg methane per year as published by IPCC (1994). This may indicate that IPCC default emission factors from the Guidelines and/ emission factors used in national communications are generally too low.

Four types of differences were found when emission estimates from national inventories and EDGAR 2.0 were compared:

Differences as a result of different emission factors
These differences can be relatively large, for instance, in the case of methane emissions from manure, rice and waste. For these sources in EDGAR 2.0 regional emission factors were used instead of country-specific factors. Apparently per region the country-specific circumstances are often quite large.

Differences because of the use of different activity levels
These differences point to the fact that EDGAR uses internationally available activity data, which, in some cases, differ from national statistics. Also, in some cases EDGAR 2.0 used available approximations instead of detailed country-specific statistics.

Differences due to gaps in national estimates or EDGAR
Various national communications and country study reports are not complete or not yet available (collection of reports in 1997, analysis took place in 1998). When compared with EDGAR 2.0 these gaps are very distinct. Country studies were made for capacity building and to learn about IPCC methodology. EDGAR 2.0 showed gaps, for example, in methane emissions from wastewater treatment. National reports showed gaps as well. No comparison of methane emission estimates was possible for the following agriculture and land use sectors: agricultural waste burning, savanna burning, deforestation and biomass burning, because the reporting in the national estimates for these sectors is very scattered.

Differences due to different definitions on the anthropogenic part of emissions
These differences occur in estimates of methane from soil, wetlands and land use change. IPCC Guidelines should make these definitions clearer.

Nitrous oxide
For nitrous oxide, the sum of inventories is close to the lower level of the range of the global budget (Table 1.8). The global budget was obtained from observed atmospheric increases and is independent of the inventory data. However, the estimate of total anthropogenic emissions (9 Tg) in Table 1.10 was based on previous IPCC estimates (IPCC, 1995). Using the *Revised 1996 IPCC Guidelines* (IPCC, 1997), the mid-point estimate for world-wide anthropogenic emissions is higher: 11-12 Tg N_2O/yr (Mosier *et al*., 1998; Kroeze *et al*., 1999), but still within the range deduced from trends in atmospheric N_2O. The Revised Guidelines methodology has been used to estimate historic emissions of N_2O, which in turn were used as input to a simple atmospheric box model for simulating trends in atmospheric N_2O

in line with the observed trends (Kroeze *et al*., 1999). These results indicate that on a global scale, the *Revised 1996 IPCC Guidelines* are not inconsistent with trends in atmospheric concentrations.

Table 1.10 Global totals for nitrous oxide in Tg N_2O per year

Source	Number of countries	NC1	NC2	Global budget[a]
Annex I countries[b]	33	2.0	2.2	-
Country studies[c]	31	0.1	0.1	-
Global database[d]	125	2.8	2.8	-
Total	189	4.9	5.1	9 (5-13)

[a] IPCC (1995) (3-8 Tg N/year , midpoint 5.7, x 44/28)
[b] UNFCCC (1997)
[c] Braatz *et al.* (1996)
[d] Olivier *et al.* (1996; 1999a)

Of the 25 countries that were included in the analysis, four (Greece, Hungary, Japan and the UK) have reported NC1 emissions within 10% of the EDGAR 2.0 estimate. For 13 countries, the EDGAR 2.0 estimate is 30 - 75% lower than the NC1 reported emission, and for 8 countries the EDGAR 2.0 estimate is 15 - 550% higher. A comparison of EDGAR 2.0 estimates with the second national communications (NC2) reveals that for only nine countries is the difference between EDGAR 2.0 and NC2 smaller than between EDGAR 2.0 and NC1. While this implies that most countries revised their estimates for total N_2O, these revisions do not reduce the difference between EDGAR 2.0 and the NC1 estimate.

For about two-thirds of the countries the EDGAR 2.0 estimate for agricultural emissions of N_2O is lower than the estimate reported in the second national communications. In addition, it is clear that most NC2 estimates are higher than NC1 estimates. Both findings may be induced by the publication of the *Revised 1996 IPCC Guidelines*, which include more agricultural sources and revised (higher) emission factors than the *1995 Guidelines*. About one-third of all countries report agricultural emissions that do not exceed EDGAR 2.0, which could be an indication that these countries do not report all agricultural sources of N_2O. In-depth analysis of a number of countries shows that country estimates could increase considerably if emissions were estimated following the *Revised 1996 IPCC Guidelines.*

For N_2O from fuel use the analysis indicates that the EDGAR 2.0 estimates for fossil fuel combustion are relatively low, while the estimates for biofuel are relatively high when compared to the National Communications. In addition, the EDGAR 2.0 estimate for N_2O from traffic is lower than in the National Communications in all countries studied. Furthermore, the comparison reveals that for all countries considered the EDGAR 2.0 estimates are lower than the National Communication, indicating that the EDGAR 2.0 estimates for industry may also be on the low side.

Other specific conclusions from the comparison with emissions in National Communications and country study reports are:

The analysis showed that national annual inventories from *industrialised countries (Annex I countries)* as reported in National Communications are not transparent, comparable, complete and accurate enough to assess compliance of the Kyoto Protocol.

Lack of statistics on long term trends and a lack of country-specific emission factors make national inventories from *non-Annex I countries* incomplete and inaccurate, especially for agriculture, forestry and land use change. Energy statistics are reasonably accurate but can be improved. A more thorough analysis for developing countries is possible after the quality of national reports is improved and more country-specific emission factors have been developed.

At this moment only *part of the global budget is addressed* by the National Communications that have been submitted by Annex I countries. The part covered by the National Communications is for CO_2 about 50%, for CH_4 about 30% and for N_2O about 25%.

It is necessary to agree on a *level of detail and accuracy of reporting* the national inventories of countries. Transparency in reporting can be improved by the mandatory use of standard data tables for reporting emissions, activity data and aggregated emission factors for all sectors

A quantitative estimate of the *uncertainty in annual emissions* is required to determine in more detail whether differences found in comparisons as observed in this study are significant or not.

Accurate verification of national inventories through an analysis of *atmospheric concentrations and the use of transport models* is limited by a lack of detailed measurement data.

1.2.1.5 Comparison with 1994 CO_2 inventory for China

For the reference year 1994 TNO has compiled a CO_2 emission inventory for China (Van Ham *et al.,* 1996). In this study for 1994 3900 Tg CO_2 emissions are reported for China, excluding biofuels, versus 2700 Tg which is reported by EDGAR for the 'China-region' (assuming 100% oxidation to CO_2). The EDGAR 2.0 'China region' includes China, Hong Kong, Kampuchea, North Korea, Loa, Macau, Mongolia, Taiwan and Vietnam. Van Ham *et al.* (1996) only considers China and uses oxidation rates taken from IPCC defaults. Also average carbon contents of coal might differ in the two studies. Of the 3900 Tg reported by Van Ham *et al*., 430 Tg is attributed to unintentional coal fires, an important source category that EDGAR 2.0 not covers. If we correct for this contribution, 3500 Tg remains. China has undergone a significant economic growth during the period 1990 to 1994 and CO_2 emissions have increased considerably. Without further analysis, a rough comparison between the emission totals from EDGAR 2.0 and Van Ham *et al.* can be made: 2700 vs. 3500 Tg, respectively. Unintentional coal fires in China will be added in EDGAR 3.0 as a new emission source category for CO_2 as well for other compounds (in particular CO, NO_x, SO_2).

1.2.2 Comparison with other gridded spatial emission distributions

Various techniques exist to compare maps. Generally, a distinction can be made between visual comparison techniques (Tukey, 1977) and quantitative comparison techniques (e.g. Finn, 1993). The latter comprises statistical techniques, expressing differences in statistical distributions, and pattern comparison techniques. Here we discuss two techniques of the second type, which will be used in a number of cases. The two are chosen because they are simple to apply, rather easy to understand and in many cases sufficient for a first check. The first technique simply computes the absolute difference of two maps at each location and counts the locations with 'no difference'. The number of similar locations is divided by all locations, so the indicator has a maximum of 1. We call this the Simple Similarity Index (SSI). Similar SSI values may however coincidentally emerge from different patterns. Therefore a second technique is used checking for pattern similarity: Map Cross-Correlation (MCC), a standard function in ArcInfo. Identical shapes would result in a MCC value of +1, whereas identical but opposite shapes (i.e. tops on one map and valleys of similar shape on at the same location the other map) would give a value of -1.

This was only possible for CO_2, NO_x and SO_2, since for other compounds GEIA inventories were either identical (N_2O, NMVOC, CO) or not yet available. For CO_2 a more detailed comparison has been made between the EDGAR and ORNL (GEIA) datasets, based on energy statistics of the IEA and the UN, respectively (Marland *et al*., 1999). This was done both at country and at grid level (Marland *et al.,* 1998) (see Section 1.2.1.2). The NO_x and CO inventories have also been compared to other global inventories (Lee *et al.,* 1997; Olivier *et al.,* 1999b).

Thus, relatively new methods for comparing the spatial distributions of emissions were used for the comparison with the three GEIA inventories of CO_2, NO_x and SO_2 as well as for the population maps underlying the GEIA and EDGAR inventories (Van Beurden and Douven, 1999) using the concepts of SSI (relative and absolute) for the total map and the MCC for the total map and for specific regions. Since the different population maps used for the major part of the within country distribution of national emissions are key to the spatial comparison here, these spatial comparison indicators are also applied to the population maps themselves. Obviously, one may not expect better comparison of emissions maps than the underlying population maps show.

Summary results on *differences in individual cell values* are presented in Fig. 1.4 showing Simple Similarity Indices (SSI). Whereas for population 78% of the cells of the EDGAR map (from Logan) has a difference of less than 100% from the GEIA map (from NASA-GISS), for the CO_2 maps of EDGAR and GEIA this is 72% (Fig. 1.1.a). For NO_x and SO_2, the fraction of the map cells with less than 100% difference is 92% and 85%, respectively. Fig. 1.4.b and 1.4.c also shows the effect of including large-scale biomass burning and international shipping in the EDGAR maps of NO_x and SO_2 (which is only partly included in the GEIA maps).

Table 1.11 Spatial comparison EDGAR V2.0 (all anthropogenic emissions below 1 km) en GEIA V1 emissions of CO_2: Map Cross Correlation (MCC) at global and regions level.

Area	Co-ordinates	CO_2	Population	Difference
World		**0.89**	**0.91**	**-0.03**
of which:				
North America	-170,23,-50,75	0.93	0.93	-0.01
Europe	-12,34,32,75	0.87	0.85	0.01
o.w. Western	-12,34,18,75	0.86	0.84	0.02
o.w. Eastern	13,40,32,75	0.91	0.87	0.04
Latin America	-120,-60,-30,30	0.92	0.97	-0.05
Africa	-20,-40,55,38	0.82	0.88	-0.06
Middle East	32,10,64,40	0.78	0.87	-0.09
Former USSR	19,35,179,85	0.92	0.92	0.00
India-China region	60,5,145,55	0.91	0.93	-0.02
Oceania	90,-50,179,8	0.73	0.70	0.03

Next, we looked into the *similarity of the shape of the maps* using the Map Cross-Correlation (MCC), both globally and per region. The Arc-Info Correlation Coefficient is 0.91 for the population maps and 0.89 for the CO_2 maps. From the results summarized in Table 1.11, it can be concluded that the shapes of CO_2 maps are pretty similar in North and Latin America, the former USSR and the India-China region; for these regions the MCC of the population maps is also above average. Population maps are rather different for Europe, in particular in Western Europe, and for Oceania, Middle East and Africa. This causes the MCC for CO_2 also to be below average for these regions (except for Eastern Europe). Further analysis showed that the regional figures are not influenced by large water areas.

The same analysis was made for NO_x and SO_2 (Table 1.12). The Arc-Info Correlation Coefficient is 0.77 and 0.49 for the NO_x and SO_2 maps, respectively. To put these into perspective these figures can be compared to the figure of about 0.90 for the CO_2 maps, which lead to the conclusion that the maps of SO_2 show much more differences in spatial patterns than the other two compounds. For NO_x, the shapes are pretty similar in North and Latin America, Middle East, Europe and Oceania. For these regions the MCC of the SO_2 maps is also above average, although much lower for the latter three. For NO_x, maps are rather different for Africa, Eastern Europe, and the former USSR (MCC < 0.6). For SO_2, maps are rather different for the India-China region, former USSR, Africa and Oceania (MCC < 0.5), which causes the overall MCC to be 0.5. Regional MCC for NO_x are rather close to the CO2 values, except for Eastern Europe, the former USSR and Africa. This suggests, that for these three regions differences are not so much caused by activity data for energy, but rather in emission factors for energy or in large differences for other sources (e.g. biomass burning and AWB). It appears that only NO_x in Africa is substantially influenced by biomass burning and/or agricultural waste burning (the MCC increases from 0.43 to 0.64 when excluding these sources).

Table 1.12 Spatial comparison EDGAR V2.0 (all anthropogenic emissions below 1 km) and GEIA V1 emissions of NO_x and SO_2: global and regional Map Cross Correlation (MCC) and comparison with CO_2. Differences with CO_2 larger than 0.3 are printed in bold.

Area	Co-ordinates	NO_x	SO_2	CO_2	Diff. NO_x-CO_2	Diff. SO_2-CO_2
World		**0.77**	**0.49**	**0.89**	**-0.12**	**-0.39**
o.w.						
North America	-170,23,-50,75	0.86	0.85	0.93	-0.06	-0.08
Europe	-12,34,32,75	0.81	0.66	0.87	-0.05	-0.21
o.w. Western Europe	-12,34,18,75	0.85	0.68	0.86	-0.01	-0.18
o.w. Eastern Europe	13,40,32,75	0.52	0.69	0.91	**-0.39**	-0.22
Latin America	-120,-60,-30,30	0.89	0.63	0.92	-0.03	-0.29
Africa	-20,-40,55,38	0.43	0.38	0.82	**-0.40**	**-0.44**
Middle East	32,10,64,40	0.82	0.80	0.78	0.04	0.01
Former USSR	19,35,179,85	0.58	0.29	0.92	**-0.34**	**-0.63**
India-China region	60,5,145,55	0.72	0.25	0.91	-0.19	**-0.66**
Oceania	90,-50,179,8	0.81	0.43	0.73	0.07	**-0.30**

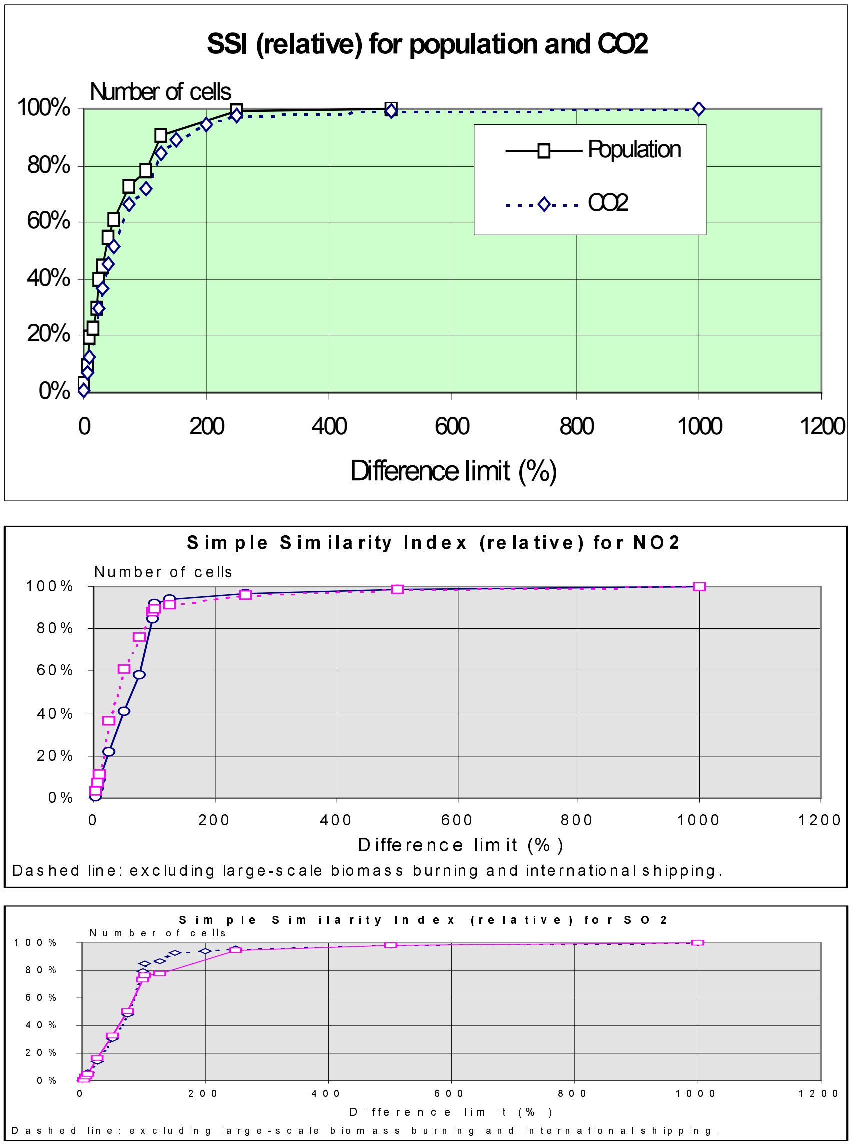


Fig. 1.4. Fraction of cells below a specific cutoff of the Simple Similarity Index (SSI) (relative difference per gridcell): a. for population (Logan-GISS) and CO_2 (EDGAR-GEIA); b. for NOx (EDGAR-GEIA); c. for SO_2 (EDGAR-GEIA).

1.3 Uncertainty analysis

It has been acknowledged, that providing improved uncertainty estimates is an urgent need for models and policy applications, but also that it is hard to achieve on the short term other than through collective expert judgement. Within the IPCC Inventory Programme a special activity has recently been started aiming at providing default values and a better framework for estimating and reporting of uncertainties. A similar activity has started within GEIA, aiming at the same results at country level as well as on grid level, but for a more extended group of compounds and in a more scientific setting. Comparisons of different datasets, e.g. as done with the EDGAR data, may be an important input to this process.

Therefore, it was decided by the EDGAR team that it was at present not feasible to go beyond the uncertainty tables compiled for Version 2.0 (see Table 1.13 and 1.14). However, in addition some apparent conclusions on uncertainty can be drawn from the comparison of V2.0 with other datasets as part of the validation and check for urgent adaptations. For more detailed info on uncertainty in specific inventories we refer to the papers on N_2O, NH_3 and CO (Bouwman *et al.,* 1995, 1997; Olivier *et al.*, 1999) and conclusions on validation in Section 1.2). For the F-gases HFCs, PFCs and SF_6 a similar table has been compiled (see Table 1.15).

To illustrate the usefulness of the uncertainty indications presented here, we translated for methane the qualifications into the percentage ranges mentioned in the notes of these tables. Next, we compared the results with the uncertainty estimates used by IPCC Working Group I for the preparation of the Third Assessment Report (Fig. 1.6). The overall picture is rather similar, which shows that this simple approach and interpretation of uncertainty ranges is still quite useful for application at global levels.

Table 1.13 Indication of uncertainty estimate for greenhouse gases. Source: Olivier et al., 1999a.

Main source	Sub-category	Activity data	Emission factors			Total emissions		
			CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Fossil fuel use	Fossil fuel combustion	S	S	M	M	S	M	M
	Fossil fuel production	S	M	M	-	M	M	-
Biofuel	Biofuel combustion	L	S	M	L	L	L	L
Industry/ solvent use	Iron & steel production	S	-	S		-	S	-
	Non-ferro production	S	-	S	-	-	S	-
	Chemicals production	S	-	S	L	-	S	M
	Cement production	S	S	-	-	S	-	-
	Solvent use	M	-	-	-	-	-	-
	Miscellaneous	V	-	-	-	-	-	-
Landuse/ waste treatment	Agriculture	S	-	L	L	-	L	L
	Animals (excreta; ruminants)	S	-	M	L	-	M	L
	Biomass burning	L	S	M	L	L	L	L
	Landfills	L	-	M	-	-	L	-
	Agricultural waste burning	L	-	L	L	-	L	L
	Uncontrolled waste burning	L	-	-	-	-	-	-
Natural sources	Natural soils	M	-	L	L	-	L	L
	Grasslands	M	-	M	L	-	M	L
	Natural vegetation	M	-	M	-	-	M	-
	Oceans/wetlands	M	-	L	L	-	L	L
	Lightning	S	-	-	-	-	-	-
			CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
All sources		-	-	-	-	S	M	L

Notes: Expert judgement of uncertainty ranges, which were assigned with the following classification in terms of order of magnitude of the uncertainty in mind: S = small (10%); M = medium (50%); L = large (100%); V = very large (>100%).
'-' Indicates that the compound is not applicable for this source or that emissions are negligible.

Table 1.14 Indication of uncertainty estimate for ozone and aerosol precursors. Source: Olivier et al., 1999b.

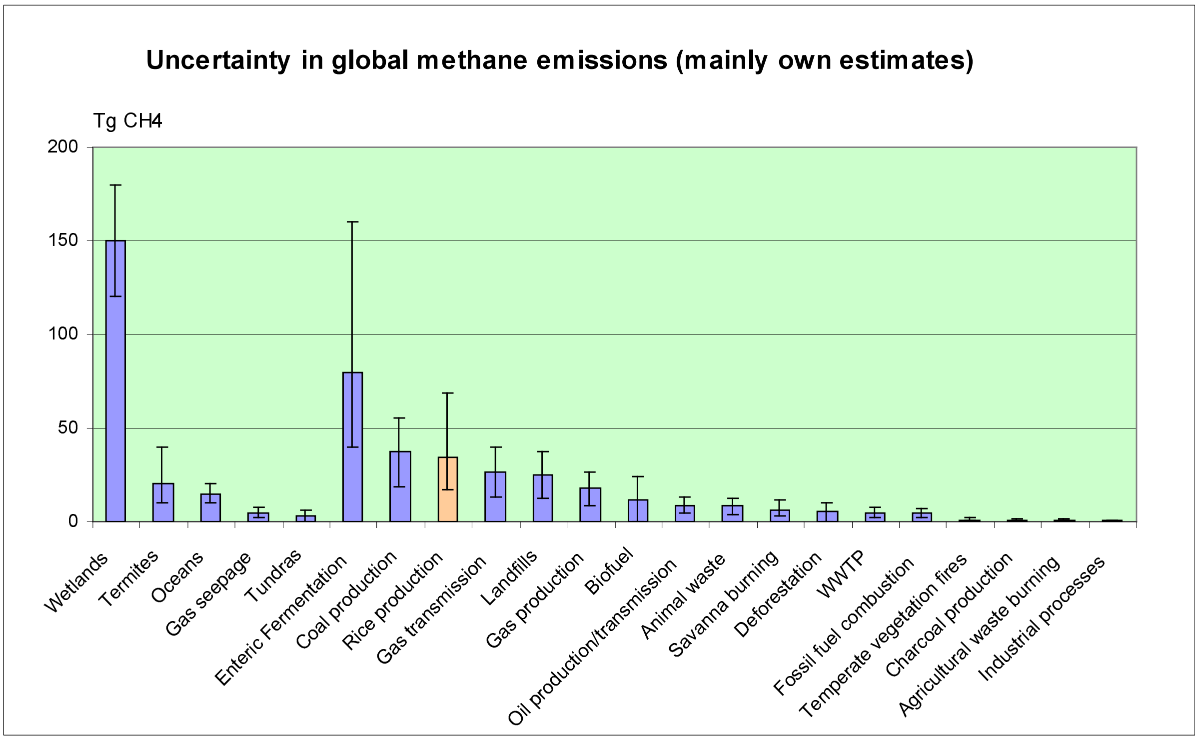
Main source	Sub-category	Activity data	Emission factors				Global total and regional emissions			
			CO	NO_x	SO_2	NMVOC	CO	NO_x	SO_2	NMVOC
Fossil fuel use	Fossil fuel combustion	S	M	M	S	M	M	M	S	M
	Fossil fuel production	S	-	-	-	M	-	-	-	M
Biofuel	Biofuel combustion	L	M	M	M	M	L	L	L	L
Industry/ solvent use	Iron & steel production	S	M	M	M	L	M	M	M	L
	Non-ferro production	S	M	M	L	L	M	M	L	L
	Chemicals production	S	M	M	L	L	M	M	L	L
	Cement production	S	-	-	-	-	-	M	-	-
	Solvent use	M	-	-	-	M	-	-	-	M
	Miscellaneous	V				V				V
Landuse/ waste treatment	Agriculture	S	-	-	-	-	-	-	-	-
	Animals (excreta; ruminants)	S	-	-	-	-	-	-	-	-
	Biomass burning	L	M	L	M	L	L	L	L	L
	Landfills	L	-	-	-	-	-	-	-	-
	Agricultural waste burning	L	L	L	L	L	L	L	L	L
	Uncontrolled waste burning	L	-	-	-	L	-	-	-	V
Natural sources	Natural soils	M	-	L	-	-	-	L	-	-
	Grasslands	M	-	-	-	-	-	-	-	-
	Natural vegetation	M	M	-	-	L	M	-	-	L
	Oceans/wetlands	M	L	-	-	-	L	-	-	-
	Lightning	S	-	L	-	-	-	L	-	-
			CO	NO_x	SO_2	NMVOC	CO	NO_x	SO_2	NMVOC
All sources		-	-	-	-	-	M	M	M	L

Notes: Expert judgement of uncertainty ranges, which were assigned with the following classification in terms of order of magnitude of the uncertainty in mind: S = small (10%); M = medium (50%); L = large (100%); V = very large (>100%). "-" Indicates that the compound is not applicable for this source or that emissions are negligible.

Table 1.15 Indication of uncertainty estimates for HFCs, PFCs and SF_6 at Global (Gl), Regional (Reg) and Country (Cnt) Level. Source: Olivier and Bakker, 2002.

Compound	Source	Activity Data			Emission factor	Emissions		
		Gl	Reg	Cnt		Gl	Reg	Cnt
HFCs								
HFC-23	By-product HCFC-22 manufacture	S	M	M	M	M	M	M
HFC-134a	Usage (various)	M	M	M	M	M	M	M
Other HFCs	Usage (various)	L*	L	L[1]	M	L*	L	L[1]
PFCs								
CF_4, C_2F_6	By-product primary aluminium prod.	S	S	S	M[2]	M[2]	M[2]	M[2]
Misc. PFCs	Use by semiconductor manufacture	V	V	V	S/M	V	V	V
Misc. PFCs	Other use	V	V	V	S/M	V	V	V
SF_6								
SF_6	Electr. Equipm. manuf. - production	M[3]	M	M	S	M	M	M
SF_6	Electr. Equipm. manuf. - site erection	M[3]	M	M	S	M	M	M
SF_6	Use of Electr. Equipment (GIS a.o.)	M[3]	M	L	M	M	M	L
SF_6	Use for accelerators	M[3]	M	M	M	M	M	M
SF_6	Unknown allocated to Electr. Equipm.	M[3]	M	M	S	M	M	M
SF_6	Use for magnesium prod. (prim./diecasting)	S[4]	L	L	S	S	L	L
SF_6	Use for semiconductor manufacture	S	V	V	L	S	V	V
SF_6	Use for adiabatic properties (tires, shoes)	S	L	L	M	M	L	L
SF_6	Use for soundproof windows	M	M	M[5]	S	M	M	M
SF_6	Use for aluminium degassing	M	M	M	S	M	M	M
SF_6	Misc. use (excluding China/Russia)	M	M	M	M	M	M	M
SF_6	Misc. use by China/Russia	L	L	L	M	L	L	L

Notes:
[1] Except USA: activity data HFC-143a, 125, 227ea: S, of HFC-152a: M; related emissions: M
[2] Assuming no significant trend 1990-1995
[3] Together: S
[4] Total for primary magnesium production and magnesium diecasting; for these two separately: L
[5] For Germany: S



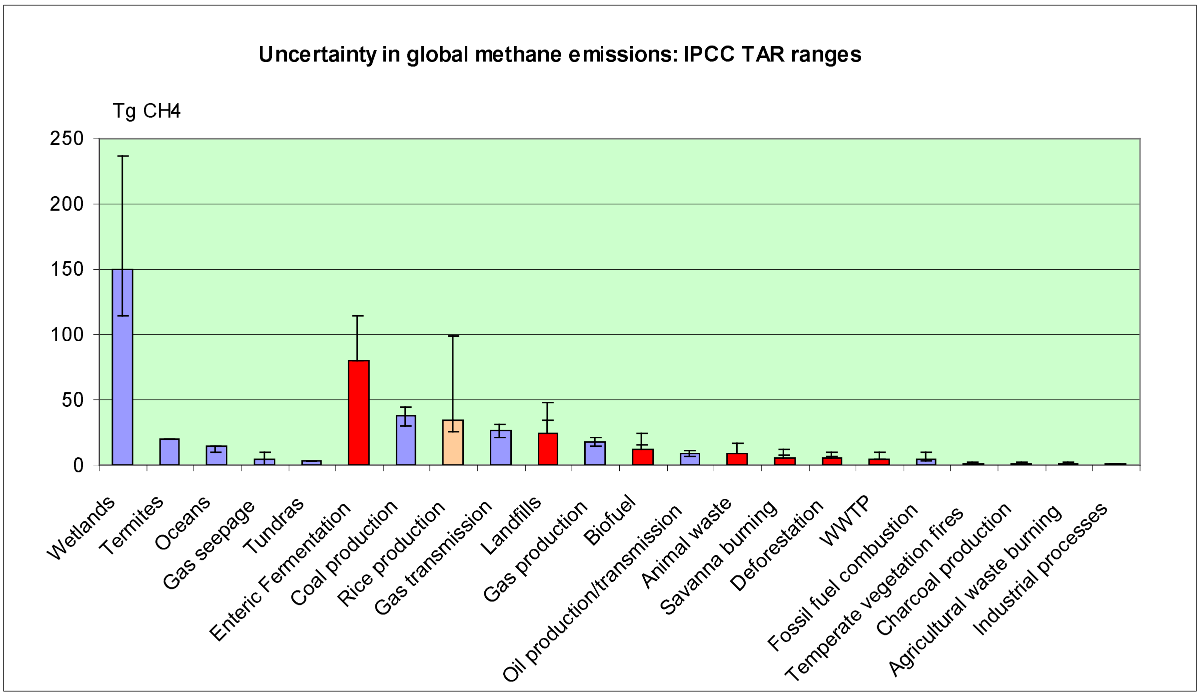


Fig. 1.5. Comparison of uncertainty estimates for major global methane sources (a) using the uncertainty estimates by the EDGAR team and (b) the compilation made for the Third Assessment Report of IPCC Working Group I.

1.4 Conclusions

As a result of the validation of EDGAR 2.0 with other global and regional emission inventories it was decided that several items should be modified for the reference year 1990. Compared to Version 2 the following recommendations were made for 1990:

* about emission factors:

Global default emission factors for NO_x, CO and NMVOC for the following non-road transport activities should be updated: Rail transport, Inland water, Other land-non-road and Non-specified transport. Emission factors are entered for coal, diesel oil and gasoline when applicable.

Global default emission factors for NO_x and SO_2 for sea-going vessels should be updated.

The emission factor for SO_2 for non-ferrous metals production should be updated.

* about missing sources:

Unintentional coal fires at shallow coal deposits could be added in EDGAR as an emission source category for China. This source appeared to be considerable and was so far lacking in EDGAR V2.

Recognising the importance of emissions related to biomass burning, temperate vegetation (forest) fires should be added as an emission source category for CO, NO_x, CO_2 and SO_2. EDGAR V2 included only anthropogenic large-scale biomass burning such as savanna burning, deforestation and agricultural waste burning activities.

Other sources of waste handling, e.g. uncontrolled waste burning, should be added as an emission source. Other municipal waste incineration (non-energy) could be added as well.

How these issues are dealt with in EDGAR 3.0 is discussed in Sections 4.2.3 and 4.2.5.

When the uncertainty indications presented here are translated into the percentage, this simple approach can be still useful for application at global levels.

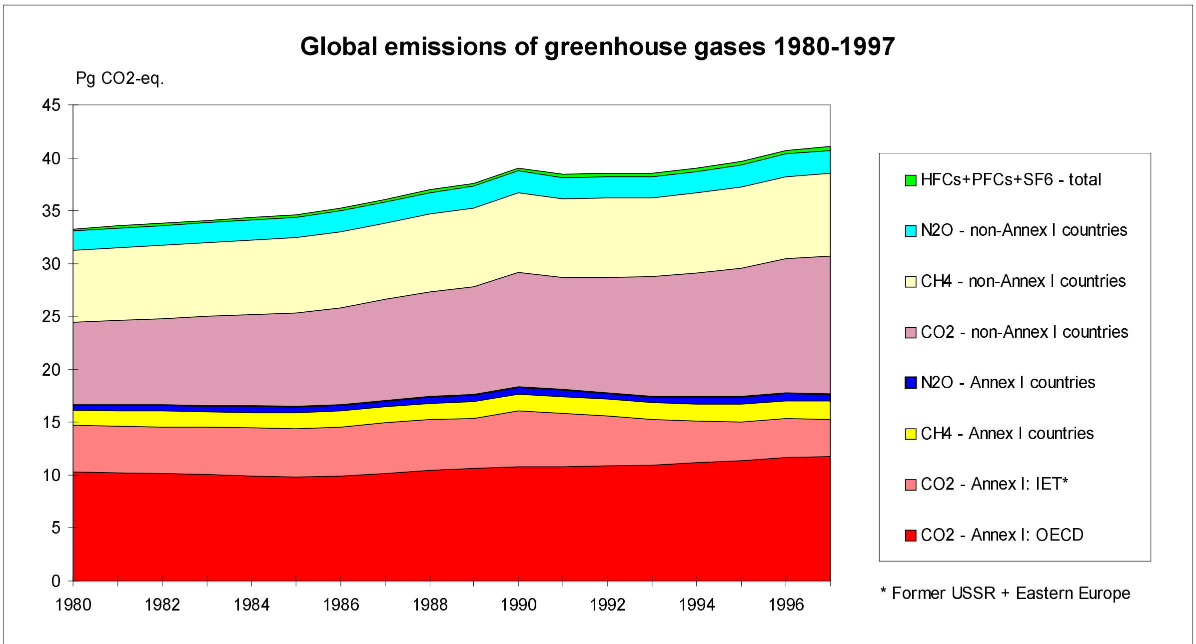
2. Trend assessments for integrated products

2.1 Introduction

Global emissions data are used in monitoring and analysis of trends in international emissions and other use in integrated assessments at national, EU and global (UNEP) level. More specifically, EDGAR data - supplemented with recent trend data are used in integrated assessments - have been used for trend analysis of global emissions as well as analysis of regional distribution of present global emissions. Results of this work were used in integrated assessments such as RIVM's annual national *Environmental Balances* and accompanying background reports (Environmental Compendium) (RIVM, 1997/98/99/2000a,b) and the national *Environmental Outlooks* (RIVM, 1997a,b; 2000a,b). Also data were provided for EEA's *Environmental Signals* report (EEA, 2000). The EDGAR datasets are also part of the core datasets for global integrated environmental assessments made in the *Global Environmental Outlooks* (GEO) of UNEP. As an illustration this type of application we present in this chapter a background analysis carried out for the *Environmental Balance 1997*.

2.2 Trend report on global emissions of greenhouse gases

Except for halocarbons, the emissions of greenhouse gases are, globally seen, continuously increasing (Fig. 2.1). The largest contribution to CO_2-eq. emissions is the CO_2 from industrialised countries, even though the growth in emissions is mainly caused by the strong economic growth in other countries, in particular South-east Asia. In 1996, global CO_2 emissions increased about 5% compared to those in 1995; global CH_4 emissions increased by 2%, against 0% increase for N_2O. Halocarbon emissions (expressed as CO_2-eq. using direct GWP values only) decreased by 10%.



Sources: EDGAR/RIM+, 1996 (CO_2, HFCs); BP, 1998 (CO_2); World Bank, 1998; FAO, 1998 (CH_4, N_2O); IMAGE 2.0, 1994 (CH_4, N_2O); own estimates (1997 CH_4, N_2O, HFCs, PFCs, SF_6).

*Fig. 2.1. Trend in greenhouse gas emissions 1980-1997 of the six 'Kyoto' gases in Annex I countries and other regions (in Pg CO_2-eq.; GWP_{100})***.**

Global emissions of the direct greenhouse gases CO_2, CH_4 and N_2O have increased by 16% since 1970. The economic decline in the former USSR and Eastern European countries brought the total global CO_2 emissions to an almost constant level in the 1990-1995 period; however, in 1996 they increased by 3%. The 4% decrease in CO_2 emissions from the former USSR in 1996 seems to be the lowest level in the decline. In 1995 and 1996 the emissions in the Eastern European countries were already increasing again by a few per cent annually. In the rest of the world, CO_2 emissions increased by 15% compared to 1990, in particular, in developing countries (+30%).

In the European Union, USA, Canada and Japan, CO_2 emissions increased in 1996 by 2, 3, 1 and 2%, respectively. Total growth in these countries since 1990 has been 1, 6, 9 and 13%, respectively. While fossil fuel consumption increased by 4%, the minor increase in the EU in the last six years was mainly due to a shift in the fossil-fuel mix from coal to gas. The share of coal decreased from 27% to 20%, while that of gas increased from 20% to 26%. Similar large shifts did not occur in other OECD countries.

Global emissions of direct greenhouse gases decreased by 7% since 1990 mainly due to the sharp decrease in CFC emissions since 1988. HFC emissions are, however, increasing fast and may start to contribute significantly to total trends from 2000 onwards, in particular, in OECD countries. In 1995, for example, the consumption of HFC-134a increased by 45%. At present, no control policies exist for HFCs at the international level.

Coupling to economic trends

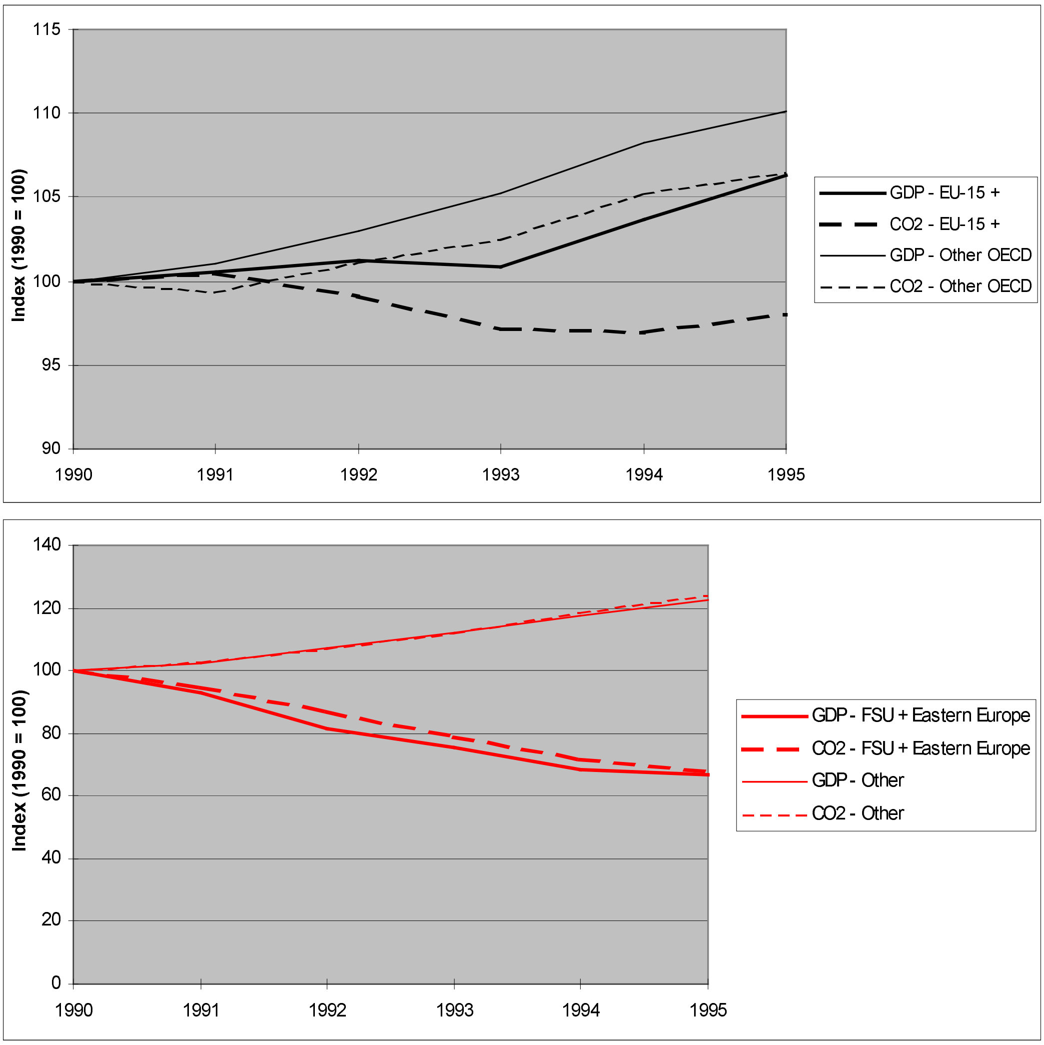
In the 1990-1995 period, global GDP increased by about 9%, while global CO_2 emissions from fossil-fuel use increased by 2%. This partial 'decoupling' was caused by a shift of the fossil-fuel mix to more gas and (a bit) less coal, in particular in OECD countries (e.g. in the EU and the USA, but not in Japan), as well as a general trend towards a less energy-intensive economy. In the EU the share of coal decreased from 27% to 21%. Between 1990 and 1995, the GDP of the EU-15 increased by 6%, fossil fuel use increased by 1%, while CO2 emissions decreased by 2%, mainly due to a decrease in coal consumption in Germany, the United Kingdom and Italy. In the USA and Australia, the increase in CO2 emissions was about half of the increase in GDP.

Other parts of the world with a relatively low GDP growth, such as Japan, Canada, Middle East (or even a drop in GDP, as in the former Soviet Union, Eastern Europe and Africa), do not show a partial 'decoupling' but rather the opposite. This also applies to Latin America. In Eastern Europe the CO2 trend is -12% vs. a GDP trend of -6%; in the former USSR, CO_2 emissions dropped less (-35%) than GDP (-40%).

In China CO_2 emissions increased by about 23%, while GDP increased almost 70%. In other Asian countries, including the so-called 'economic tigers', the increase in CO_2 emissions is similar to the development of GDP. It should be noted, though, that due to the quality and limited comparability of available statistics, trends analyses particularly for GDP, but also for CO_2, are less reliable for countries like the former USSR and China than for most others.

Emission intensity

Per capita emissions of CO_2 for countries within the European Union are 2 to 3 times as high as the global average. In 1990 the EU average was about 20% lower than for the Netherlands, whereas the OECD average was about 6% higher. Per capita emissions are the highest in the USA. In 1990 per capita emissions in the former USSR were comparable with the OECD average and stood at 35% above the EU average (Fig. 2.3).



Sources: BP, 1997; World Bank, 1997; EDGAR V2.0.

Fig. 2.2. Index of CO_2 emissions from fossil fuel use 1990-1996 related to GDP (1990 = 100).

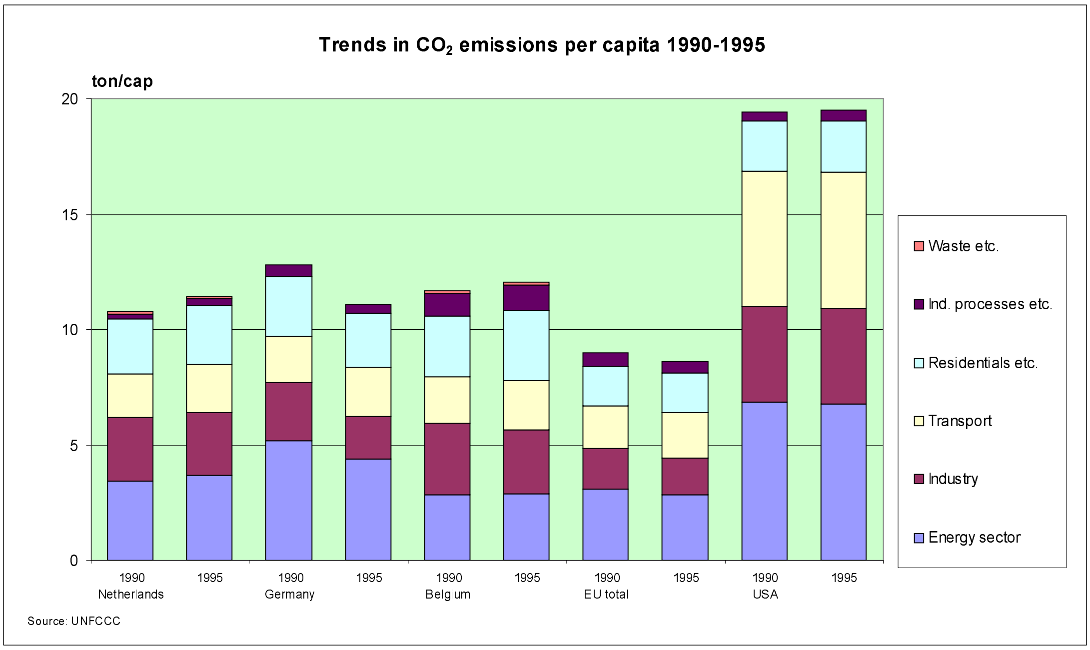


Fig. 2.3. Comparison of trend in per capita CO2 emissions between the Netherlands, neighbour countries, EU-total and USA.

Global spatial distribution of greenhouse gases

Global emissions of the direct greenhouse gases, CO_2, CH_4, N_2O and CFCs, are concentrated in the USA, Europe, the former USSR, China and, to a lesser extent, India (see Fig. 2.4). The largest *hot spots* are CO_2 emissions, per region contributing 13, 9, 9, and 7% to global CO_2-eq.emissions, respectively. Within Europe the intensity is highest in the north-western part. Globally, carbon dioxide contributes 2/3, methane 1/5, CFCs 1/10 and nitrous oxide 1/20. In the USA, the European Union and Japan, CFCs contribute 1/5 locally; in India methane and nitrous oxide contribute more than 50% to the national total.

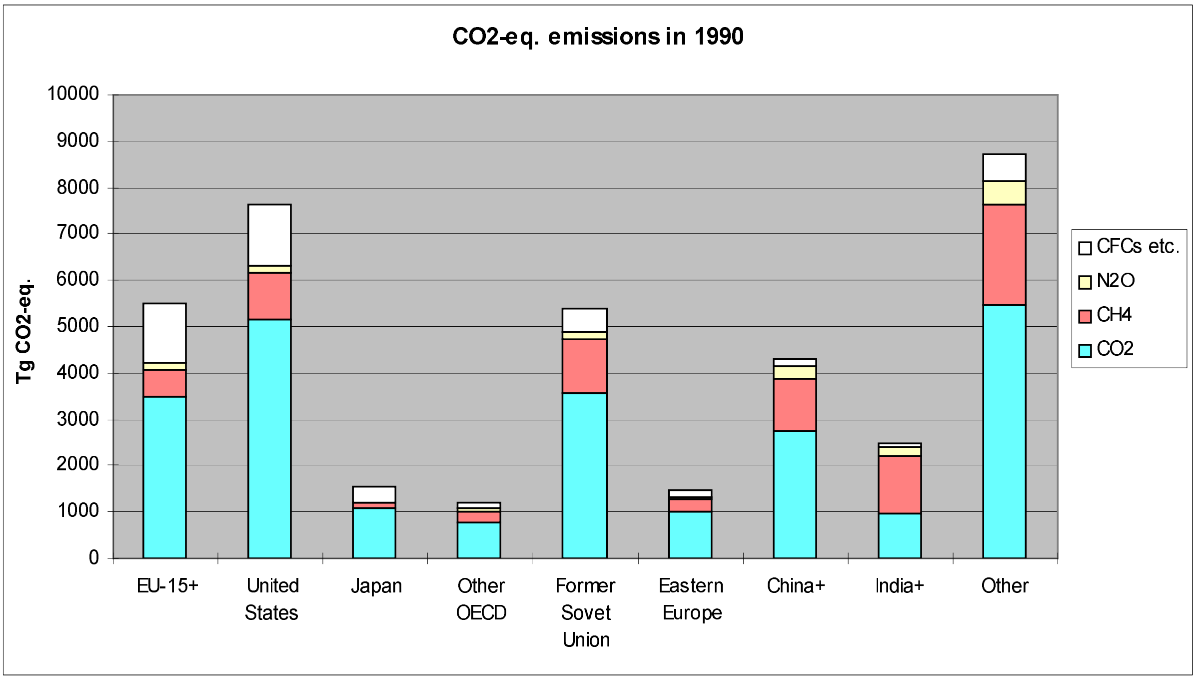


Fig. 2.4. Distribution of greenhouse gas emissions in 1990 over sources and regions (Tg CO_2 equiv.; GWP_{100}). Source: EDGAR V2.0.

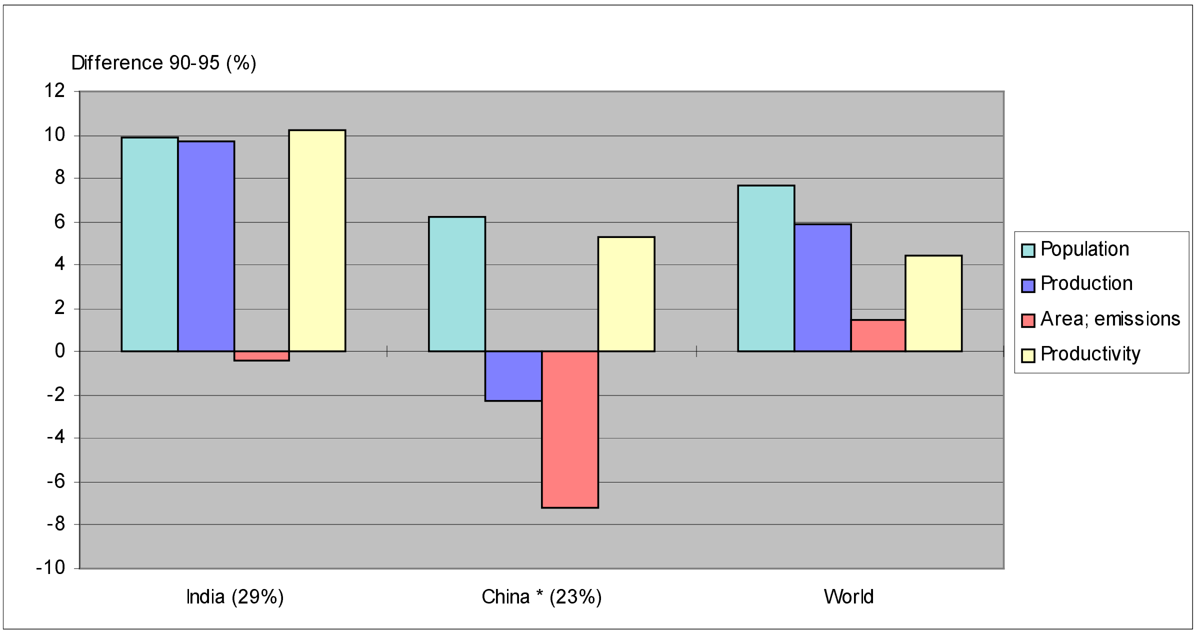
Distribution of greenhouse gases by region and source

Two-thirds of the global CO_2 emissions originate in OECD countries and the former USSR. Globally, emissions of CH_4 contribute about 20% to total direct greenhouse gases. In India, however, this percentage is more than twice as high, mainly due to the large share of rice cultivation and cattle, whereas the contribution of methane in OECD countries is about 10%. In developing countries the share of N_2O emissions is twice as high as in industrialised countries (20% in OECD and 10% in the former USSR and Eastern Europe). Depending on the mix of alternatives for CFCs used (notably HCFCs and HFCs), halocarbons will continue to contribute significantly to total CO_2-eq. emissions from industrialised countries.

Of direct greenhouse gas emissions from fossil fuel use, which contribute to half of the total CO_2-eq. emissions, about half of this stems from the USA, the European Union and the former USSR. Amongst the ‘fossil fuel’ sources, electric power plants are the largest and industrial plants second largest, while about 10% comes from methane losses during production and transmission of fossil fuels. Emissions from agriculture and land use, mainly in developing countries, contribute together about 20% to the global total.

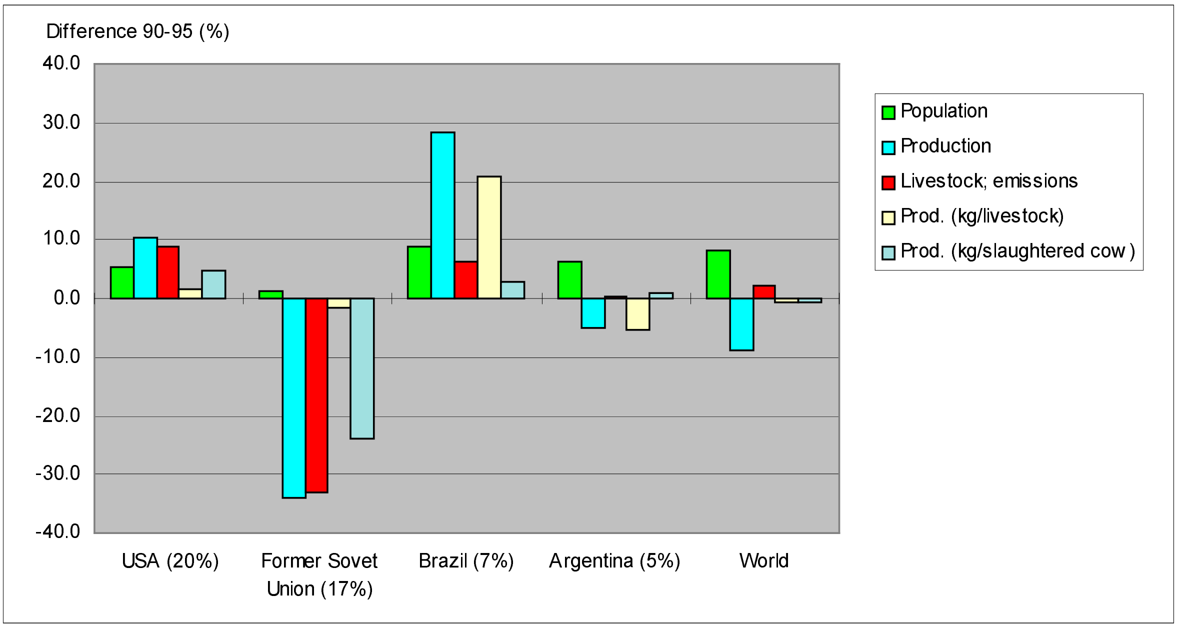
Indicators for methane and nitrous oxide

Globally, agricultural activities represent one of the largest sources of methane and nitrous oxide. Animals, in particular, beef cattle, and rice production, account for a large share of these emissions. Methane emissions per capita from the USA and the former USSR are twice as high as the global average, due to mainly coal and gas production, and distribution and landfills. In the European Union these are almost equal to the global average. In Latin America CH_4 emissions per capita are 20% higher compared to the global average, whereas in India, China and most other Asian countries these are about 2/3 of the global average. Thus, CH_4 emissions per capita due to agriculture are relatively low, but in the EU they are almost equal to the world average. However, it should be stressed that due to the high uncertainty in emission factors, only high-level comparisons between countries are meaningful.



* 1990 was a peak year for China. Productivity = production/ha harvested. Source: FAO, 1997; World Bank, 1997; EDGAR V2.0.

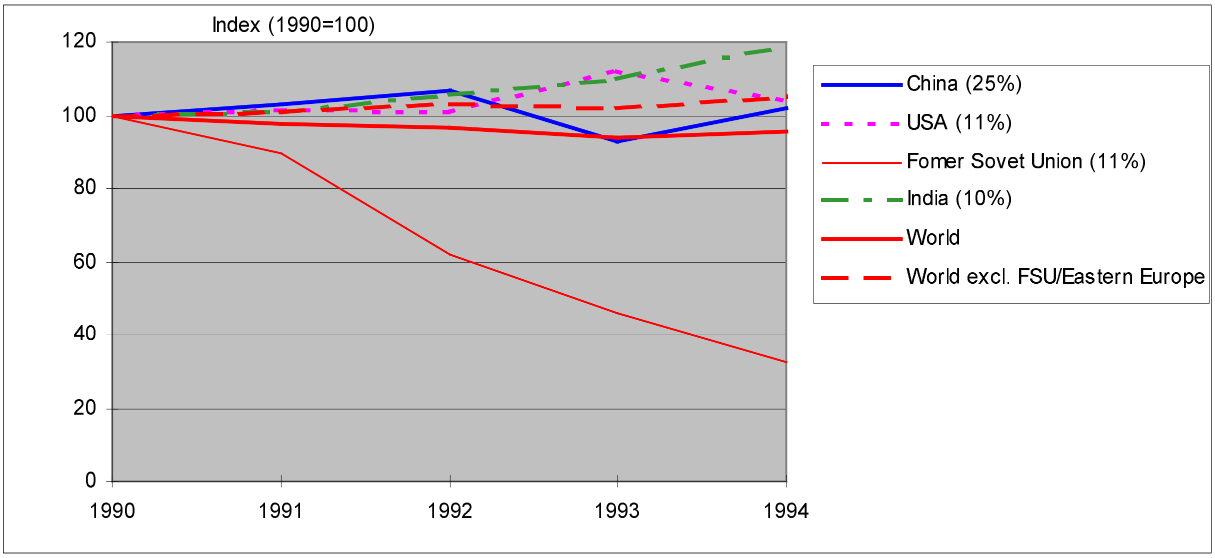
Fig. 2.5. Agricultural indicators: CH_4 emissions from rice cultivation 1990-1995 compared to total rice production (1990 = 100).



Source: FAO, 1997; World Bank, 1997; EDGAR V2.0.

Fig. 2.6. Agricultural indicators: emissions of CH_4 and N_2O (only direct emissions) from cattle breeding (non-dairy) 1990-1995 compared with meat production (1990 = 100).

Set against a global population increase of 8% in the 1990-1995 period, global total rice production increased 6%, while the global harvested area increased by 1.5%, meaning an average productivity (production per unit of harvested area) increase of about 4%. Methane emissions from rice cultivation increased by 1.5%, at least when no shift to more wetland rice cultivation nor to more fertiliser use had taken place. At present, the information available is not sufficient to evaluate the last-named influences. Rice cultivation is concentrated in India and China, which together account for half of the global rice production. In India, population, rice production and productivity has increased by 10% in the last five years. In China the population has increased by 6%, while the production has decreased by 2% and productivity has increased by 5%. This is due to the 7% decrease in the harvested area in the last five years.



Source: FAO, 1997.

Fig. 2.7. Indicator for N_2O: trends in global consumption of nitrogen fertilisers 1990-1994 (1990 = 100).

Beef cattle account for about half of the global total of CH_4 and N_2O emissions from cattle breeding. In Fig. 2.6 a number of trend indicators for the five most important countries are shown for emissions from beef cattle for the 1990-1995 period. In this period meat production has decreased by 9% globally (compared with an 8% increase of population), largely due to a decrease in meat production by the former USSR and Germany (one-third), while the cattle stock increase was 2%. Productivity expressed as meat production per cattle head in stock differs substantially between countries: in North America, Europe and the former USSR it is three times as high as in Latin American countries. This large difference in 'cattle stock management' also causes large differences in emissions per cow in stock. The trend in meat production and the size of the cattle stock in the last five years differs considerably between countries. No conclusion can be drawn about there being a structural decoupling of emissions from meat production.

The use of nitrogen fertilisers decreased by 5% in the 1990-1994 period. This is the result of the following three trends:

- a great increase in fertiliser use in developing countries, e.g. by 19% in India;
- a dramatic decrease in fertiliser use in the former USSR (2/3);
- a stabilisation of fertiliser use in OECD countries as a whole, but with highly different trends in individual countries, e.g. +13% in USA and Canada, -7% in France and the UK, and constant use in Germany and Spain.

Without the sharp negative trend in the former USSR, total global fertiliser consumption would have increased by 5%, instead of decreasing by 5%, which has actually occurred. N_2O emissions from agricultural soils may be assumed to have shown a similar trend.

2.3 Trend report on global emissions of ozone depleting compounds

International policy for the protection of the ozone layer was established through the *Montreal Protocol* of 1987 and the subsequent *Amendments of London*, 1990, and *Copenhagen*, 1992. Sixty-five countries have now ratified the *Copenhagen Amendment* including the largest industrialised ones. According to this *Copenhagen Amendment* countries have to phase out the production and consumption of CFCs by 1996. Other countries, in particular developing countries with a relatively small CFC use per capita, have to phase out production and use by 2005. International funds are available for financing projects in developing countries for preventing further expansion of the use of CFCs. In 1994 the countries of the European Union agreed to phase out the use of CFCs and carbon tetrachloride by 1995 (EEA, 1999).

As a result of these measures world-wide production and consumption of ozone-depleting substances have been reduced substantially during the last years. In 1995, consumption dropped to almost zero in industrialised countries (including the former USSR), in compliance with the agreements. From a policy point of view, the issue has been sufficiently dealt with. Several factors, as outlined below, contributed to the success of the *Montreal Protocol* and *Amendments*:

- technical alternatives are available for substituting CFCs at acceptable costs: HCFCs, HFCs, other processes without halocarbons;
- damage to the ozone layer has now become particularly evident, partly because of the relatively direct relationship between cause and effect: i.e. one major group of harmful substances and one major impact;
- the *Montreal Protocol* contains well-defined flexible implementation schemes and evaluation procedures.

The most important factors now determining the success of international policy are found in the sustaining sphere, e.g. compliance with international agreements, resistance to smuggling and illegal production of CFCs, and implementation of recycling or destruction of CFCs emitted from existing applications. In 1995, the respective stocks of CFC-11 and 12 at global level contained in appliances such as refrigerators was 8 and 3 times the amount actually emitted in 1995. This was 8 times the amount actually emitted for halon-1211and 25 times for halon-1301. Thus, also after the phase-out of production and consumption, emissions to the atmosphere of substances contained in existing applications will continue for a number of years. The use of methyl bromide in developing countries is also an important factor; in industrialised countries this has already been controlled. The EU has a 25% reduction target for methyl bromide in 1998 compared to the 1991 level (EEA, 1999).

HCFCs and HFCs are used as substitutes for CFCs. In the *Montreal Protocol* and *Amendments* the consumption of HCFCs is still allowed for a number of years. As a result, the production of HCFCs has recently substantially increased. Also the ODPs of HCFCs are only about 5% of that of CFCs. Therefore the impact of HCFCs on the ozone layer is currently very small. However, since there are now hardly any measures taken in developing countries to reduce the consumption of these substances, in the future HCFCs could contribute to ozone depletion in non-negligible amounts in the future. While HFCs do not deplete the ozone layer, they are potent greenhouse gases.

Trends in production and consumption

Total global reported production of CFC-11 and CFC-12 has decreased in 1995 by 46% and 38%, respectively, compared to 1994. In 1995, total reported production was 15% of the 1986 level. However, the consumption of HCFCs increased in 1995 relative to 1994, in particular for HCFC-141b at 39%. The consumption of CFC-22, currently the most widely used HCFC, increased by 2%. The consumption of HFC-134a increased in 1995 by 46% (AFEAS, 1997). The estimated production of so-called non-reporting countries has been relatively constant since 1986. As illustrated in Fig. 2.8, the consumption of CFCs in industrialised countries dropped to almost zero in 1994. In most of the developing countries, which will have no restrictions on their consumption for ten more years, the overall consumption has slightly decreased (by 6%). Since 1986, the CFC consumption in the former USSR has decreased by 60%, whereas the consumption in China has increased by 60% since 1990 (by 140% since 1986) (see Fig. 2.9 and UNEP, 1997abc).

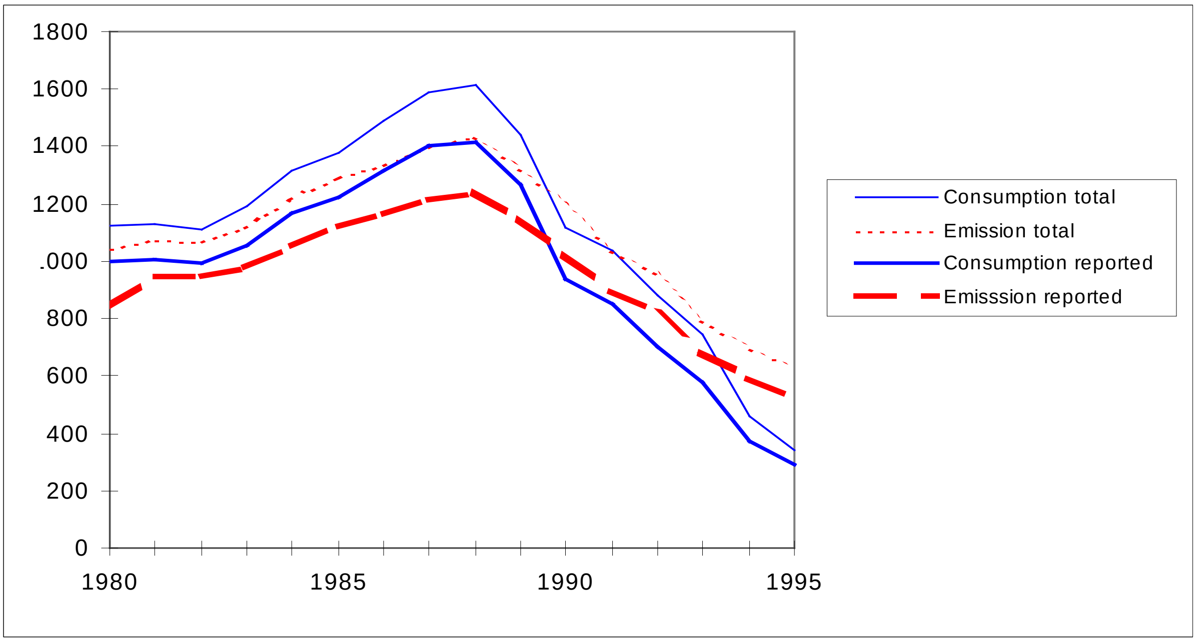


Fig. 2.8. Global consumption and emissions of ozone depleting substances 1980-1995 (kton ODP-equiv.).

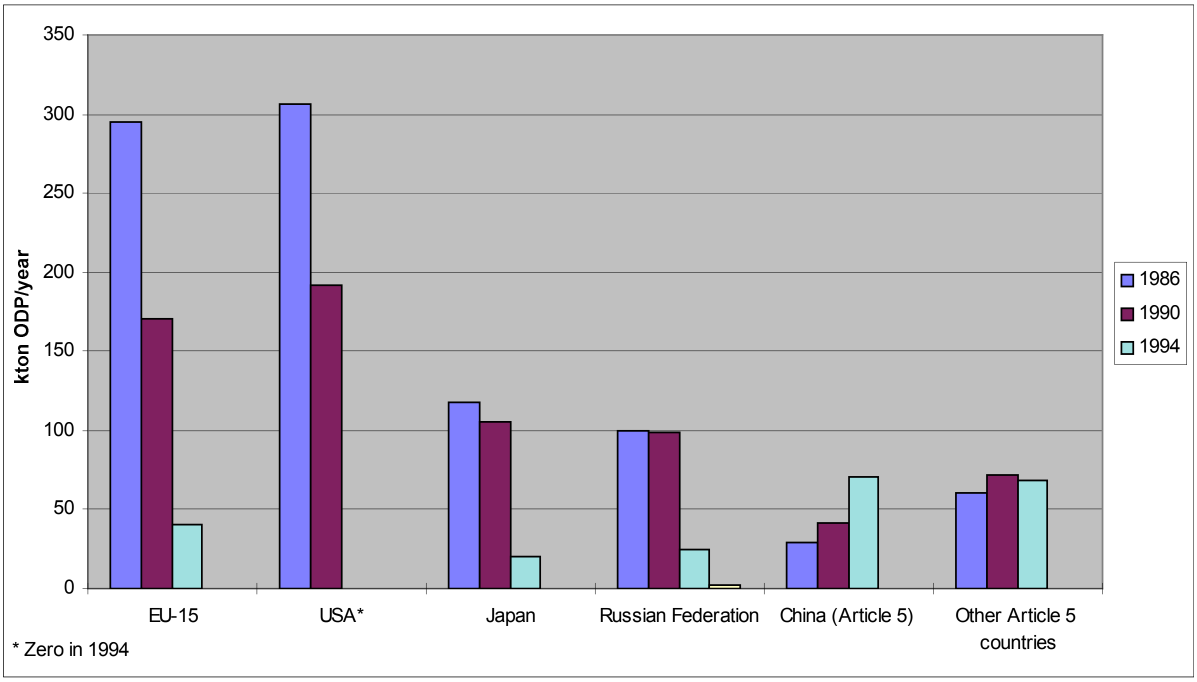


Fig. 2.9. Trend in CFC consumption by various countries in the 1986-1994 period (kton ODP equiv.).

Fig. 2.8 presents the trend in global consumption and emissions from 1980 onwards. The emissions of CFCs, HCFCs and HFCs of the so-called reported consumption decreased in 1995 by 12% compared to 1994, whereas compounds still in use in products that will eventually be released to the atmosphere decreased by 10% (AFEAS, 1997). While the trend in emissions was similar to the trend in consumption till 1994, since that time is the annual decrease in emissions (of about 14%) is about half the annual decrease in consumption (about 30%). This is caused by the part of the compounds consumed that are embedded in applications with a long lifetime released after a delay of several years.

Fig. 2.10 shows the spatial distribution of CFC emissions in the reference year, 1986, in ton CFC-11-equivalents, clearly illustrating the *hot spots* of the world in terms of ODP-eq./km^2 for the USA, European Union - in particular the Netherlands, Belgium and Germany - and Japan. As a result of CFC substitution, global use of the substituting compounds HCFCs and HFCs are expected to increase substantially. The consumption of HFCs is particularly important since they contribute to greenhouse gas emissions.

In terms of CO_2-equivalents, CFC emissions show a similar pattern as in CFC-11-eq. A country with a high historical CFC use, as shown in Figure 2.10, may show a sizeable contribution of CFC substitutes to national CO_2-eq. emissions in the future.

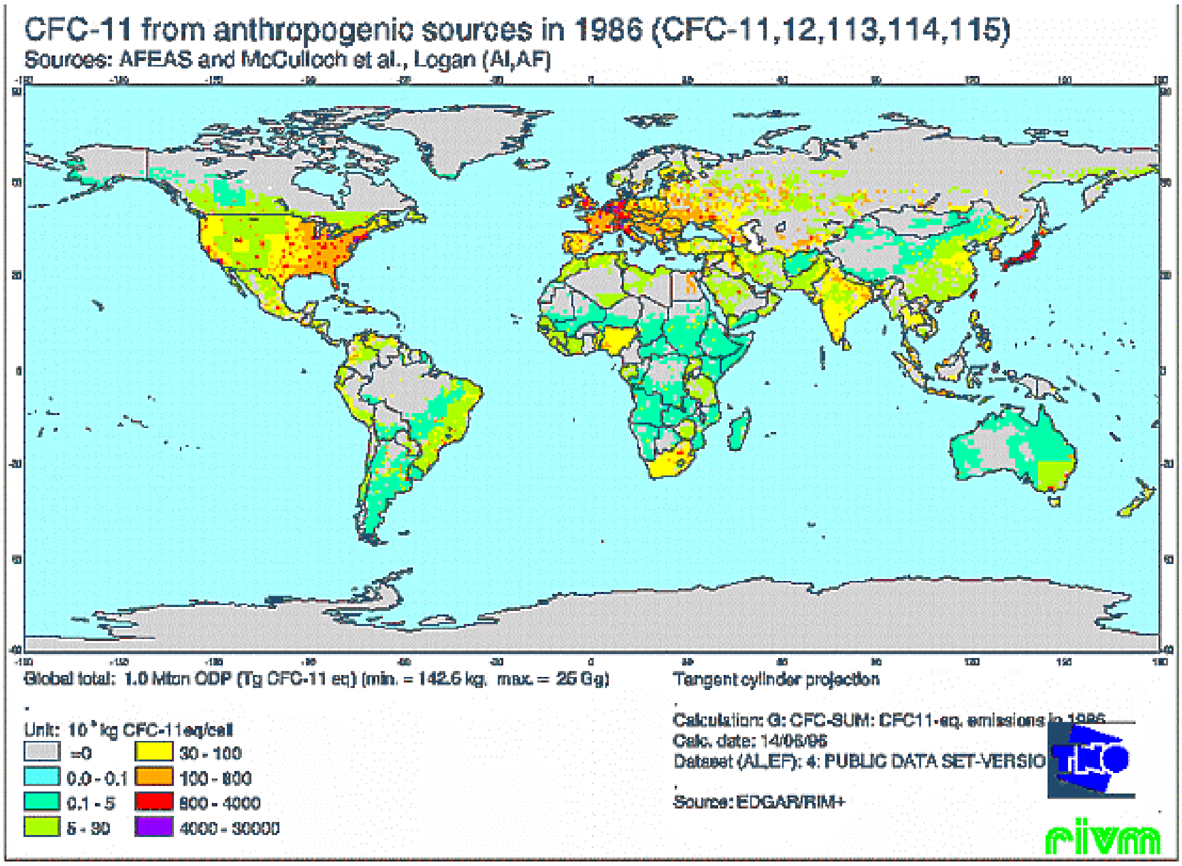
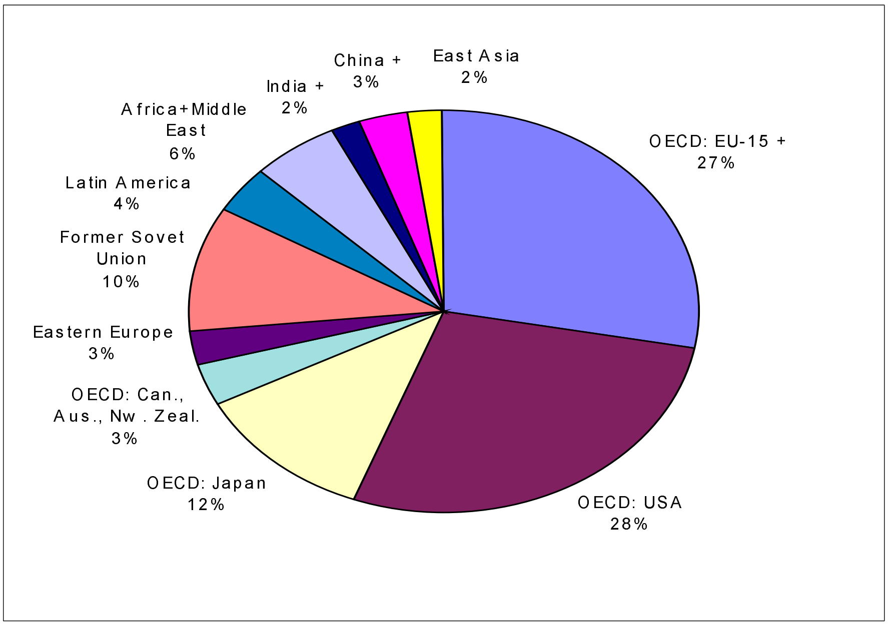


Fig. 2.10. Spatial distribution of CFC emissions in 1986 (in ton CFC-11-eq.).

In 1995, the global emissions of CFC-11 and 12 contributed about 70% to total ODP emissions, which is 10% higher than in 1990 (Fig. 2.11.a). In 1990, the European Union contributed about a quarter of the total to global CFC-11-eq. emissions, which are in turn comparable to the USA emissions (Fig 2.11.b).



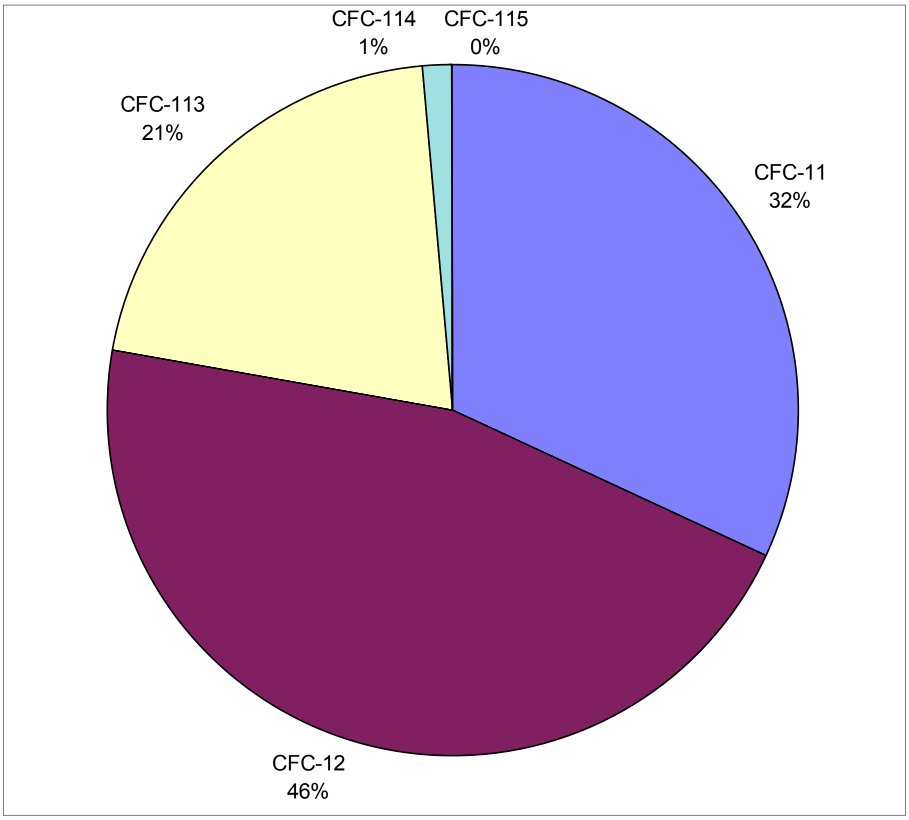


Fig. 2.11. Distribution of CFC emissions in 1990 according to (a) world regions and (b) compounds (in kton ODP equiv.).

3. Applications of EDGAR data

3.1 Introduction

Results from EDGAR V2.0 have been made available to other internal and external users through RIVM's anonymous FTP site. Box 3.1 summarises the data and additional information provided at the FTP site.

Box 3.1. EDGAR V2.0 data publicly available at anonymous FTP site.

FTP site:	info.rivm.nl
directory:	/pub/lae/EDGARV20 *
data:	- 1x1grid files of annual emissions in 1990 for x sources and y compounds (1986 for halocarbons)
	- tables with source/region split per compound
	- documentation
help:	read_me.1st
	general.hlp
	detailed.hlp
	caveats.hlp
	whatsnew.hlp
	references.hlp

From 1 April 2000 the FTP site has been moved to: ftp://info.rivm.nl/pub/lae/EDGARV20/
Also accessible through website: http://www.rivm.nl/env/int/coredata/edgar/

In the next sections, the usage of the EDGAR 2.0 datasets is analysed based on logs of downloads from the FTP site. From these applications by other users and contacts with users, both at national and international level, a number of lessons were learned for improvement in EDGAR 3.0. These are discussed in Section 3.3.

3.2 Downloads of EDGAR data

The present Version 2.0 has been used for comparison of inventories provided in the first National Communications of Annex I countries and available inventories resulting from country studies for other countries (Van Amstel *et al.,* 1997a,b; 1999a,b,c). This has shown to be a useful tool to check the submitted inventories for their comparability. However, the most intensive use of the inventories is by modellers, who can download the gridded inventories and tabular data for regions from the FTP site.

Figures 3.1.a and 3.1.b present the number downloads by different users per quarter in the period 1997-mid 1999 as well as the country of origin. It shows that the number of different users increased from about 50 in 1997 to nearly 100 per quarter in 1999. Of the almost 700 quarterly registered users in the logged 2½ year period most reside in OECD countries, in particular in the USA (about 200) and the Netherlands (about 125). Other countries with more than 25 quarterly users in this period are the Germany, Japan, UK and France. Fig. 3.2.a and 3.2.b shows more detail on the trends in quarterly downloads of individual OECD countries.

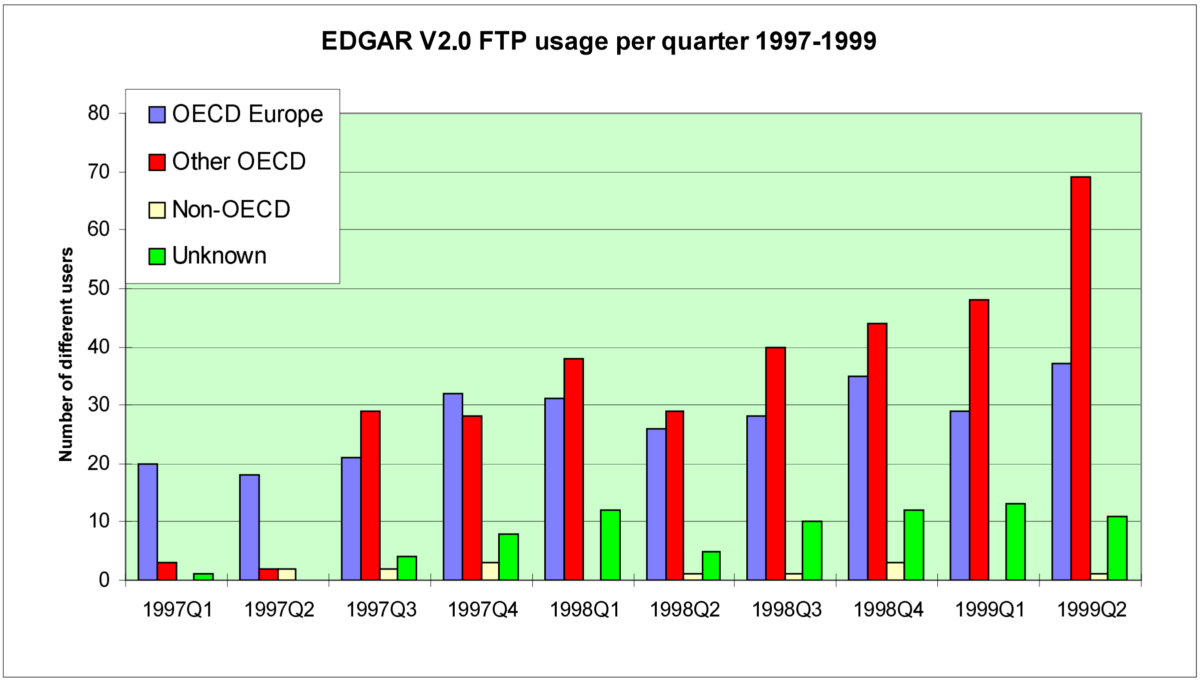


Fig. 3.1.a. EDGAR V2.0 downloads by different users per quarter 1997-mid 1999 by region of origin.

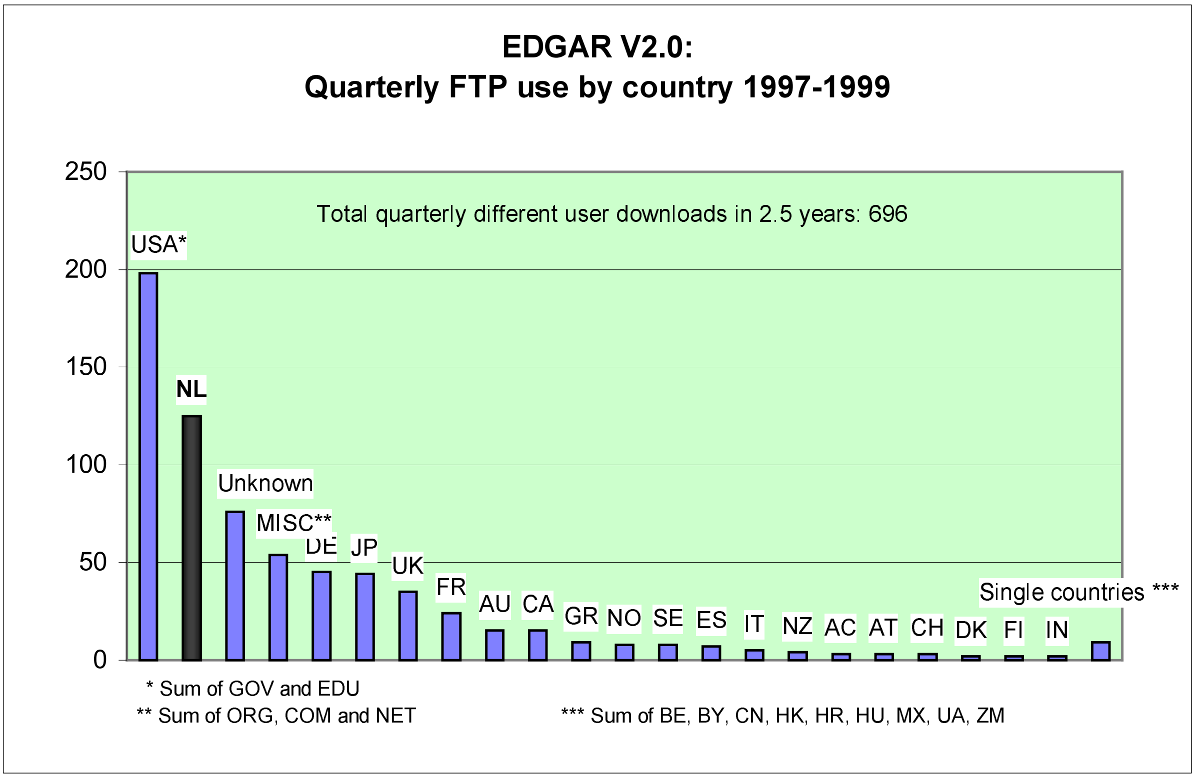


Fig. 3.1.b. Ranking of EDGAR users according to the country of origin.

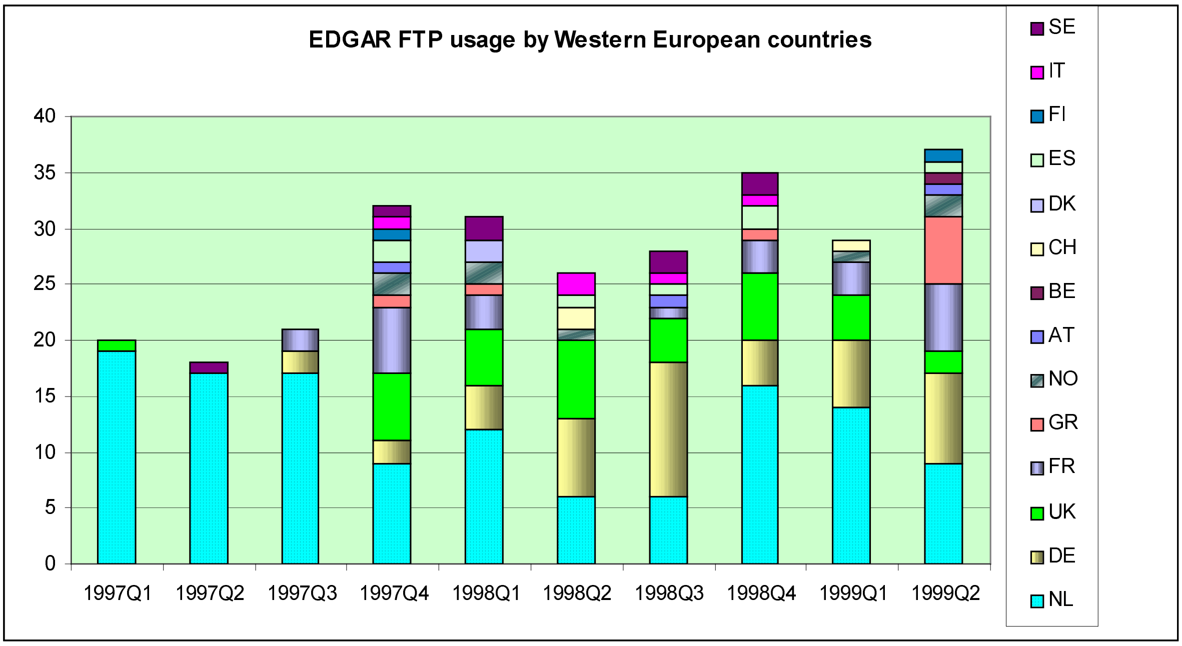


Fig. 3.2.a. EDGAR V2.0 downloads per quarter 1997-mid 1999 by different users in Western European countries.

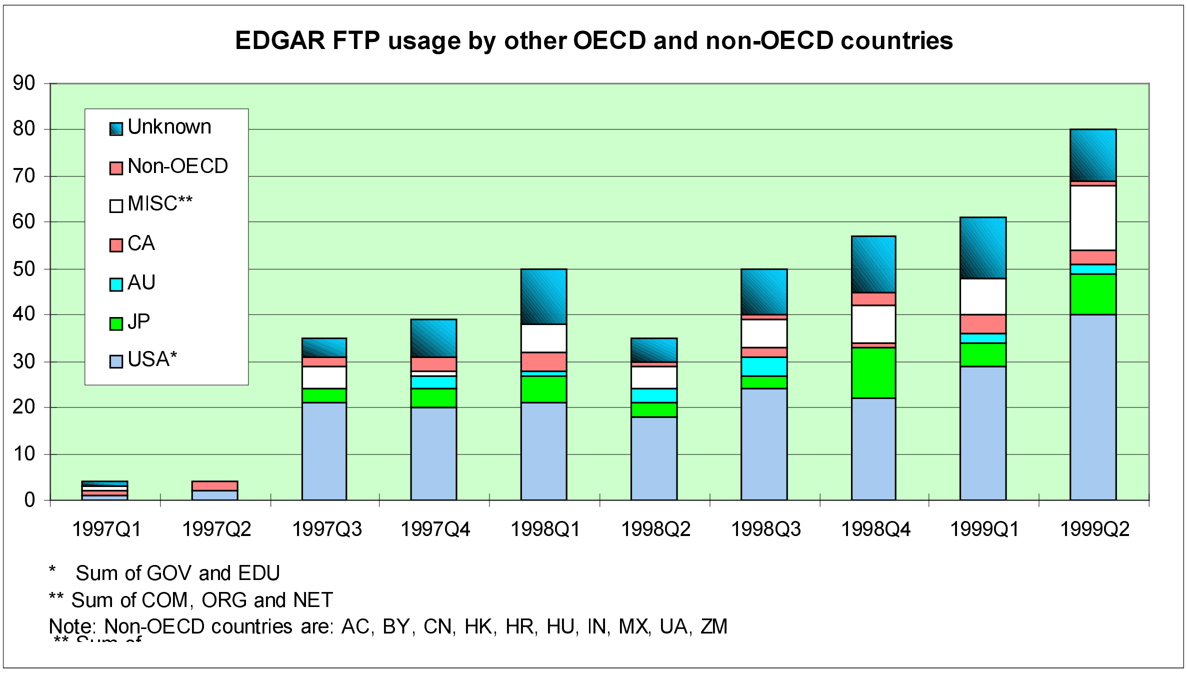


Fig. 3.2.b. EDGAR V2.0 downloads per quarter 1997-mid 1999 by different users in non-Western European countries.

3.3 User survey results

To get a better picture of the usefulness and appreciation of the data sets in 1998 an EDGAR user survey was conducted in parallel with a similar survey for GEIA, the results of which are summarised in Fig. 3.3 and described in more detail in Appendix 5. Also the comments received were very encouraging. Also in Appendix 5, different aspects of the datasets are ranked according to their quality and priority expressed by the 19 users who responded.

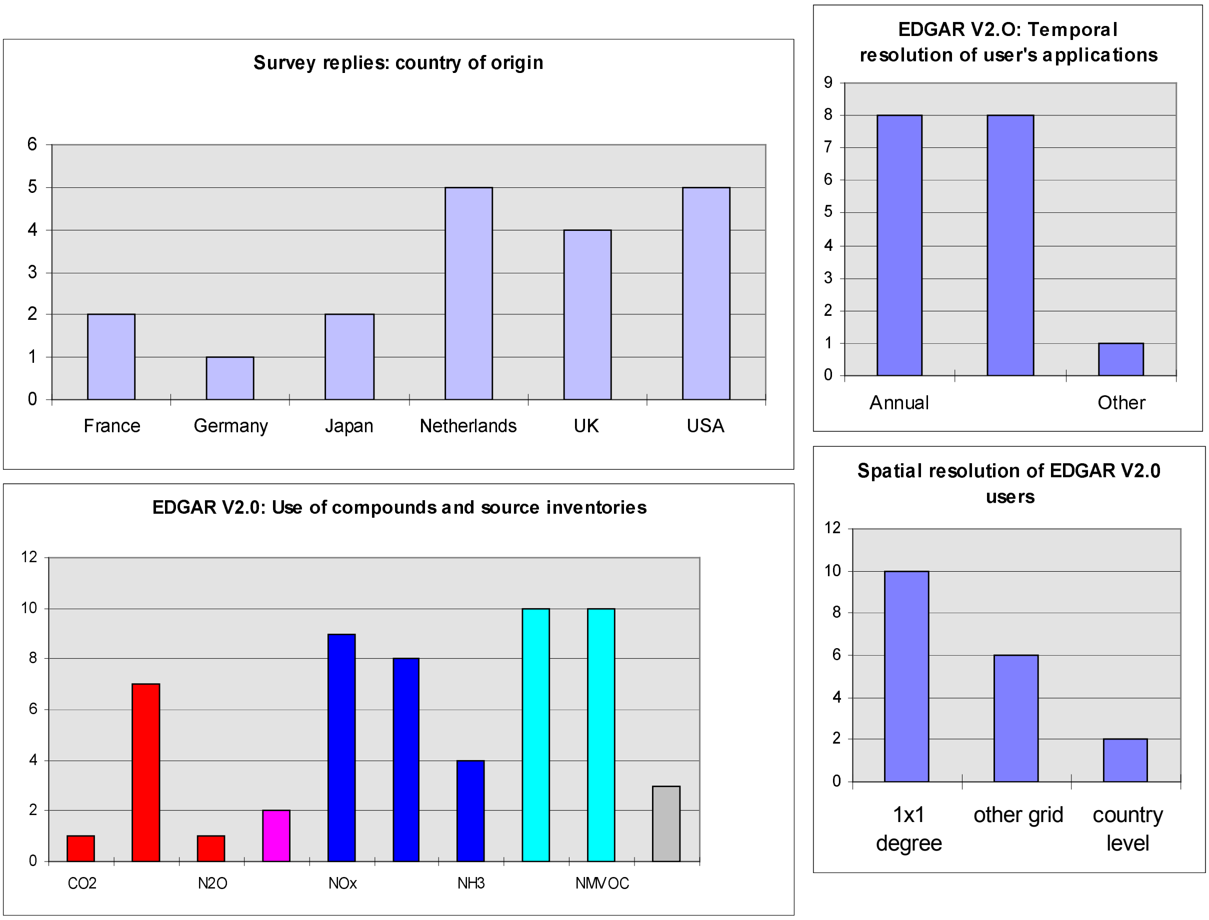


Fig. 3.3. EDGAR survey: use of EDGAR V2.0 data.

The average ranking by the users was (calculated as total evaluation points minus total priority points):

1. Data retrieval (0.37)
2. General appropriateness (0.15)
3. Reference year (-0.29)
4. Consistency with other datasets (-0.50)
5. Documentation on file (-0.57)
6. Description of applicability/caveats (-0.77)
7. Available compounds/sources (-0.92)
8. Data in general (-0.92)
9. Data quality (-0.92)
10. Scientific description (-1.25)
11. Description of uncertainty (-1.31)

In other words, the easiness of data retrieval is considered to be the best part according to the user needs, while the uncertainty description is apparently the weakest part according to the users of the survey.

3.4 Contributions to scientific activities / GEIA

The EDGAR inventories are used for providing realistic emission factors as well as activity data to the RIVM's Global Change model 'IMAGE 2', in particular for fuel combustion, but also regional averaged emission factors for other sources.

EDGAR inventories are also used by many modellers, either as EDGAR inventories or as specific GEIA inventories, which have been developed to support atmospheric modelling work, in particular under the umbrella of IGAC. EDGAR inventories developed as GEIA inventories are (A = Anthropogenic sources; N = Natural sources):

N_2O (A + N) (Bouwman *et al.,* 1995)
NH_3 (A + N) (Bouwman *et al.,* 1997)
NMVOC (A) [total and for 23 compound groups] (Berdowski *et al.,* 2001; in prep.)
CO (A) (Olivier *et al*., 1999b)
PFCs (A) and SF_6 (A) (Olivier and Bakker, 1999c)

as well as:

CO_2 (A) – as alternative dataset, showing sectoral details
parts of CH_4 (A) – as part of the GEIA CH_4 (A + N) inventory

Other compound inventories are sometimes used as default for GEIA inventories (e.g. the SO_x/NO_x 1990 inventories, for countries where no official data exists). The TNO expertise in PM_x emissions in Europe is also used in the compilation of the GEIA primary particles inventory.

The 6th Scientific Conference of the International Global Atmospheric Chemistry Project (IGAC) held in Bologna, Italy, in September 1999, was attended by about 370 scientists. IGAC, part of IGBP, is the forum for atmospheric chemistry modelling research. It was observed that of the 55 oral presentations about 20% referred to GEIA or EDGAR inventories. In addition to the 35 persons showing interest in GEIA products, GEIA members contacted about 30 other modelers at the conference on the subject of emissions. Thus, it can be concluded that at least about 20% of the modelers are using, or intending to use GEIA inventories (or may contribute to improving them). Most of the modelers not using GEIA inventories did not do so because there was not a GEIA inventory available for the species they were modeling. EDGAR inventories were often used when specific GEIA inventories were either unavailable or were considered out of date for the modeling purpose (i.e. not existing for a recent year). As a result of a poster presentation of GEIA and EDGAR inventories, about 35 modelers expressed their interest in receiving information on updates of GEIA and EDGAR. Some of them also offered to become member of a GEIA Study Group or to contribute specific inventories; eight of these 35 are working in developing countries.

Other identified users include:

Members of the Netherlands Centre for Climate Research (CKO), e.g. IMAU (e.g. Houweling et al., 2000; Roelofs and Lelieveld, 2000)
NCAR/NOAA (Smith *et al*., 2001)
Max Planck Institute Mainz (Lawrence *et al.,* 1999a; Lawrence and Crutzen, 1999b)
Historical emission inventories of EDGAR/HYDE (Den Elzen *et al*., 1999)
Integrated N assessments using NH_3, NO_x and N_2O inventories (Olivier *et al.,* 1998)
MIT Joint Program on the Science and Policy of Global Change, e.g. in the Emissions Prediction and Policy Analysis (EPPA) model (Mayer *et al*., 2000)
Other NRP-MLK projects: e.g. emission reductions for non-CO_2 greenhouse gases by De Jager *et al*.; validation of CH_4 emissions in Northwest Europe by Berdowski *et al.;* and CH_4 from rice fields in Asia by Denier van der Gon *et al*.).

These are just a selection of the applications of the gridded inventories.

3.5 Policy supporting activities

The EDGAR inventories are used for assessment of annual trends in global and regional emissions of greenhouse gases and ozone depleting compounds as part of the annual *Environmental Balance* reports to provide the background picture for climate change policy in the Netherlands (RIVM, 1997/87/99/2000a,b). In addition, EDGAR data have been used in international integrated environmental assessments by the European Environment Agency (EEA, 2000) and UNEP for its Global Environmental Outlooks.

Besides providing the IMAGE 2 model with a realistic dataset for defining emission scenarios, in particular aggregated emission factors for energy sources (as well as other data), other policy supporting applications include:

- the use of non-CO_2 emission factors for fuel combustion in the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 1997).
- comparison between national emission inventories for CO_2, CH_4 and N_2O submitted to the UN Climate Change Secretariat as part of the National Communications and EDGAR inventories as reference database in two sequential reports (Greenhouse Gas Accounting, Van Amstel *et al*., 1997a,b; 1999a,b,c).
- using experience gained with uncertainty in emission inventories and knowledge about methodologies in IPCC workshops on *Good Practice Guidance and Uncertainty Management* (N_2O, SF_6, verification) and in UNFCCC workshops (Olivier *et al*., 1999d,e,h).
- estimations of emissions of the fluorinated gases for EU-15 countries for a EU study performed by Ecofys (Hendriks, pers. comm.).
- evaluation of the Brazilian proposal to the Conference of Parties to the UNFCCC for burden sharing utilising historical emission estimates for years prior to 1990 using the historical emission dataset for the period 1890-1990 developed as EDGAR/HYDE (Den Elzen *et al*., 1999; Van Aardenne *et al.,* 2001).
- analysis of CO_2 emissions from international aviation and shipping (so-called bunker fuels) (Olivier and Peters, 1999f).
- IPCC integrated assessment of the impact of future emission scenarios on multiple environmental themes such as radiative forcing (greenhouse effect), acidification and urban air pollution (ozone etc.). These were based on the EDGAR 2.0 inventories because they are one of the few sets of inventories which provide sectoral details and are essentially spatially consistent across compounds, essential features for compiling emission scenarios on grid and use in environmental effect models which are multi-compound and utilise the spatial distribution of these emissions.
- contribution of no-CO_2 sources and othen CO_2 sources than fossil-fuel combustion to the IEA publication *'CO_2 emissions from fossil fuel combustion'* (Olivier, 2001; Olivier *et al.,* 2001).

A recent application is using EDGAR estimates for evaluating the options for emission trading under the UNFCCC (e.g. as part of the *Clean Development Mechanism* (CDM) or *Activities Implemented Jointly* (AIJ), in particular for sources for which reporting by Annex I (‘more developed’) countries is rather weak, incomplete or not comparable, such as for the F-gases, or for non-Annex I (‘less developed’) countries, for which often to date no official national inventory exists. This requires the availability of EDGAR data at country level for recent years and at a source level, which is adequate for identifying areas where technology improvement can reduce greenhouse gas emissions substantially. EDGAR 3.0 provides this type of data.

3.6 Conclusions

EDGAR data are being used extensively for both scientific and policy applications, even without considering applications unidentified by the EDGAR-team. Gridded datasets are used as official or preliminary GEIA inventories and have the advantage that they reflect a recent year, show sectoral details, are consistent across compounds and have a good coverage of anthropogenic sources. Also the sectoral data at regional and national level appear to be quite useful for a lot of policy-oriented applications.

The documentation of EDGAR and the information on the associated uncertainties are relatively less appreciated. However, we have noticed that the accompanying documentation files at the FTP site are not always read carefully. Also, in a number of papers specific compound datasets and the uncertainty in these emissions are described in more detail.

Seasonality information is important because of the reactivity of some of the compounds (e.g. leading to ozone formation) and to compare with observed seasonality in local atmospheric concentration measurements. Specific additional wishes of EDGAR users, notably an update to include a more recent year, adding information on time profiles and trend data, are dealt with in Version 3.0 (see Chapter 4). Also, we hope that by providing also access to the data through the EDGAR website, in addition to anonymous FTP, users are more triggered to read the supporting information provided with the data as it is presented in a more attractive form.

4. EDGAR 3.0: reference database with trend data for 1970-1995

4.1 Introduction

EDGAR Version 2.0 provides global annual emissions of greenhouse gases, both per region and on a 1^ox1^o grid. The overall aim for Version 3.0 was to update the inventories from 1990 to 1995, and for direct greenhouse gases also to 1970, to include new greenhouse gases. After consultation of the users, the objectives have been somewhat changed and extended. Thus, specific aims were:

- update/extension from 1990 to 1995;
- extend time series for greenhouse gases to 1970-1995;
- include new greenhouse gases HFCs, PFCs, SF_6;
- greenhouse gases also on per country basis using IPCC source categories;
- include NH_3;
- improve/include uncertainty and time profiles.

Also during the project, we have tried to identify the most urgent wishes of current and potential users and checked whether we could include these in the updated programme. In addition the work is linked into and part of the *Global Emissions Inventory Activity* (GEIA) of IGBP/IGAC.

4.2 Updated elements

For the update to EDGAR 3.0 of the old Version 2.0, we followed the following principles:

- *Activity data*: update by including relevant statistics for the period 1970-1995, after checking for possible changes of source categories; this implies the inclusion of the 'new' countries, i.e. for the former USSR, former Yugoslavia, former Czechoslovakia, the merger of BRD and DDR into Germany (united) and the split of Ethiopia into Ethiopia and Eritrea.
- *Emission factors*: only to be changed for 1990 if validation showed major discrepancies; only to be changed for 1995 compared to 1990 if there are concrete indications that there major changes have occurred that cannot be neglected; the same holds for factors for 1970, in particular for direct greenhouse gases.
- *Grid maps*: only to be updated if maps available of better quality or better applicability.

4.2.1 Validation

In order to judge whether update of methods or emission factors for 1990 is needed, a validation of V2.0 data for 1990 was performed: for greenhouse gases with National Communications submitted under the UN Climate Convention and for other gases with data from CORINAIR, GEIA and others (see Chapter 2). In addition, inventories in National Communications were checked for the use of different emission factors for 1990 and 1995 in order to select sources and gases for which specific emission factors for 1995 in EDGAR V3.0 need to be determined.

This has been done for the purpose of the update, but also as application of Version 2.0 as reference dataset for comparing with official national greenhouse gas inventories to flag possible inconsistencies in source allocation, incompleteness of sources, and areas of incomparability. In addition, for CO_2, NO_x and SO_2 a comparison was made with the present GEIA inventories, both on grid and per country, from which interesting conclusions could be drawn regarding the apparent uncertainty in international statistics, on emission factors, missing sources and on apparent strong emission trends in specific regions/sources.

4.2.2 Activity data

Next, data were collected for the period 1970-1995. A major part could be drawn from IEA (energy), UN (supplementary energy, industrial production) and FAO (agriculture) databases. But for some source like biofuels and specific industrial production of commodities like adipic acid, nitric acid and fluorinated carbons country statistics are not readily available. For each of these latter compounds additional data sources were found and used. See Box 4.1 for an overview of data sources used.

For Latin American countries ***biofuel*** statistics from OLADE were used for the period 1970-1995 (OLADE, 1999, pers. comm). For other developing countries biofuel data in 1990 have been based on Hall *et al.* (1994), as in EDGAR 2.0, with biofuel type splits from EDGAR 2.0 (Olivier *et al*., 1996, 1999), which includes vegetal waste used as fuel. For these other less developed regions the time series 1970-1995 was constructed by extrapolating the 1990 dataset towards 1970 and 1995, according to the trends in urban and rural population. In OECD'90 and EIT countries (Economies-In-Transition, i.e. Eastern Europe and former Soviet Union countries) fuelwood and charcoal consumption (also production) was based on FAO (1998b), thereby replacing any IEA data for biofuel combustion in the 'Other sector' in these countries. For biofuel combustion in industry and power generation in OECD'90 countries, we used the data as provided in the IEA dataset (IEA, 1997). However these data were often not provided for all years and all countries. The resulting dataset for biofuel consumption shows an increase in the total global amount of non-commercial biofuel use from 28 EJ in 1970 to 33, 39 and 42 EJ in 1980, 1990 and 1995, respectively. It is stressed, though, that these estimates are very uncertain.

Production data of ***cement, nitric acid, iron and steel, and various chemicals*** were based on UN Industrial Commodity Statistics (UN, 1997). However, for many countries interpolations and extrapolations were necessary to arrive at complete time series per country for 1970-1995. Special attention had to be given to new EIT countries, in particular to former SU countries, to match the older totals for the former countries. Cement production data were supplemented with data from the USGS. For ***adipic acid production*** data were taken from SRI (1998) (smoothed and averaged); steel production was split into different technologies using data from IISI (1998), supplemented with UN data.

If we compare global total ***nitric acid*** (NA) production in 1990 or 1995 as reported by the UN (7.3 Mton) with industry estimates of 56 Mton, then 40% is missing in the UN statistics (even after correcting the statistics for a major country from units in N to full molecular mass). This large discrepancy may be partly explained by the fact that NA is often an intermediate product of which a large part is not sold externally. Thus, manufacturing companies and countries may not always report according to the definition asked for, e.g. only reporting production for external sales, thereby neglecting production at the plant as intermediate product that is processed by the same company. We got a clear indication of this phenomenon when we realised that most NA produced is used for nitrogen fertiliser production (only about 10% is used for other uses, e.g. adipic acid production). Looking at national fertiliser statistics by FAO and IFA shows that 31 countries produce either ammonium nitrate (AN), calcium ammonium nitrate (CAN) or other complex nitrogen fertilisers, without a corresponding production of NA according to the UN statistics. Apparently, these countries did not sell any NA produced externally and also did not report the production of NA as intermediate. This is a substantial amount: the total amount of N of these countries as NA accounts for 10.7 Mton or about 15% point of the 40% gap. Therefore we decided to bring the NA production dataset in line with industry estimates by the following procedure: (a) we started with the UN dataset, corrected and inter/extrapolated where necessary; (b) subsequently we added the NA equivalent of the 31 N fertiliser producing countries not included in the UN set; (c) we added 40% to the NA production data of the UN set in order to match the required total, assuming this fraction underreporting by these countries.

Box 4.1. Overview of data source for activity data in EDGAR 3.0

1 ENERGY *[RIG = Revised IPCC Guidelines]*

A. Consumption:

	Fossil fuel:	IEA (112) (sectoral) + UN (IEA split for 71 small countries) + chemical industry: CHE/NEC split + road gasoline: fraction catalyst equipped cars
	Biofuel:	BUN + OLADE for non-OECD + fuel/sector split for non-OLADE IEA for OECD countries, for Industry and Transformation only + FAO Fuelwood/charcoal (in Other sector)
B. Production:		IEA + UN (+ charcoal ~ FAO + own estimates) + coal 60-77: hard coal/brown coal split in CAN, CZE, MEX, ESP, TUR, BUL, NKO, SLV + coal: split Underground/Surface FAO Charcoal

2 INDUSTRIAL PROCESSES

Cement:	UN + USGS	} CO_2
Soda ash:	UN+	}
Steel:	UN+ + IISI: type split (OHF/BOF/EAF)	} CH_4
Chemicals:	UN+	}
Adipic Acid:	SRI (+ rounding/avg.)	} N_2O
Nitric Acid:	cf. Bøckmann indicators	}
HCFC/HFC:	AFEAS + UNEP + own estimates	} HFC/
Aluminium:	UN+ + USGS + World Alu Directory: technology split	} PFC
Semi-conduct.:	(DataQuest)	} PFC/SF_6
SF6 application:	S&PA (CESP/RAND)	}
Magnesium:	UN+ + USGS	} SF_6
GDP:	Worldbank+ (+others) (OECD/CEPII)	}
Electricity cons.:	IEA (+ UN; see 1)	}

3 SOLVENTS/PRODUCT USE

N_2O consumption:	population ~ UN/WB+; GDP/cap. ~WB/UN+ + kg/cap. estimate

4 AGRICULTURE

Animals:	FAO + cattly split dairy/non-dairy + manure management types cf. RIG + *Lerner et al.* for Caribous
Rice:	FAO + 40% correction for China + area harvested by type cf. FAO-database + split intermitted/continuously flooded cf. RIG+
N-fertilisers:	FAO + IFIA + organic fertiliser use cf. RIG
N-fixation:	FAO + correction cf. Mosier/RIG
Savanna burning:	FAO (ha)+ *Hao et al.*
Agric. waste burn.:	FAO + fraction burned by type cf. *Bouwman et al.* + own estimate for fr. waste
Deposition:	NH_3/NO_x emission cf. GEIA/EDGAR
Leaching/runoff:	1) N-fertiliser ~ FAO x factors cf. RIG 2) N-manure ~ FAO x factors cf. RIG

5 LUCF

Deforestation:	FAO (ha)	+ ton/ha cf. *RIG*
Sinks:	(FAO) (ha)	+ ton/ha cf. *RIG*
Wildfires:	UN/ECE	+ ton/ha cf. *RIG*

6 WASTE

Landfills:	population (urban/rural) ~ UN/WB+ + kg/cap generated + fraction landfilled + fraction BOD: cf. RIG+
Waste incineration:	1) controlled: see landfills + fraction for energy: cf. IEA 2) uncontrolled: population ~UN.WB+ + kg/cap cf. *TNO*
Waste water:	1) domestic: population ~ UN/WB+ 2) industrial: 5 commodities ~ UN+ x kg water/ton product cf. *Doorn et al.* + fraction treated cf. *Doorn et al.*
Human sewage N_2O:	protein/cap ~FAO + fraction treated cf. RIG+

In addition, for the IPCC sources ***'Land-use change and forestry'*** (LUCF) and 'Waste' there is no readily available data in time-series per country. Here, in line with the approach taken for the compilation of the GEIA NH_3 inventory, biomass burning data (vegetation fires) for LUCF were based on FAO reports providing 10-year or 5-year averaged estimates (see Tables 4.1 and 4.2), supplemented with an estimate for agricultural waste burning essentially based on the methodology used for NH_3. Fig. 4.1 shows the resulting regional trend in deforestation based on the assumptions used.

Table 4.1 Data used for deforestation 1970-1995

Annual change	70-80 [ha]		use same rate as extrapolated to 1980
Annual change	80-90 [ha]	FAO, 1998:	State of the Worlds Forests 1997 (Annex 1, Table 3)
		FAO, 1993	Forest resources assessment 1990; Tropical countries (FP-112): provides annual deforest. in 5 forest types Annual def. rate 81-85: 11.3 mln ha/yr; 81-90: 15.4 mnl ha/yr (Table 5)
Total change	90-95 [ha]	FAO, 1995	Forest resources assessment 1990; Global analysis (FP 124) (Annex 1, Table 4)
Biomass	90 [ton/ha]	FAO, 1995	Forest resources assessment 1990; Global analysis (FP-124) (Annex 1, Table 5)

Note: The following procedure was used to connect the annual average in the 80's with the annual average in the period 90-95:
(a) the 1990 level was chosen to be 2/3*90's-average + 1/3*80's-average
(b) the linear trend 1990-1995 was determined by the condition that the 90-95 average should equal the FAO figure for that period.
(c) the linear trend 1980-1990 was determined by the condition that the 80-90 average should equal the FAO figure for that period
(d) for the period 70-80 we assumed the same annual figure as determined for 1980 in (c).
(e) for years where this procedure resulted in negative values, the figure has been set to zero.

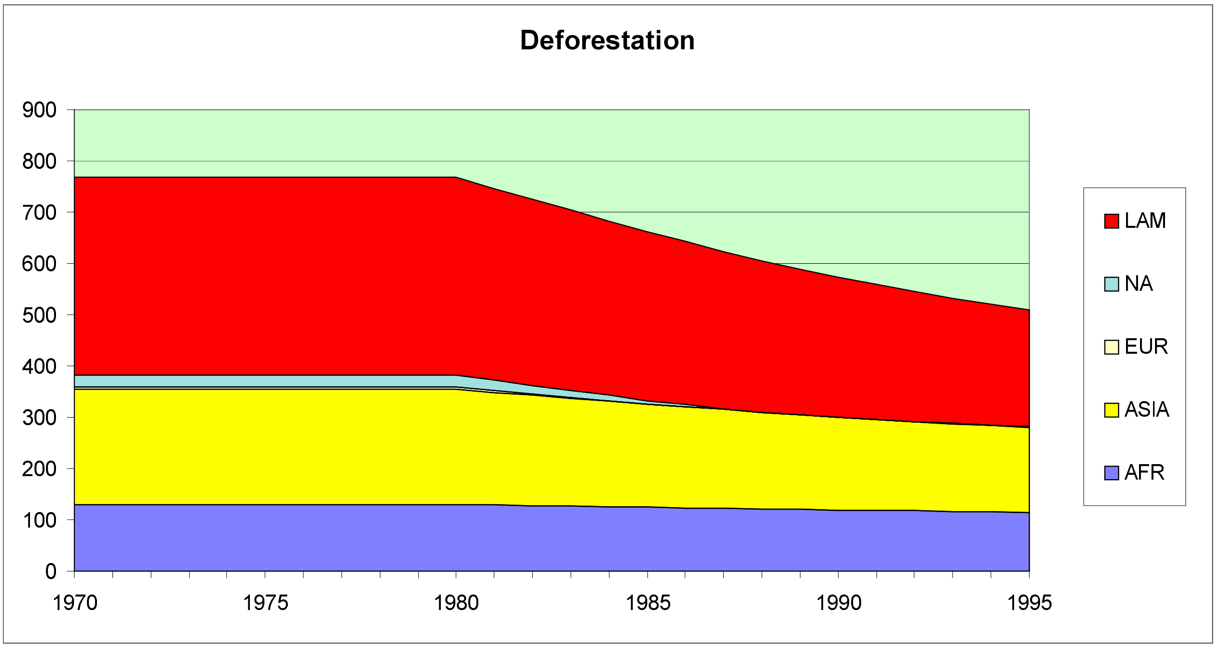


Fig. 4.1 Resulting historical trend in regional deforestation.

Table 4.2 Historical trend in regional savannah burning (index; 1990=1).

Region	1970	1975	1980	1985	1990	1995
Latin America	1.11	1.08	1.06	1.03	1.00	0.98
Africa	1.02	1.01	1.00	1.00	1.00	0.93
South Asia	0.97	0.97	0.98	0.99	1.00	0.94
East Asia	3.69	2.82	2.04	1.58	1.00	<u>0.50</u>
Southeast Asia	1.12	1.07	1.06	1.03	1.00	0.97
Oceania	1.00	1.00	1.00	1.00	1.00	<u>1.00</u>
World	1.07	1.05	1.03	1.02	1.00	0.94

Source: simulation of IMAGE 2.1 (Baseline A), except underlined values for 1995, where IMAGE values were considered unrealistically low (own estimate).
Source of activity data: FAO (1993).

For ***agricultural waste burning*** (on-site), the fractions burned on-site have been changed substantially, based on analysis made for the GEIA ammonia inventory for non-OECD'90 countries (Bouwman, 1997) and data reported in National Communications of OECD countries (i.e. of USA, Japan, Australia). For both developed and developing countries the fractions burned are now estimated considerably lower than in EDGAR 2.0. We assume 5% in OECD regions, 20% in EIT (Eastern Europe and former USSR) and 40% in developing regions, except for Oceania where we used a percentage of 30% (Nat. Com. Australia) and for OECD Europe where we assumed a decreasing trend from 40% in 1980, 20% in 1990 to 5% in 1995 based on data for the UK in Lee and Adkins (1994). Also the fractions of agricultural waste associated with the net crop production have been modified (Smill, 1999). The resulting trend in amounts burned on site is presented in Fig 4.2. The 40% for less developed countries includes the amounts used as biofuel; for OECD and EIT the fractions are assumed to refer to field burning only. The resulting fractions of agricultural waste assumed to be burned on the field is presented in Table 4.3, where these are presented per EDGAR3/IMAGE2 region for the period 1970-1995. Due to varying % of amounts used as biofuel in LDC regions, the effective fraction of field burning also varies in these regions. For OECD regions the fractions are assumed to refer to field burning only, and are assumed to remain constant, except for OECD Europe as discussed above.

Table 4.3 Regional fractions of agriculture waste burning on-site in EDGAR 3, (excluding per LDC country the amount used as biofuel) (unit: % field burning of total agricultural residues).

EDGAR 3	IM 2	1970	1975	1980	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
01: Canada	1	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
02: USA	2	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
03: OECD Europe	9	40%	40%	40%	30%	28%	26%	24%	22%	20%	15%	10%	8%	7%	5%
04: Japan	17	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
05: Oceania	16	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%
06: Eastern Europe	10	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
07: Former USSR	11	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
08: Latin America	3	17%	17%	19%	21%	19%	20%	19%	19%	21%	21%	21%	20%	21%	21%
08: Latin America	4	22%	21%	18%	16%	16%	15%	16%	16%	15%	16%	16%	18%	17%	17%
09: Africa	5	25%	20%	22%	21%	23%	17%	24%	24%	19%	20%	14%	14%	22%	13%
09: Africa	6	23%	24%	24%	23%	22%	22%	22%	23%	22%	23%	23%	23%	23%	23%
09: Africa	7	24%	24%	20%	21%	20%	21%	20%	21%	22%	21%	20%	27%	26%	27%
09: Africa	8	21%	21%	24%	22%	22%	21%	22%	24%	22%	21%	23%	26%	24%	22%
10: Middle East	12	31%	31%	32%	31%	31%	31%	32%	31%	31%	31%	30%	30%	31%	31%
11: South Asia	13	0%	0%	2%	3%	3%	1%	3%	4%	3%	2%	3%	4%	5%	4%
12: East Asia	14	5%	7%	5%	3%	3%	2%	3%	3%	2%	2%	2%	2%	2%	2%
13: Southeast Asia	15	23%	22%	23%	22%	23%	23%	23%	22%	22%	21%	21%	20%	21%	21%

Note: IM 2 = IMAGE 2 region (see Appendix A.4.4).

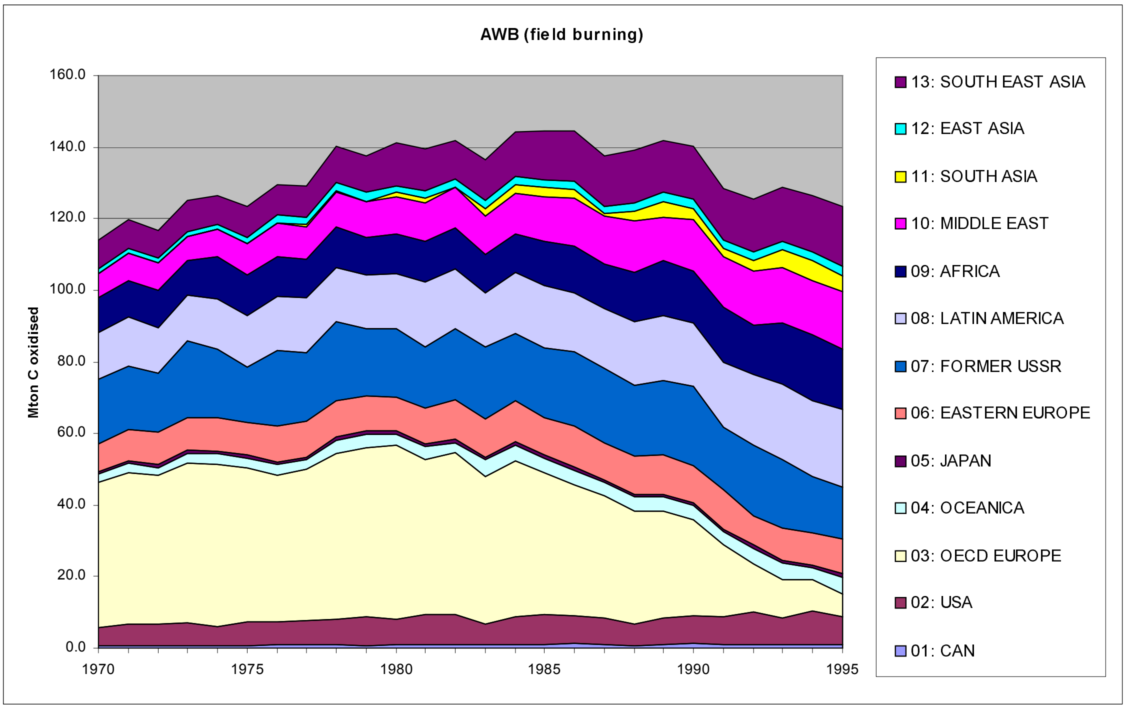


Fig. 4.2. Trend 1970-1995 in agricultural waste burning (on site).

For ***waste in landfills***, the 1970-1995 trend in activity data per country has been based on a fit with of international waste generation figures per capita for 1990 - as recently published by IPCC and EPA and references mentioned therein - with per capita income per country (Fig. 4.3). This fit was also used to estimate the activity data for 1990, for countries not mentioned in IPCC (1997) and in an EPA report (Adler, 1994).

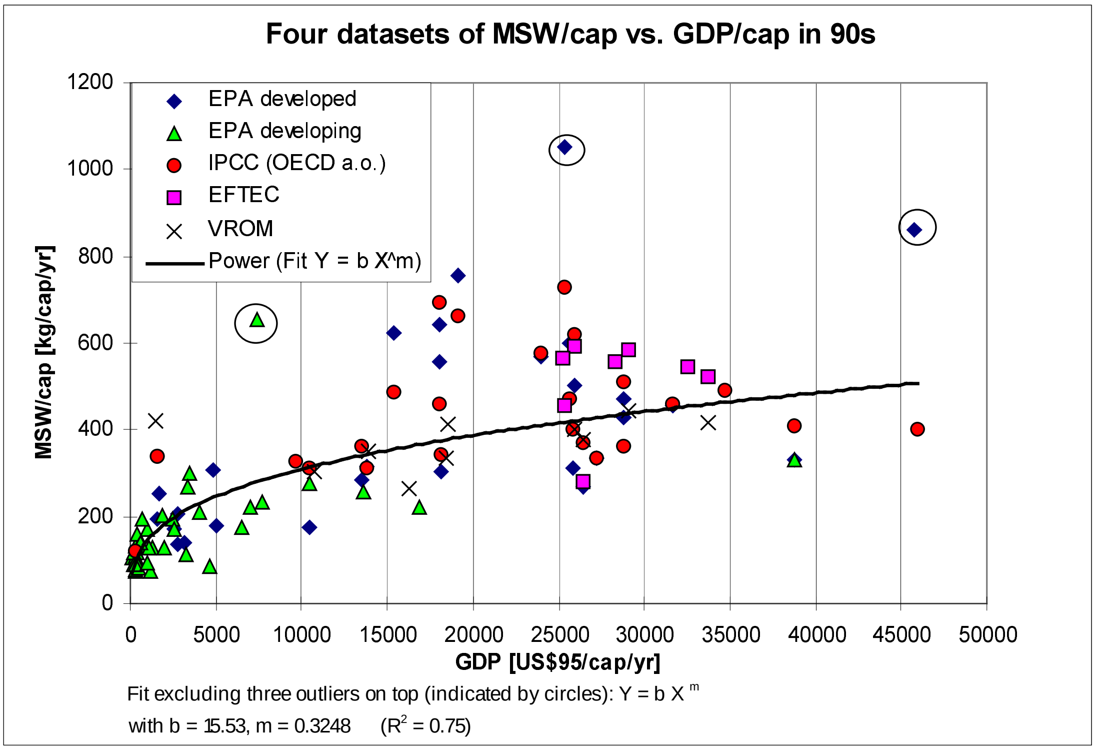


Fig. 4.3. IPCC, EPA, EFTEC and VROM datasets for MSW/cap vs. GDP/cap (US$95) in 1990 for individual countries and power fit to to $Y = b*X^m$.

In the process of updating 1990 activity data with more recent statistical datasets, these levels are often changed to a lesser or larger degree. This is caused by the phenomenon that statistics of activity data of the most recent years tend to change during a couple of years after the first compilation. This happens in particular in non-OECD countries, however, also in industrialised countries this phenomenon can be observed, although in these countries the changes are often only minor. In addition, data for the former USSR have become rather weak due to inconsistencies between the sum of the new countries and the 1990 data for the former USSR.

Moreover, international statistics often do not include full time series for all countries. Often for the most recent year(s) as well as in the more distant past data are missing. For industrial production statistics this has been 'repaired' by extrapolating at constant levels to 1995 and linearly back to 1970 in these cases. Interpolation was used when intermediate years were missing. For the so-called 'new' countries (e.g. of the former USSR), extrapolation of the official time series back in time was done by applying the annual growth rates of the former country to all new countries.

4.2.3 Update of emission factors for 1990

As a result of the validation of EDGAR 2.0 with other global and regional emission inventories it was decided that several items should be modified for the reference year 1990. Compared to Version 2.0 the following amendments have been made for 1990:

The emission factors for 1990 for direct greenhouse gases CO_2, CH_4 and N_2O have been brought more in line with the defaults recommended in the *Revised 1996 IPCC Guidelines for Greenhouse Gas Inventories* (IPCC, 1997) and for reference purposes any departures from them will be clearly identified. For CO_2 from fossil fuel use, emission factors per detailed fuel type are used as recommended as default in the *Revised 1996 IPCC Guidelines*, including the default fractions of fuel not oxidised (in V2.0: one aggregated factor for coal, oil and gas). For CO_2 from non-energy use of fossil fuels we used the default carbon storage factors recommended by the *Revised 1996 IPCC Guidelines* (see Table 4.4). This also means that the agricultural emissions have been changed substantially by the inclusion of 'indirect' emissions of N_2O. Other examples of areas where emission factors were updated are CH_4 from rice and landfills (see separate sections 4.2.4.5 and 4.2.4.6).

Global default emission factors for NO_x, CO and NMVOC for the following non-road transport activities are updated: Rail transport, Inland water, Other land-non-road and Non-specified transport. Emission factors are entered for coal, diesel oil and gasoline when applicable. These new EDGAR factors are taken from the EMEP-CORINAIR Atmospheric Emission Inventory Guidebook.

Global default emission factors for NO_x and SO_2 for sea ships have been updated; in particular the emission factor for NO_x has increased significantly. The new emission factors for NO_x and SO_2 are based on Corbett *et al.* (1997, 1999) and for others on the IPCC default values (IPCC, 1997) (see Table 4.5).

Global emission factors for biomass burning (savannah burning, deforestation, agricultural waste burning) have been updated, based on existing GEIA inventories and default values recommended by IPCC (1997) (see Table 4.6.a and b). The emission factors for biofuels were updated based on a recent literature review, which are similar to the default values recommended in IPCC (1997). The main differences with the emission factors for vegetation fires in EDGAR 2.0 are the factors for CH_4 and CO from agricultural waste burning and for NO_x from deforestation fires, which are presently about half of the old values.

Table 4.4 Non-energy use: IPCC Tier 1 default fractions of carbon stored and resulting effective CO_2 emission factor as used in EDGAR 3.

Fuel type	Carbon content (kg C/GJ)	Fraction stored (-)	Emission factor (kg C/GJ)	Ibid. (kg CO_2/GJ)
Bitumen	22.0	1	0	0
Ethane	16.8	0.8	12.3	45.2
Gas/Diesel oil	20.2	0.5	37.0	135.8
LPG	17.2	0.8	12.6	46.2
Lubricants	20.0	0.5	36.7	134.5
Naphtha	20.0	0.75	18.3	67.2
Coke-oven coke&lignite coke	29.5	0.75	27.0	99.1
Gas coke	29.5	0.75	27.0	99.1
Natural gas	15.3	0.33	37.6	137.8
Other derived gases	15.3	0.33	37.6	137.8

Source: IPCC (1997).

Table 4.5 Emission factors in EDGAR 3.0 for international shipping based on Corbett et al. (1997, 1999) and IPCC (1997) (kg/GJ)

Compound	Emission factor HFO (kg/GJ)	Emission factor diesel (kg/GJ)
NO_x	1700	1700
SO_2	1500 (3%)	500 (1%)
CO	15	30
NMVOC	3	3

Table 4.6.a Emission factors in EDGAR 3.2 for biomass burning (vegetation fires) (g/kg C)

Source	CO_2	CH_4	N_2O	CO	NMVOC	NO_x	NH_3	SO_2
Deforestation	3667	10	0.11[1)]	200	10	4	1.85	1.4
Savannah burning	NA	5.3	0.07	133	9	7.9	1.85	1.4
Agricultural waste burning	NA	6.7	0.165	133	16	6	1.85	1.4
Temperate vegetation fires	3667	10	0.22	300	40	12	1.85	1.4
Fuelwood	100[2)]	6.8	0.08	64.3	13.5	1.4	1.4	0.2
Fuelwood (g/GJ)	*[1)]*	*300*	*4*	*5000*	*600*	*150*	*55*	*15*

[1)] Excluding post-burn effects (Bouwman *et al.*, 1997).

[2)] 10% of C content, comparable with an unsustainable production at about 10% (reference value, to indicate possible order of magnitude).

Table 4.6.b Emission factors in EDGAR 3 for vegetation fires (large scale, field) in (g/kg dm)

Source	CH_4	N_2O	CO	NO_x	NMVOC	SO_2	NH_3
Deforestation	5.6	0.055[1)]	111.0	3.6	7.7	0.7	0.93
Savannah burning	2.2	0.033	66.5	3.6	5.5	0.7	0.93
Agricultural waste burning	6.7	0.083	116.5	4.1	7.8	0.7	0.93
Temperate vegetation fires	5.6	0.055	111.0	3.6	40.0	0.7	0.93

[1)] Excluding post-burn effects (Bouwman *et al.*, 1997).

Recently, Andreae and Merlet (2001) compiled a comprehensive set of emission factors based on 130 publications (Table 4.7). Comparison with this set shows that most of the EDGAR 3.2 emission factors are in line or within the uncertainty of the reference set presented in this recently published review paper. Marked differences are:

- CH_4 in agricultural waste burning (twice as high, however based on only one measurement, thus very uncertain);
- N_2O from temperate vegetation fires (twice as high, at the upper side of the 2σ range);
- N_2O from deforestation (4 times lower, however based on only one measurement, thus very uncertain);
- N_2O from savannah burning (6 times lower, near the lower side of the 2σ range);

NO_x from savannah burning (almost half lower, but well within the 2σ range);
NMVOC from temperate vegetation fires (5 times as high);
SO_2 from savannah burning (twice as high, at the upper side of the 2σ range).

So we may conclude that all EDGAR 3.2 emission factors are within the uncertainty of the data set presented recently, except for NMVOC from temperate vegetation fires, which we based on figures reported by Hobbs et al. (1996).

Table 4.7 Emission factors in for vegetation fires presented in Andreae and Merlet (2001) (g/kg dm)

	CH_4	N_2O	CO	NO_x	NMVOC	SO_2	NH_3
Deforestation	6.8±2.0	0.2	104±20	2.5±1.6	8.1±3.0	0.57±0.23	1.3
Savannah burning	2.3±0.9	0.21±0.10	65±20	6.0±3.8	3.4±1.0	0.35±0.16	0.6-1.5
Agricultural waste burning	2.7	0.07	92±84	3.8±1.7	7	0.4	1.3
Temperate vegetation fires	4.7±1.9	0.26±0.07	107±37	4.6±2.3	5.7±4.6	1	1.4±0.8
Biofuel: fuelwood	6.1±2.2	0.06	78±31	1.7±1.1	7.3±4.7	0.27±0.30	1.3

Note: one figure, a range and (value standard deviation) corresponds with one, two or more than two measurements, respectively.

After an evaluation of available data sources for biofuel use (see references listed in Table 4.8), including measurement data that has been published recently, we selected the emission factors in Table 4.8 for use in EDGAR 3. The largest differences compared with EDGAR V2.0 are found in:

CH_4 and CO from dung (doubled) and vegetal waste (+50%);
NO_x from fuelwood (doubled); NMVOC from wood waste (1/10 of the old value);
SO_2 from vegetal waste (+50%).

Table 4.8 Emission factors in EDGAR 3.2 for biofuel combustion in the residential sector and for charcoal production (g/GJ)

Biofuel type	CH_4	N_2O	CO	NO_x	NMVOC	SO_2	NH_3	References
Fuelwood	300	4	5000	150	600	15	55	2,3,5,6,7,8,9,10,11,12
Charcoal	150	1	7000	100	100	20	55	2,3,6,8,9
Agricultural waste	300	3	5000	150	600	60	55	3,5,11
Dung	400	4	7000	250	800	400	55	2,3,5,11
Wood waste	400	4	4700	100	65	15	0	4
Charcoal production	1000	1	7000	10	1700	5	3	2,3,7,8,9,10

Sources: 2 (Berdowski *et al.*, 1993); 3 (Veldt and Berdowski, 1995); 4 (Olivier *et al.*, 1999); 5 (Smith and Ramakrishna, 1990); 6 (Smith *et al.*, 1993); 7 (Delmas, 1993); 8 (Delmas *et al.*, 1995); 9 (Brocard *et al.*, 1996); 10 (USEPA, 1985); 11 (Joshi *et al.*, 1989); 12 (Ellegard and Egneus, 1992).

The emission factors for N_2O from nitric acid (NA) production have been compiled using the emission factors provided in the IPCC *Good Practice Guidance* report (IPCC, 2001):

For 1990 we used 1.2 kg/ton for the 20% NA plants in the world equipped with Non-Selective Catalytic Reduction (NSCR) control technology (this is the lower end of the 1.12-2.5 range) (Choe *et al.,* 1993). For other NA plants without NSCR we use the emission factor of 9 kg/ton (average of the 8-10 range default for non-NSCR) (IPCC, 2001). We assume that all NSCR plants are within OECD; i.e. of the 68% of total world production in OECD countries, 20% points have an emission factor of 1.2 and the other 48% points has an emission factor of 9. Since we do not know which OECD plants are equipped with NSCR, we use the weighted average emission factor of 6.7 for all OECD countries. For non-OECD countries the default of 9 kg/ton is used.

According to Choe/EMFA cited in the IPCC (2001), older plants, i.e. pre 1975, may have emission factors around 19 kg/ton. Therefore we assume that all NA plants in 1975 and earlier have this emission factor of 19. Interpolation is used for the emission factors between 1975 and 1990.

The emission factors for N_2O from adipic acid production were determined by the fraction abatement assumed:

According to Reimer *et al.* (1992) globally 32% of N_2O from adipic acid manufacture in 1990 was abated and on average 53% of the emissions from Du Pont plants, including 98% abatement at the Du Pont plant in Victoria, USA.

Our production data from SRI (1998) (smoothed and averaged) and point source information from Castellan *et al.* (1991) leads to the conclusion that on average 22% of the non-Du Pont plant emissions were abated in 1990.

For other years we assumed that the emission factors have remained constant.

4.2.4 Update of the EDGAR emission factors from 1990 to 1995

Basically, for EDGAR 3.0 the emission factors for 1995 are imported from EDGAR 2.0 (1990) without any changes except for an improved data format for Europe and the USA. However certain developments influencing emission factors that have taken place during the first half of the 1990s cannot be ignored. Updated emission factors, or another mix of sub-activities, for 1995 will be required for sources such as coal mining, gasoline cars, shifting type of rice cultivation, landfills with gas recovery. In addition, also for power plants and some industries in countries where additional control technology e.g. for SO_2 and NO_x has been installed. For extension of emission factors for CH_4 and N_2O towards 1970 similar considerations have been made.

Given the limited resources available for the 1995 update it was decided to focus only on the most important developments and changes that might influence emission factors. There are many sectors in which important emission reduction measures have been implemented. For the update of the 1990 EDGAR 3.0 emission factors to 1995 the following three sectors have been selected: large combustion plants, mobile sources and solvent use.

4.2.4.1 Coal mining

For coal mining, we used the same country-specific emission factors for underground and surface mining, respectively, as in EDGAR 2.0 for 1990. However, the steadily increasing share of surface mining in total hard coal and brown coal production results in decreasing emissions as the emission factor for surface mining is much lower than for underground mining. Therefore we used country-specific information of the largest producing countries to compile for EDGAR 3.0 a dataset for the split of national total production into surface and underground mining in the period 1970-1995. Taking into account this shift, it appears that the impact on global methane emissions by and large compensates the increasing trend of total coal production (see Fig. 4.4).

Another reason why global total coal mining emissions remained more or less constant in the '80s and '90s is the increasing amount of methane recovered (and combustion for energy purposes or flared), which increased to 1 and 2 Gg in 1990 and 1995, respectively (see Table 4.9).

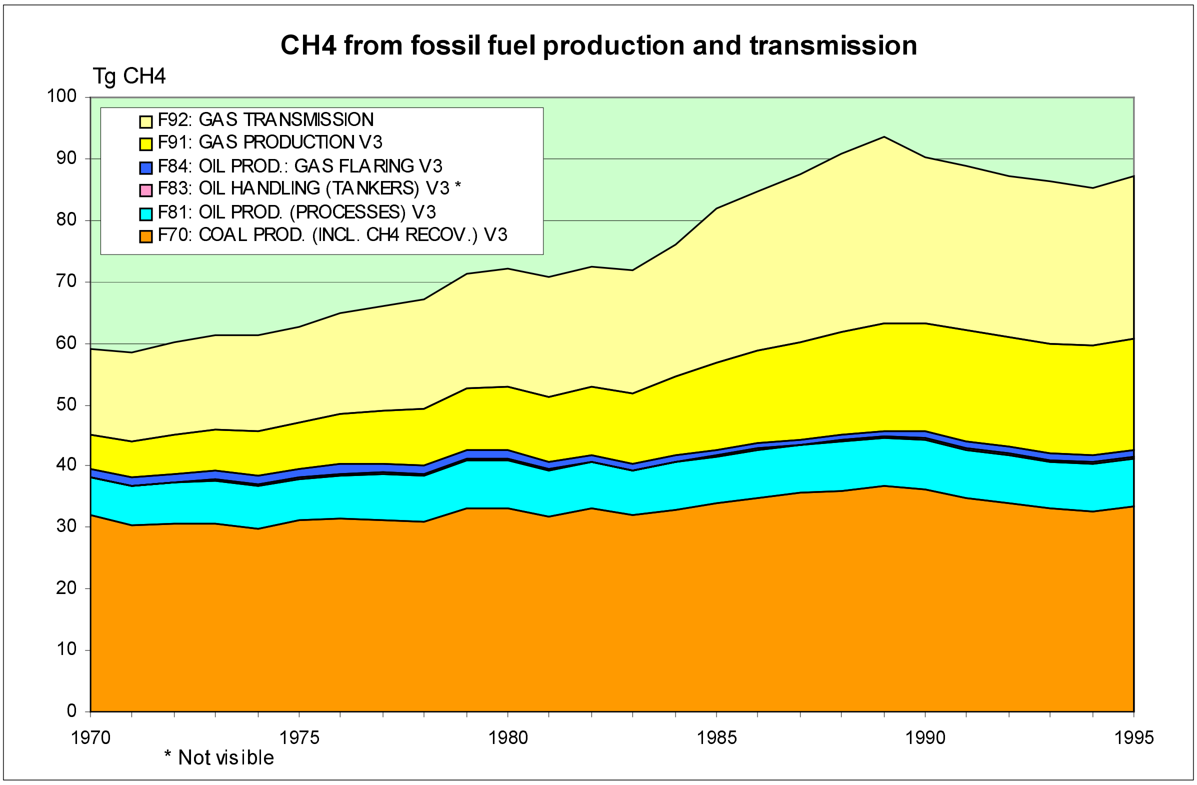


Fig. 4.4. Trend 1970-1995 of methane emissions of fossil fuel production and gas and oil transmission.

Table 4.9 Methane recovery from coal mining, landfills and wastewater treatment plants (WWTP) (in Gg)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Coal mining	**0.0**	**0.2**	**0.4**	**0.6**	**0.7**	**0.7**	**0.9**	**1.0**	**1.1**	**1.0**	**1.0**	**1.0**	**1.4**	**1.7**	**2.1**	**2.2**
USA	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.4	0.5	0.7	0.8
OECD Europe	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.3	0.3	0.3	0.4	0.4	0.3	0.3
Oceania	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
Eastern Europe	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2
Former USSR	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3
East Asia	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.4	0.4
Landfills	**0.1**	**0.3**	**0.5**	**0.6**	**0.9**	**1.1**	**1.3**	**1.5**	**1.7**	**1.9**	**2.5**	**2.7**	**3.1**	**3.4**	**3.8**	**4.3**
Canada	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3
USA	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.2	1.4	1.6	1.8	2.1	2.4
OECD Europe	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.1	1.1	1.2	1.4	1.4	1.5
Oceania	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
WWTP	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.7**	**0.7**
Canada	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
USA	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3
OECD Europe	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3
Oceania	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Japan	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Grand total	**0.7**	**1.1**	**1.4**	**1.8**	**2.2**	**2.4**	**2.8**	**3.2**	**3.4**	**3.6**	**4.1**	**4.4**	**5.1**	**5.8**	**6.5**	**7.1**

Sources: coal mining: Bibler *et al.* (1998); landfills, WWTP: National Inventory Reports to UNFCCC; Strogies, 2001, pers. comm.

4.2.4.2 Large combustion plants

Emission of SO_2 and NO_x from large combustion plants in Europe and the USA have decreased considerably as a result of the progress made in national and international programmes against acidification. For Europe an appropriate data source would be the CORINAIR95 inventory. However there are several difficulties in using these data, being the fact that CORINAIR95 is still incomplete and even more important, emissions are mostly not specified by fuel type. This is essential for processing results to a suitable input for the EDGAR model. Hence use has been made of the data from the RAINS7.2 module (Cofala and Syri, 1998a,b). This module is able to generate emissions by fuel type and sector for all countries in UN/ECE Europe for among others 1995 based on estimates by IIASA for the gradual implementation of reduction measures for acidifying pollutants. With the aid of RAINS it has been attempted to estimate the total emission reduction by sector, fuel type and country, which had been achieved in 1995 compared to the uncontrolled situation. The reduction percentages thus calculated have been multiplied with the 1990 EDGAR emission factors in order to come to 1995 emission factors for NO_x and SO_2 for the EDGAR sectors Power generation and Industrial combustion. The EDGAR V2 factors for 1990 did not take into account existing emission control, therefore all emission control implemented by 1995 has been considered.

Also for the USA, the SO_2 and NO_x emission factors for the sectors *Power generation* and *Industrial combustion* have been updated to 1995. This has again been done using emission reduction percentages, which have been calculated from the detailed NAPAP emission inventory results for 1990 and 1995 and the IEA energy statistics.

4.2.4.3 Mobile sources

During the period 1990 to 1995 significant emission control measures have been taken for mobile sources. For instance a further penetration of the exhaust catalyst has taken place in most regions of the world. In order to estimate the resulting effect of these measures on the emission factors for the road transport sector, several methodologies have been used. For NO_x emission in Europe use has been made of IIASA's RAINS7.2 module (Cofala and Syri, 1998a,b). EDGAR requires data to be specified by fuel type and the RAINS module can produce this data for 1990 and 1995. Based on the RAINS results the relative reduction in emission factors is calculated by fuel type for the period 1990 to 1995. These reduction factors are multiplied with the EDGAR 1990 emission factors to account for the emission control measures taken. NO_x, CO, SO_2 and NMVOC emission factors for road transport for the USA have been calculated from the detailed NAPAP emission inventory results for 1990 and 1995 and the IEA energy statistics.

For N_2O and NH_3 the effect of the introduction of catalytic converters for petrol cars in the '80s in the USA, Canada, Japan and Australia, and in European countries effectively since the early '90s on the emission factors was estimated by using country-specific time series 1970-1995 for these countries (see Table 4.10).

For N_2O and NH_3 the effect of the introduction of the catalytic converter for petrol cars in the '80s in the USA, Canada, Japan and Australia, and in European countries effectively since the early '90s on the emission factors was estimated by using country-specific time series 1970-1995 for these countries (see Table 4.10).

4.2.4.4 Solvent use and other product use and miscellaneous process emissions of NMVOC from the chemical industry

For solvent use an improved method is under development but was not yet available for implementation in EDGAR 3.0. For NMVOC emissions from miscellaneous industrial processes in EDGAR 2.0 we applied a method by Piccot *et al.* (1992) using a global emission factor based on a ratio to a countries population, calibrated to data for the USA.

Analysis of emissions from non-combustion processes in the USA (Nizich and Pope, 1998) showed that the largest remaining NMVOC process source was hazardous waste: Treatment, Storage or Disposal Facility ('TSDF'), which accounts for 10% of total solvent use of the USA. This factor was used in EDGAR 3.0 for all countries, resulting in 2.2 Tg NMVOC globally in 1990 for the new source called *Hazardous Waste*. For the remaining *Miscellaneous industrial processes* in EDGAR 3.0, the old method was replaced by a more realistic approach, using an emission factor based on the ratio to remaining uncovered NMVOC emissions from known chemical process sources, calibrated to data for the USA (150 Gg cf. Nizich and Pope, 1998). This reduces global NMVOC emissions from *Miscellaneous industrial processes* from 10 Tg in version 2.0 to 0.5 Tg in EDGAR 3.0 plus the *Hazardous Waste* emissions of 2.2 Tg in 1990.

For N_2O from the use of anaesthesia in hospitals we used a fixed amount of N_2O per capita in OECD'90 countries, tentatively set at 25 g/cap/year, based on Kroeze (1994).

Table 4.10 Fraction of petrol cars with catalytic convertor. (sources: NEW CRONOS, Eurostat (01/10/1997))

	1980	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
OECD Europe													
AUT		0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.42	0.48	0.53	0.58	0.65
BEL		0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.16	0.29	0.41	0.51	0.62
DNK		0.00	0.00	0.00	0.00	0.00	0.02	0.07	0.12	0.17	0.26	0.34	0.41
FIN		0.00	0.00	0.00	0.00	0.00	0.05	0.09	0.12	0.16	0.20	0.24	0.29
FRA		0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.03	0.09	0.15	0.20	0.26
DEU		0.00	0.06	0.12	0.17	0.23	0.29	0.36	0.43	0.52	0.58	0.64	0.70
GRC		0.00	0.00	0.00	0.00	0.00	0.03	0.13	0.24	0.30	0.33	0.39	0.42
IRL		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.16	0.23	0.30
ITA		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.13	0.19	0.26
LUX		0.00	0.00	0.00	0.00	0.00	0.03	0.07	0.15	0.24	0.33	0.41	0.48
NLD		0.00	0.00	0.00	0.01	0.04	0.10	0.18	0.25	0.30	0.36	0.45	0.55
NOR		0.00	0.00	0.00	0.00	0.03	0.07	0.11	0.14	0.18	0.23	0.28	0.37
ESP		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.11	0.16	0.20
SWE		0.00	0.00	0.00	0.04	0.13	0.22	0.28	0.34	0.36	0.40	0.44	0.48
CHE		0.00	0.08	0.16	0.26	0.32	0.40	0.48	0.56	0.62	0.68	0.73	0.78
GBR		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.10	0.17	0.25	0.31
Other Europe													
CZE		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.08	0.13	0.20
EST		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.06	0.12
LIE		0.00	0.09	0.18	0.28	0.35	0.46	0.60	0.63	0.76	0.83	0.85	0.97
MLT		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.11	0.18
Other OECD													
USA	0.0	0.5	0.6	0.7	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0
CAN	0.0	0.5	0.6	0.7	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0
JPN	0.0	0.5	0.6	0.7	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0
AUS	0.00	0.00	0.1	0.2	0.17	0.34	0.5	0.6	0.7	0.8	0.9	1.0	1.0

4.2.4.5 Rice production

Activity data for rice cultivation, i.e. harvested area, was based on FAO (1997). The shares of the four cultivation types over time is based on a provisional version of the RICE-ECO database of FAO of March 1997, which comprises per country estimates of rice harvested areas under different ecologies 1970-1995 (Van Nguu Nguyen, pers. comm., 1997). In addition, for total harvested rice production data of FAO for China a correction of 40% has been applied to account for the officially recognised underreporting in the official Chinese rice production statistics (Denier van der Gon, 2000, pers. comm.).

In EDGAR 2.0 we applied emission factors regionally aggregated for the regional mix of four types of rice cultivation. As was shown in the comparison with country study reports, this often does not result in a fair estimate of the country-specific mix, which appears to differ largely between countries within a region. Therefore, in EDGAR 3.0 we used country-specific emission factors for various type of rice production: irrigated, rainfed, deepwater and upland rice, respectively, applied to country-specific rice production data for these types. The emission factors for 1990 are based on a compilation of Neue (1997). We assumed an emission factor improvement in period 1970-1990 based on trend data for Indonesia, the Philippines, Thailand and for China in Van der Gon (1999, 2000), respectively (Table 4.11):

for irrigated rice in other South Asia, East Asia and Southeast Asia we used the multiplication factor of 1.81, which is the weighted average of data for Indonesia (1.83) and the Philippines (1.73); the same value was used for all OECD and EIT regions. For all other LDC regions we used the same multiplication factor of 1.81 as for China.

- for rainfed rice we used the figure of 1.17 for Southeast Asia, which is the weighted average of data for Thailand (1.09) and the Philippines (1.73); the same value was used for all other regions.
- for deep water rice we used the same factors as for irrigated rice.

In this way we included in the methane emissions trend for 1970-1990 the influence of the changing mix of cultivation types as well as of the of rice varieties used and the declining amounts of organic inputs in rice cultivation. The resulting trend of this methodology is shown in Fig. 4.5.

Table 4.11. Trend in emission factors for CH_4 from rice cultivation 1970-1990: assumed emission factor improvement in period 1970-1990 based on country trend data in Denier Van der Gon (1999, 2000) and emission factors for 1990 from Neue (1997) (in kg/ha harvested area).

Rice ecosystem/country	Emission factor 1990	MF*	Emission factor 1970
Irrigated lowland rice			
Global default	295	1.81	534 [1)]
		1.50	442 [2)]
Thailand	480	1.81	869
China	340	1.50	510
Korea, Republic of (South)	330	1.81	597
Indonesia	310	1.83	567
Philippines	270	1.73	467
United States (USA)	250	1.81	452
Rainfed lowland rice			
Global default	161	1.17	188
India	170	1.17	199
Thailand	150	1.17	175
Indonesia	80	1.17	94
Other lowland rice [3)]			
Global default	190	1.00	19

* Multiplication Factor: $EF_{1970} = MF * EF_{1990}$.
1) The three Asian regions and OECD and EIT regions.
2) Other LDC regions.
3) Deep water and tidal land.

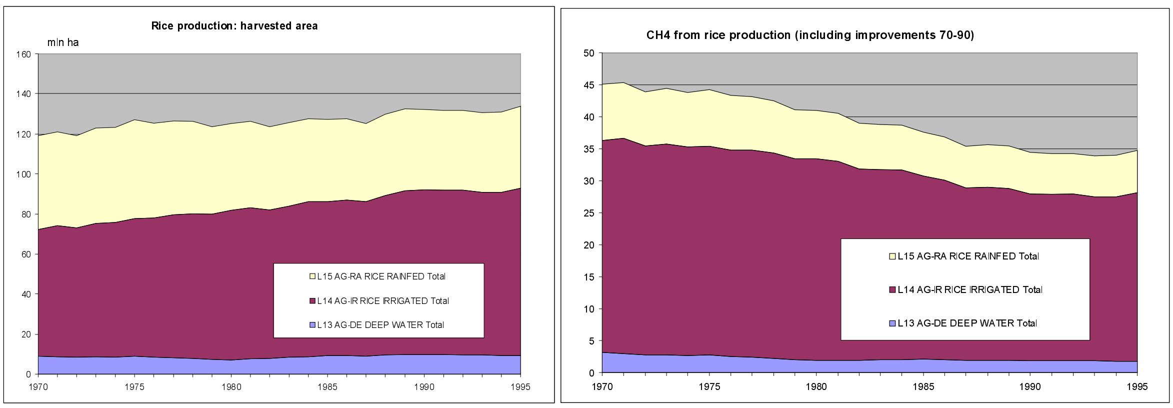


Fig. 4.5.a. Trend 1970-1995 in methane emissions from rice cultivation: by ecosystem.

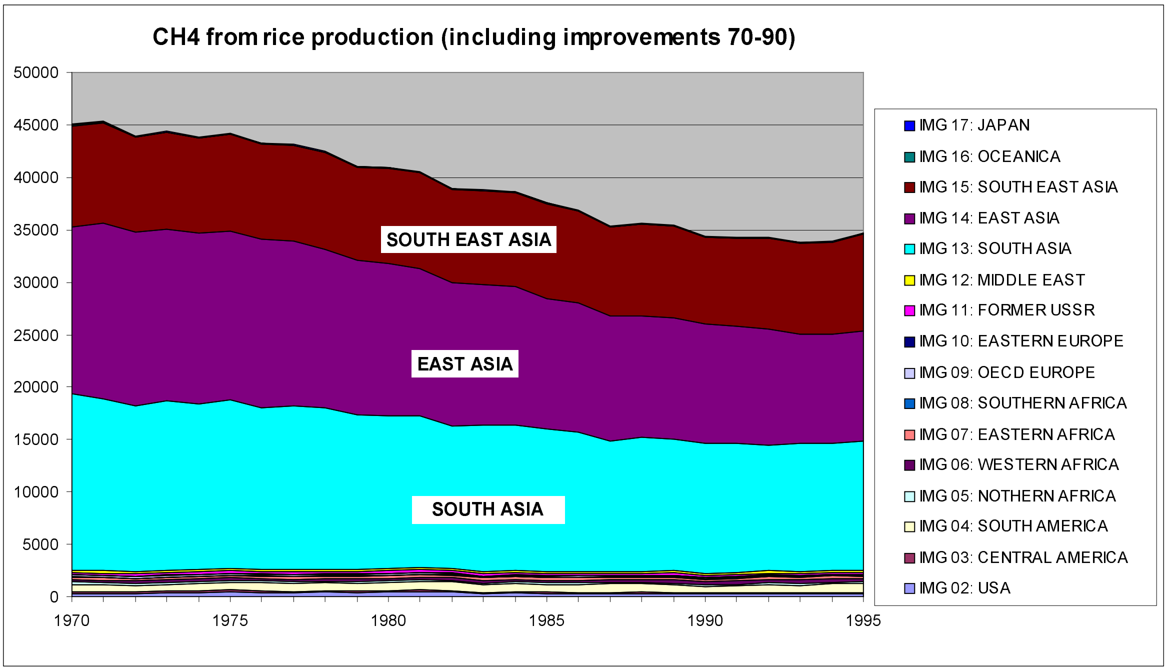


Fig. 4.5.b. Trend 1970-1995 in methane emissions from rice cultivation: by region..

4.2.4.6 Landfills

The methodology used for the calculation of CH_4 emissions from landfills in EDGAR 3.0 is a *first order decay model* resembling the description in the *Revised IPCC Guidelines* of the more complex Tier 2 method, taking into account that the generation of methane from landfills is not an instantaneous process. Thus, the methodology calculates emissions in a specific year as the sum of delayed emissions from all MSW deposited in past years. We use a 40-year integration period, assuming emissions from MSW deposited more than 40 years ago are negligible:

$$\text{Methane generated } G(t) = \sum_{x=1}^{40} D(x) * k * L_0 * N * e^{-k\,(t-x)}$$

where:

$G(t)$ = CH_4 generated in year *t* [Gg/yr]

$D(x) = MSW_{Tot}(t) * MSW_{Fr}(t)$ [Gg/yr]

where:

$MSW_{Tot}(t)$ = Total MSW generated [Gg/yr]

$MSW_{Fr}(t)$ = Fraction of MSW disposed to landfills

k = methane generation rate constant = ln 2 / HL [1/yr]

where HL = Half Life value

L_0 = methane generation potential = $MCF*DOC(t)*DOC_{Fr}*F*16/12$ [Gg CH_4/Gg waste]

where:

MCF = Methane Correction Factor [fraction]

DOC(t) = Fraction of *Degradable Organic Carbon* in MSW [Gg C/Gg waste]

DOC_{Fr} = Fraction of DOC ultimately dissimilated (excl. lignin C); **default 0.77**

F = Fraction of CH_4 in landfill gas; **default 0.55** (IPCC default is 0.5)

N = normalisation factor = $(1 - e^{-k}) / k$; to ensure that the sum years the correct value of the methane generation potential L_0.

For k we use as **defaults k = 0.1, 0.15 and 0.05**, depending on the regions. In practice the value can vary between 0.005-0.4 year. N = 0.95 when using k = 0.21; doubling or halving the k-value gives the range for N of 0.90-0.98 (the extremes mentioned give 0.82-1.00 as range).

To calculate the actual emissions in year *t* the methane generated should be corrected for any amount recovered *R* (e.g. used energetically or flared) and the fraction of methane *OX* that is oxidised in the upper layers of waste and in the site cover material, before it is released to the atmosphere:

$$\text{Emissions } E(t) = [G(t) - R(t)] * (1 - OX)$$

where:

R(t) = Recovered amount of CH_4 [Gg/yr]; **default 0**
OX = Oxidation factor [fraction]; **0 except for OECD'90 and EIT: 0.1** (IPCC default is 0)

Results of this model are presented in Fig. 4.6.

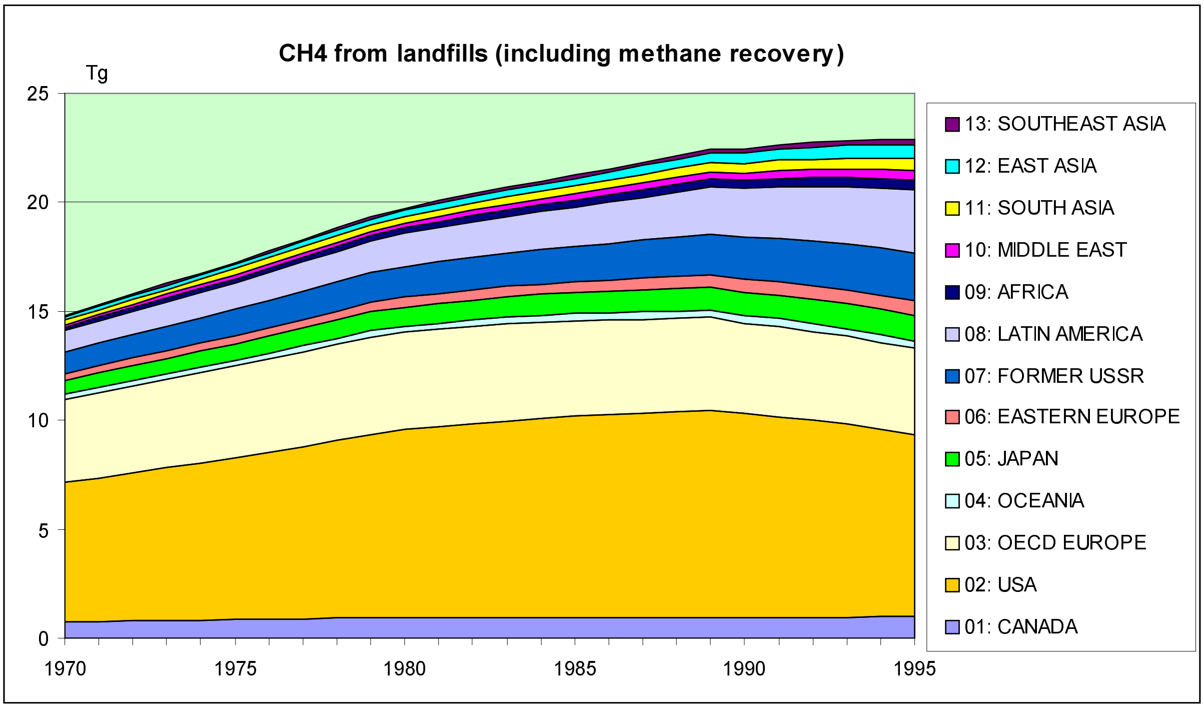


Fig. 4.6. Trend 1970-195 in gross methane emissions from landfills using a first order decay model (including methane recovery).

According to our analysis, global total net landfill emissions increased from 15 to 23 Gg in the 1970-1995 period. This includes the effect of increasing amounts of methane being recovered and combustion for energy purposes or flared, which increased from virtually 0 to 2.5 and 4.3 Gg in 1990 and 1995, respectively (see Table 4.9). Figure 4.6 clearly shows the impact on emissions from the USA in the early '90s. Table 4.12 shows how the amount of waste deposited into landfills has increased over time but started to decrease in the 1990's in the USA and in the countries of the former USSR.

Table 4.12 Amount of waste annually stored in landfills per region 1970-1995 (in Tg)

	1970	1975	1980	1985	1990	1995
01: CANADA	9.2	10.5	11.6	12.6	13.8	14.7
02: USA	82.5	96.9	112.9	117.7	121.3	110.8
03: OECD EUROPE	82.5	88.6	94.4	97.8	104.4	107.8
04: OCEANIA	6.6	7.5	8.0	8.8	9.5	10.5
05: JAPAN	38.6	43.4	48.0	51.8	56.6	58.4
06: EASTERN EUROPE	11.6	13.3	15.1	16.2	16.8	16.8
07: FORMER USSR	31.9	36.9	42.2	46.5	50.9	44.2
08: LATIN AMERICA	30.8	38.9	48.1	54.0	61.4	70.4
09: AFRICA	7.6	9.4	11.6	14.0	17.0	20.2
10: MIDDLE EAST	5.9	7.5	9.0	11.2	13.4	15.4
11: SOUTH ASIA	7.1	8.4	10.1	12.2	14.9	18.2
12: EAST ASIA	10.6	13.2	17.5	24.1	32.7	44.5
13: SOUTHEAST ASIA	3.0	3.9	5.1	6.5	8.5	11.1
Global total	328	378	434	473	521	543

4.2.5 New sources

In EDGAR 3.0 the following new sources have been added:

Coal fires: Unintentional coal fires at shallow coal deposits have been added in EDGAR as an emission source category for China. This source appeared to be considerable and was so far lacking in EDGAR 2.0. Only for China this emission source has been taken into account, although these fires are known also to occur in other countries (e.g. USA, India, Indonesia). Estimates for gridded activity rates have been based on Feng Wang *et al*. (1999). First order emission factors for CO, NO_x, CO_2 and SO_2 were taken from Genderen *et al*. (1997).

Oil fires: The Kuwait oil fires in 1992 due to the Gulf war have been included as separate source.

Wildfires/vegetation fires in non-tropical regions: Recognising the importance of emissions related to biomass burning, forest fires have been added as an emission source category of CH_4, N_2O, CO, NO_x, NMVOC and SO_2. EDGAR 2.0 included only anthropogenic large scale biomass burning in tropical regions such as savanna burning, deforestation and agricultural waste burning activities. At this stage only for Europe, North America, Japan and Oceania forest fire activity levels are included in Version 3 (Fig. 4.7). These are based on the UN/ECE forest fire statistics for 1990 and 1995 (UN/ECE-FAO, 1996). Spatial distribution of activity levels has been made by vegetation type, based on in the distribution of these vegetation types by country. The emission factors used for forest fires are the same factors that are used for other large-scale biomass burning activities.

Waste handling: Recognizing the possible importance of this source category, besides landfills and waste incineration for energy purposes (which are included under energy) as new source of waste emissions we have added: wastewater treatment and domestic waste burning.

The methane emissions from industrial and domestic wastewater treatment are based on studies by Doorn *et al.* (1997; 1999). We estimated the amount of industrial waste water generated for the production of meat, alcohol (methyl and ethyl), raw sugar, pulp and organic chemicals using FAO and UN production statistics and wastewater generation rates by Doorn *et al.* (1997) of 13, 24, 9, 162 and 67 ton/ton, respectively. In addition, we estimated the amount of human wastewater treatment. To estimate the associated CH_4 emissions, region-specific and sometimes country-specific values of amounts of high organic loadings of chemical oxygen demand (COD) and the fraction of wastewater treated anaerobically (TA_c) were used to derive country-specific emission factors. The TA_c values were estimated from country-specific values for septic tanks, latrines, open sewers and wastewater treatment in urban and rural areas following the methodology and assumptions of Doorn *et al.* (1997).

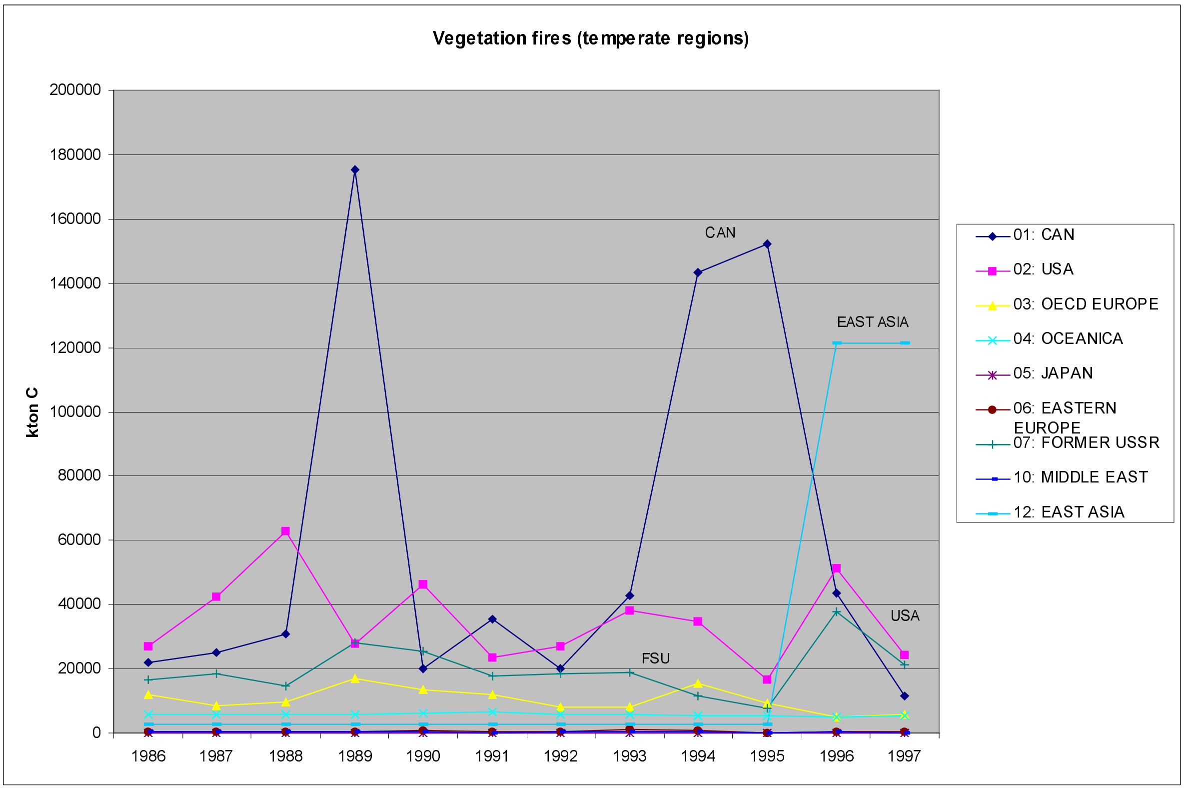


Fig. 4.7. Trend 1985-1995 in vegetation fires in temperate regions. Sources: UN/ECE, FAO.

In addition, several national greenhouse gas inventories reports mention a methane recovery rate of about 75% for their with wastewater treatment plants (WWTPs). Therefore we tentatively assumed a 75% methane recovery for all WWTPs, which amounts to a global total of about 0.6 Tg. The resulting emissions of the new category are presented in Fig. 4.8. According to this dataset, the emissions from waste water treatment and disposal increased from 19 to 33 Tg in the period 1970-1995, with 85% stemming from waste water disposal, i.e. from latrines, septic tanks and open sewers. This leads to the conclusion that landfills and domestic and industrial wastewater disposal (latrines, septic tanks, open sewers, and WWTPs) appear to contribute about the same to global methane emissions.

For domestic waste burning (i.e. by households for non-energetic purposes, just to get rid of the refuse) we tentatively assumed that about 10 kg waste per urban capita is burned per year *by urban households* in less developed countries. This values has been adopted from Gupta *et al.* (1998) who use the assumption that in India about 10 kg/cap is burnt per urban household per year. This is about 5% of total waste generation per household in India. In rural areas of LDC we assume no uncontrolled burning in addition to the agricultural residue burning and biofuel use that is already accounted for in another source category (either all domestic waste is assumed to be dumped or the amount burnt for non-energy purposes is neglected). In contrast, for industrialised countries, we assume that domestic waste burning only occurs in rural areas, where waste incineration regulation is less well controlled. Based on NMVOC data for the USA (Nizich and Pope, 1998) we estimate the amount burned at 250 kg/cap per year for households *in rural areas* of OECD'90 countries, except in Western European countries and Japan, where we assume that this amount is much lower. For these countries, as well as for EIT countries, we tentatively assume a burning rate of 25 kg/cap for rural households per year.

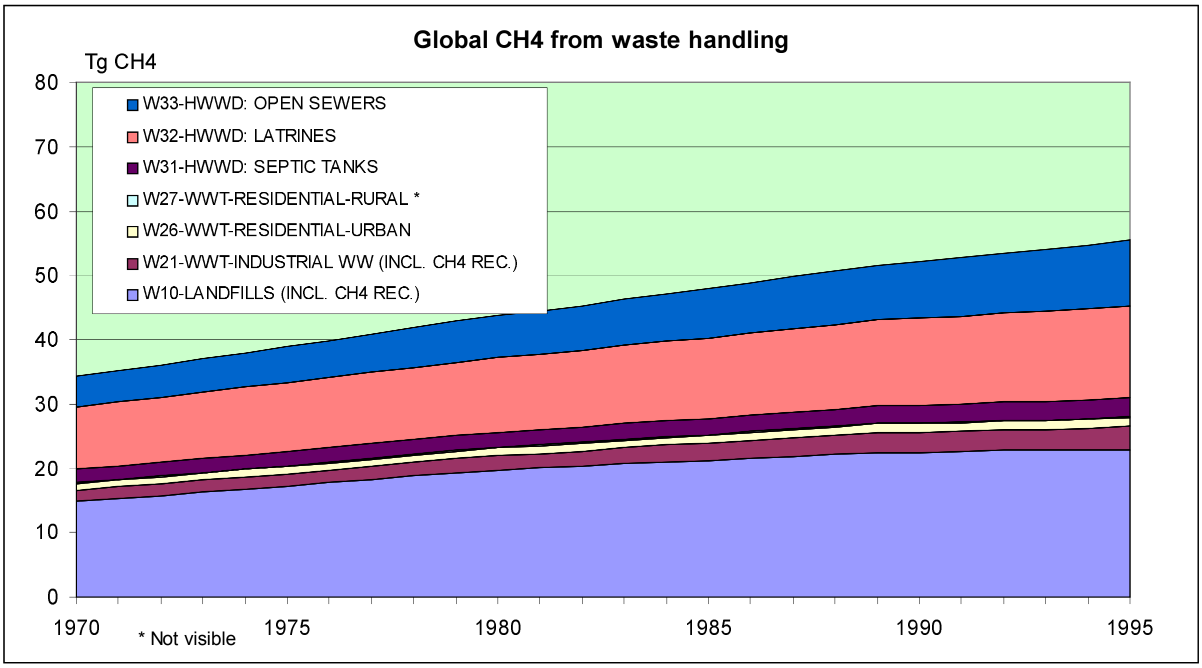


Fig 4.8. Global methane emissions 1970-1995 from domestic and industrial wastewater disposal (latrines, septic tanks, open sewers) and treatment (including methane recovery).

4.2.6 Grid maps

Although no specific effort has been made to improve the current grid maps used for allocating country emissions of specific sources to the 1°x1° grid, the following new maps have been included:

- population distribution, split into urban and rural population, based on a new GEIA total population map (Li, 1998)
- steel production by process type, covering a large part of coal/coke combustion in the industry sector (also used for locating coke ovens)
- cement production
- nitric acid production, by including plant locations of N fertilisers production as surrogate
- aluminium smelters
- rice production in Asia (Denier van der Gon, 2001, pers. communication, and IMAGE rice production maps)
- coal fire map for China and other countries.

4.3 New compounds: NH_3, HFCs, PFCs, SF_6

For updating and extended time series different priorities were given for the following groups of gases:

- direct greenhouse gases CO_2, CH_4, N_2O and new gases HFCs, PFCs, SF_6: 1970-1995;
- ozone precursors CO, NO_x, NMVOC as well as SO_2 and NH_3: update 90 and 95;
- extend CFCs, halons, HCFCs to 1900-1995

Special attention was given to the compilation of a reference dataset for new gases as none was available (Fig. 4.9.a). As illustrated in Fig. 4.9.b, these compound account for 1/3 of all greenhouse gas emissions from industrial process sources in 1995.

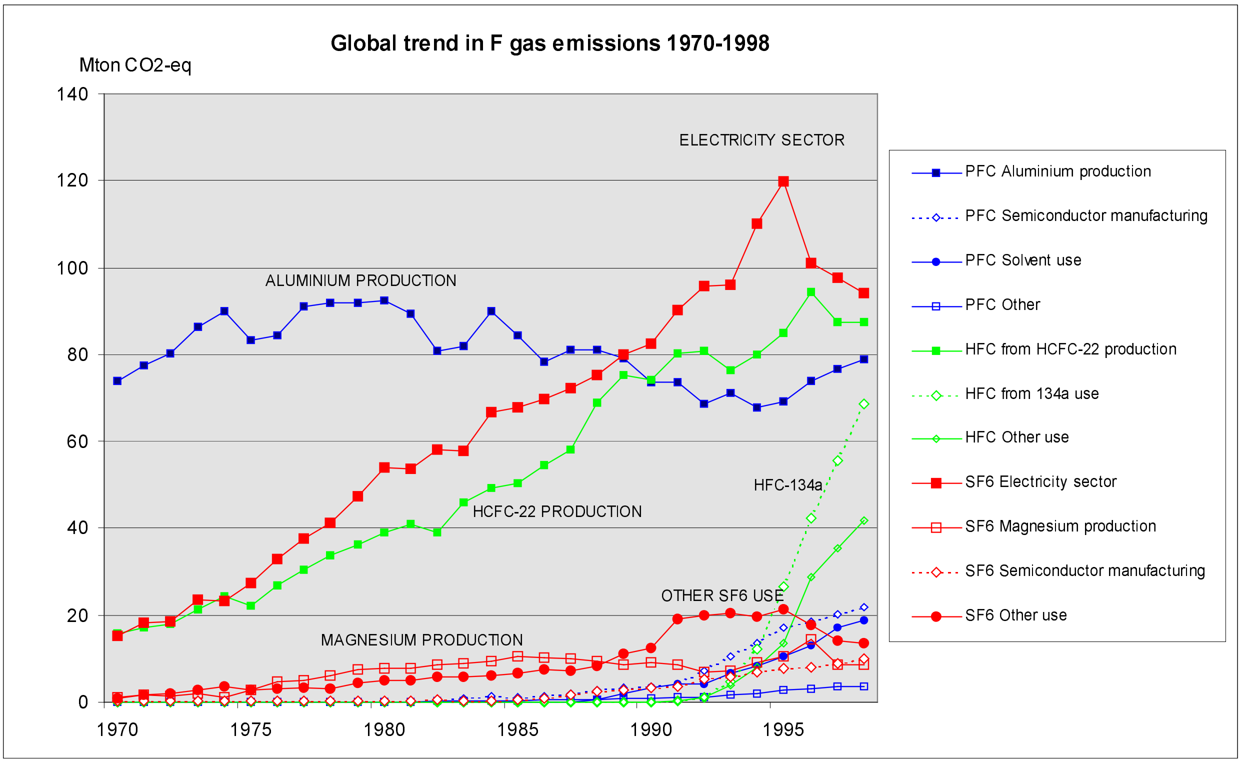


Fig. 4.9.a. Global trend in emissions of HFCs, PFCs and SF_6 1970-1998 per source category (in CO_2-eq.).

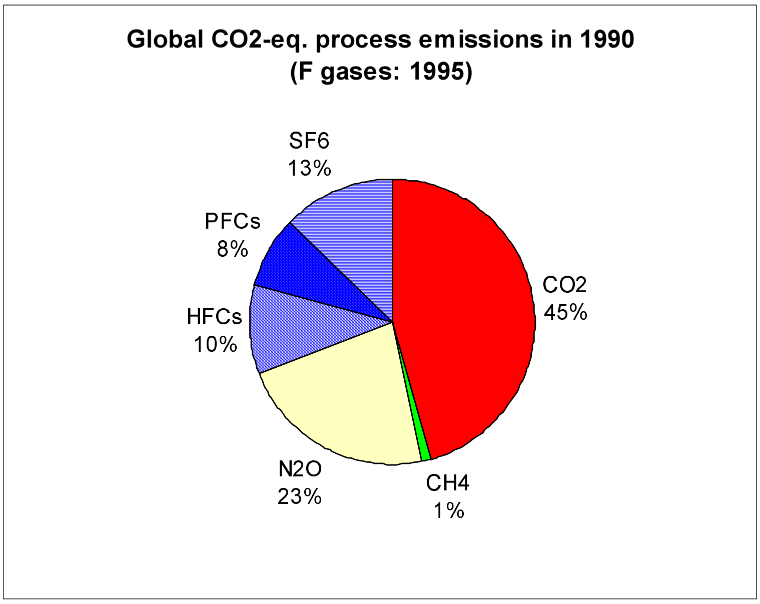


Fig. 4.9.b. Global CO_2-eq. emissions of industrial process sources in 1990 (F gases: 1995).

4.4 Time profiles

Time profiles are distributions to describe the monthly, daily, and sometimes also weekly variation in annual emissions to account for seasonality and diurnal variation as well as the weekly rhythm of working and recreational hours. These are often required for atmospheric modellers as input into their models. In general, likewise increasing spatial resolution from global to regional to country to grid emissions, increasing temporal resolution from annual emissions to monthly to weekly to daily variation also increases the uncertainty in the estimates. Here the distinction can be made between *characteristic* temporal variation which is a kind of 'multi-year average' and temporal variation in a specific time interval, so-called *episodic* variation. From comments by the atmospheric modelling community it appears that for global modelling, at which the global inventories specifically aim, seasonality is the most important time aspect to consider. It depends on the type of model whether they need characteristic of episodic time profiles. It should be stressed, however, that anthropogenic emissions show much less temporal variation compared to natural emissions which are often strongly dependent on weather factors. In Table 4.13 the priority setting for compiling time profiles is summarised per source category in relation with their contribution to total emissions of specific compounds.

Table 4.13 Priorities for sectoral time profiles based on their contribution to emissions of various compounds.

MAIN CATEGORY	DETAILED	PRIORITY	COMPOUND				REMARK
			CO2	CH4	N2O	Other	
Fossil fuel combustion	**Industry**	4	x		x		IRO-coal, culture?
	Power plants	1	x		x		HDD, avail. hydro, CDD in USA
	Other transf. sector						
	Residentials etc.	2a	CO2		N2O		HDD
	Road transport	?	CO2		N2O	x	culture?
	Other land transport						
	Air transport						
	International shipping					SO2	
	Non-energy use						
Fossil fuel production	Coal	5a		CH4			coal?
	Oil	5b	(x)	CH4		(VOC)	main practices oil/gas; demand flow?
	Gas	5c		CH4		(VOC)	main practices oil/gas; demand flow?
Biofuels	Industry						
	Residentials etc.	2b	(x)	CH4	N2O	x	avail. dry woodfuel; avail agr. residues
Industrial processes	Iron&steel		o				culture?
	Non-ferro					SO2	demand flow?
	Chemicals						
	-Adipic Acid	10a			N2O		
	- Nitric Acid	10b			N2O		fertilizer demand flow?
	- NMVOC sources					VOC	
	Cement		(x)				demand flow?
	Glass		o				demand flow?
	Solvents					VOC	
Agriculture	Rice	6		CH4			
	Fertiliser use	9			N2O		
	Animals	7		CH4	N2O		
	Biomass burning	3	CO2		N2O		based on satellite data?
Waste handling	Landfills	8		CH4			
	Incinneration						
	Agric. waste burning						
	Domestic waste burning						
Natural sources	Soils			CH4	N2O	x	
	Vegetation		CO2			VOC	
	Oceans		CO2		N2O		

Within the project, available information on time profiles of anthropogenic sources has been collected and listed, focussing on their monthly variation. Within GEIA, however, a full study of time profiles for all sources is in progress. The presented results of the NRP-MLK project feed into this larger study. In this section the temporal variation of anthropogenic sources is illustrated by a selection of graphs. In Appendix 2 you will find a more detailed summary of the available data.

As a first approximation seasonal variation of anthropogenic emissions may be considered as an uniform distribution, as illustrated in Fig. 4.10 showing the limited monthly variation in global total fossil fuel consumption.

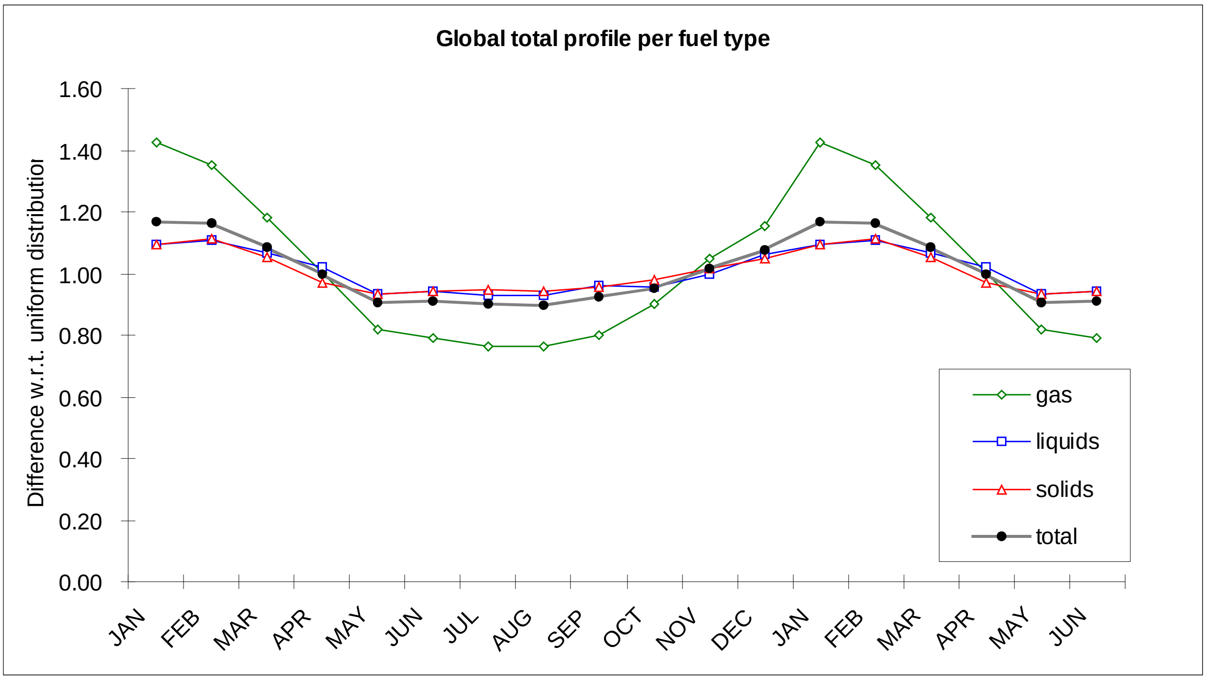


Fig. 4.10. Monthly variation in global total fossil fuel combustion per fuel type. Source: Rotty, 1987.

An clear exception to this rule is biomass burning (see Appendix 2), which is limited to the dry season (deforestation, savanna burning, field burning of agricultural waste). Other climatic, cultural and economic influence contributing to non-uniformity of human activities is:

- space heating, influencing the demand on fuels in the residential and commercial sectors
- space cooling, affecting the demand for electricity in the residential and commercial sectors
- availability of hydropower, influencing the use of fossil fuels or electricity production.
- holiday periods, influencing both road traffic intensity and manufacturing activities
- maintenance periods for large plants relating to favourable periods (e.g. due to holidays, demand drops, weather conditions), influencing the demand for fossil fuels and the activity level of industrial processes
- seasonality of agricultural production, influencing the amount of national and international transport (predominantly road and shipping, respectively)
- car cooling, influencing emissions of CFCs and HFCs from mobile air conditioners.

However, regarding monthly indicator data for specific economic sectors at country level, data are not so easily available, in particular with global coverage. In general one can say that for OECD countries more statistics are available than for non-OECD countries.

In the LOTOS approach (Veldt, 1992) time profiles are based on reasonable, simplified assumptions for key sources (Fig. 4.11).

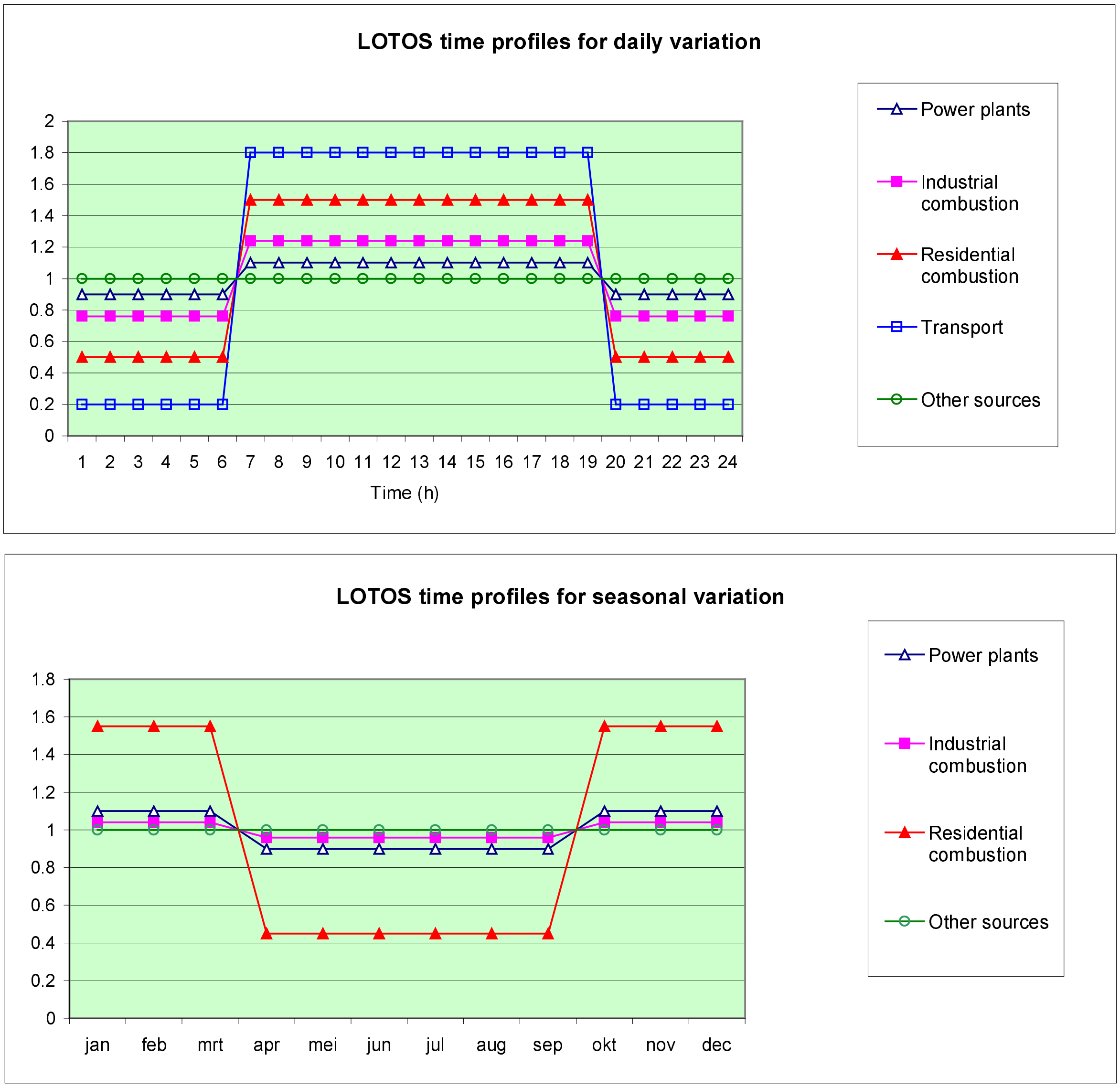
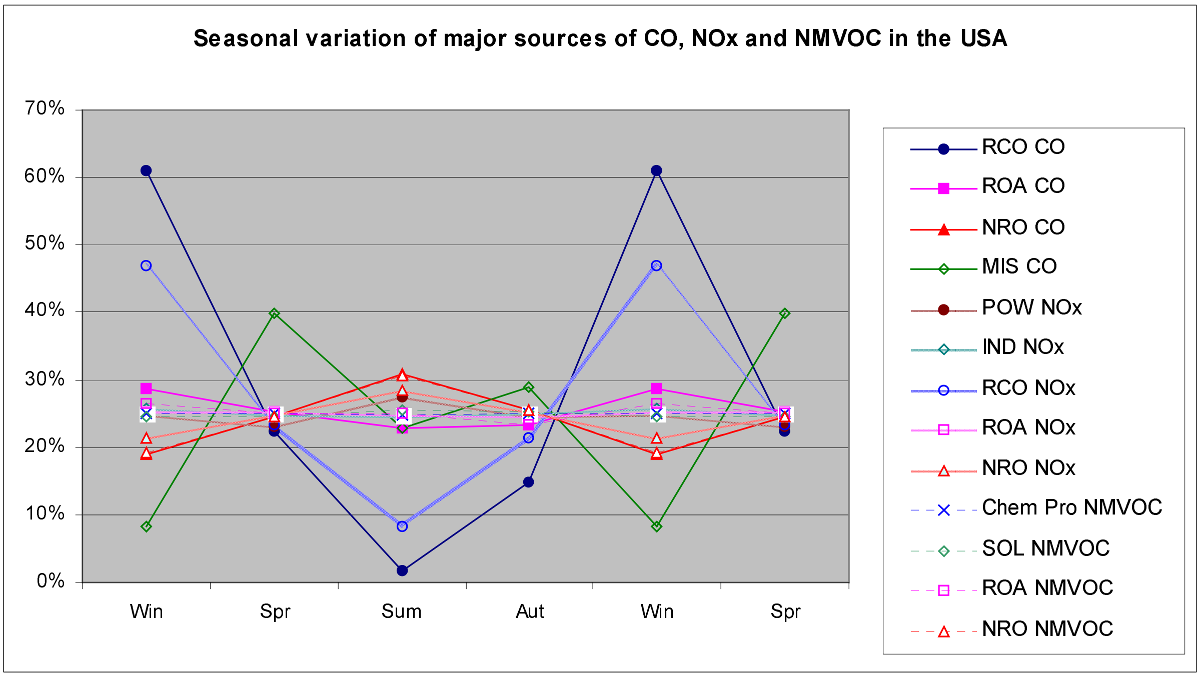


Fig 4.11. LOTOS time profiles for estimating emissions with temporal resolution at monthly and daily level (source: Veldt, 1992).

In the USA, time profiles have been defined and used for estimating quarterly emissions of NAPAP emission inventories (Fig. 4.12). As for Europe, many data sources are available as indicator for monthly variation. Compared to the LOTOS time profiles, the results of the NAPAP study show more variable seasonal profiles, also differing per compound.



Note: RCO = residentials etc.; ROA = Road transport; NRO = Non-road tra sport ; MIS = Miscellaneous; POW = Power generation; IND = Industry; SOL = Solvent use

Fig. 4.12. Seasonal variation of major sources of CO, NOx and NMVOC in the USA. Source: EPA, 1995.

4.5 Results

As examples of the capability of the new version some preliminary results have been presented of the historical trend in global emissions of the new greenhouse gases and of the six gases included in the Kyoto Protocol on the reduction of greenhouse gas emissions in the period 2008-2012 by so-called Annex I countries [OECD and Economies In Transition (EIT)]. These emissions are either based on global total activity data and subsequently allocated to individual countries or based on activity data per country (e.g. aluminium production). Fig. 4.9 showed trends in HFCs, PFCs and SF_6, per application, whereas Fig. 2.1 presented the trend in global CO_2-eq. emissions, by gas and by group of countries. As one of the final products from Version 3.0 we will publish the trend in emissions of all these gases 1990-1995 for all individual countries. Fig. 4.13 presents the trend in methane emissions 1970-1995 based on EDGAR 3.0 data. More information on data sources and methodologies used can be found in Olivier (2001).

Another product of the database are the so-called EDGAR-HYDE V1.0 inventories, which provides gridded and regional emissions of the direct and indirect greenhouse gases included in EDGAR V2.0 for 1990, but now for the whole period 1890-1990 with time steps of 10 year (Van Aardenne, 2001).

The trend features of the new EDGAR inventories are used for the annual Environmental Balance of RIVM as well to calibrate new versions of the emission scenario modules of the IMAGE model. We anticipate that the new EDGAR/GEIA inventories on direct greenhouse gases will be used as scientific reference data sets for comparison of official country data. In addition, the EDGAR software is capable of converting official emission figures per country into gridded emissions which can then be tested or even verified by atmospheric model calculations, provided that there are sufficient atmospheric concentration measurements to compare with. Here too, knowledge of the time profiles of sources is relevant aspect that needs to be considered. Also, EDGAR data may be used as defaults for more spatially detailed GEIA inventories.

A recent application is using EDGAR estimates for evaluating the options for flexible mechanisms (i.e. emission trading) under the UNFCCC (e.g. as part of the Clean Development Mechanism (CDM) or Activities Implemented Jointly (AIJ)), in particular for sources for which reporting by Annex I ('more developed') countries is rather weak, incomplete or not comparable, such as for the F-gases, or for non-Annex I ('less developed') countries, for which often to date no official national inventory exists. This requires the availability of EDGAR data at country level for recent years and at a source level, which is adequate for identifying areas where technology improvement can reduce greenhouse gas emissions substantially. EDGAR 3.0 provides this type of data, both at the website and through collaboration with the International Energy Agency (IEA) (Olivier *et al.,* 2001).

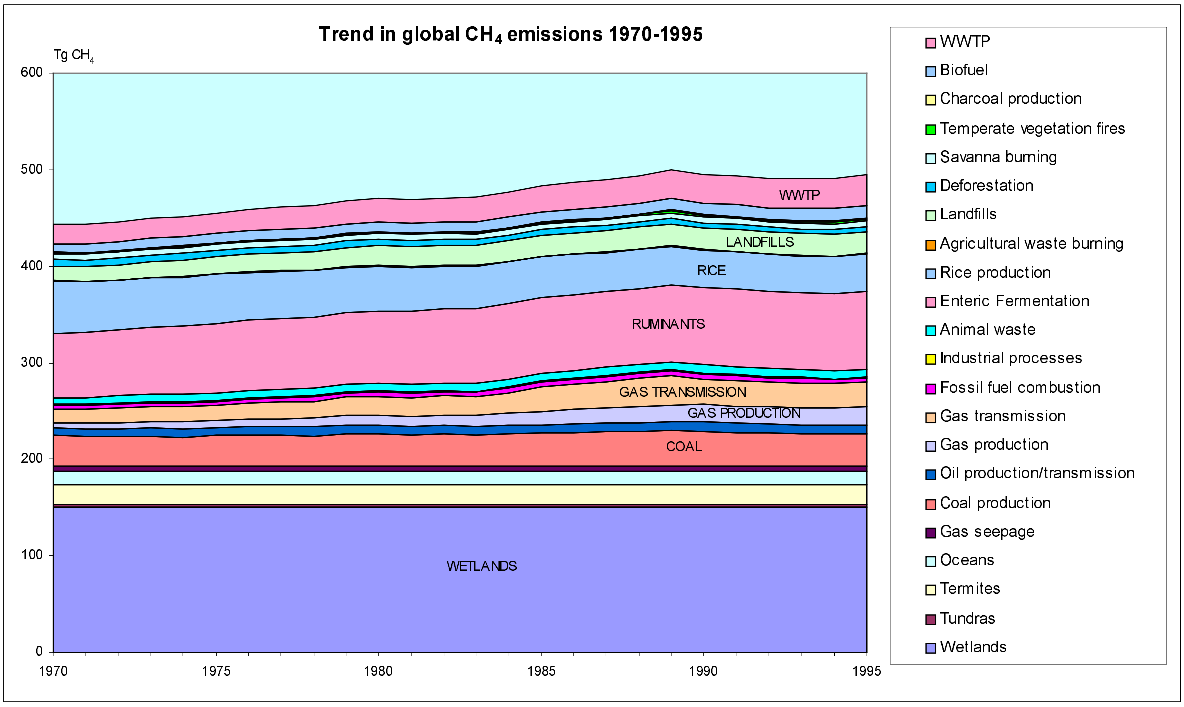


Fig 4.13. Trend 1970-1995 of global methane emissions; natural sources were added at constant levels to illustrate the relative importance compared to total anthropogenic emissions.

5. Conclusions and recommendations

The Emission Database for Global Atmospheric Research (EDGAR) system is able to generate the annual global emissions of the greenhouse gases from anthropogenic both at regional/country and at 1x1 degree grid levels. The finest spatial resolution of the data is $1^o x 1^o$ (with an altitude resolution of 1 km for aircraft emissions), as agreed upon in *the Global Emissions Inventory Activity* (GEIA) of the *International Global Atmospheric Chemistry Programme* (IGAC). EDGAR 2.0 has proven to meet the most pressing requirements of modellers as well as the needs for policy applications; EDGAR 3.0 updates this data to more recent years, includes new sources and provides historical time series for the direct greenhouse gas emissions.

Methodology

The common approach for all countries in source definition, selection of activity data, emission factors and grid maps for 1x1 degree grid distribution of country total emissions of all compounds ensures a global consistency across countries, sources, compounds that cannot be achieved otherwise by concatenation of official national emission inventories, e.g. of ECE/CORINAIR, NAPAP, UNFCCC. Though the latter approach appears to provide the most accurate global emissions as the national inventories were developed by local experts using country-specific datasets, there is also a fair change of bias in emissions of certain countries, when the national inventories have not been intercompared.

Applications of EDGAR 2.0

The number of downloads from the FTP site increased from 50 per quarter in 1997 to nearly 100 in mid-1999. Of the 700 quarterly registered users in the logged 2½ year period, most reside in OECD countries. Most of these are modellers, but EDGAR data are also extensively used for policy applications for which emissions data on country level were calculated with the EDGAR information system.

Validation

An extensive validation of EDGAR 2.0 data for 1990 was performed: for greenhouse gases with National Communications submitted under the *UN Framework Convention on Climate Change* (UNFCCC) and for other gases with data from CORINAIR, GEIA and others. In addition, inventories in National Communications were checked for the use of different emission factors for 1990 and 1995 in order to select sources and gases for which specific emission factors for 1995 in EDGAR V3.0 need to be determined. In addition, for CO_2, NO_x and SO_2 a comparison was made with the present GEIA inventories, both on grid and per country. Conclusions were drawn regarding the apparent uncertainty in international statistics, on emission factors, missing sources and on apparent strong emission trends in specific regions/sources.

EDGAR 3.0 data

The largest differences with EDGAR 2.0 emissions are in the following sources:

- wastewater treatment has been added, which is a substantial source of CH_4;
- indirect emissions of N_2O from agriculture have been added;
- agricultural waste burning emissions have been decreased substantially, in particular for CO;
- temperate forest fires show considerable emissions, though highly variable between years;
- NMVOC from domestic waste burning, in 2.0 called uncontrolled waste burning have decreased substantially;
- fossil fuel fires have been added, increasing fuel-related emissions in China considerably;

NO_x from international shipping has increased substantially;
the spatial distribution of sources allocated with the population maps has changed substantially, due to the introduction of another base map and applying urban and rural maps where appropriate;
the use of other vegetation maps for allocating deforestation and savannah burning on the grid.

The 1990 emissions have not only changed due to updates of emission factors, but also since international statistics of activity data of the most recent years tend to change during a couple of years after the first compilation. This happens in particular in non-OECD countries, however, also in industrialised countries this phenomenon can be observed, although in these countries the changes are often only minor. In addition, data for the former USSR have become rather weak due to inconsistencies between the sum of the new countries and the 1990 data for the former USSR.

The new inventory data will be available through anonymous FTP as well as the EDGAR website, both as grid files on 1x1 degree as well as per country.

Uncertainty and seasonal variation

Further studies of uncertainty estimates is recommended, but is intrinsically getting more difficult when zooming in at smaller spatial and temporal scales (e.g. 1x1 degree grid cells and monthly emissions). Conceptually, here a distinction should be made between 'representative' emissions at these scales and 'episodic' datasets trying to include very detailed time-dependent features. Examples are actual economic activities such as temporary, unplanned shutdowns of production facilities, temporary malfunction of emission control equipment, weather conditions that may differ from the average pattern, etc. In this report summary description is given of the state of the art of knowledge at the global level of uncertainty in emissions and in available time profiles for seasonal variation of emission sources. A lot of material is available, but requires a great deal of effort to compile representative seasonal time profiles for all regions/individual countries of the world. The importance of this issue, which is pivotal information for connecting bottom-up emission estimates with inverse modelling results of atmospheric models that use atmospheric concentration measurements. Further study of these topics is embedded in the GEIA work, in which RIVM and TNO participate.

The Future

For greenhouse gases a possible future direction for the EDGAR system could be that, in co-operation with other international and regional organisations, the database is maintained for the purpose of reference EDGAR/GEIA datasets to the official country submissions. In addition, linking official country data with atmospheric models through the conversion to the grid could be done as part of the interaction between bottom-up and top-down evaluation of annual budgets as well as the trend in them. Confronting bottom-up emission inventories and top-down calculations using concentration measurements require global coverage and spatial resolutions at grid level, for which the EDGAR system is specifically designed. For the other gases the system could play a similar role.

Acknowledgements

Constructing these global emission inventories would not have been possible without the funding and co-operation of many individuals and organisations. Besides the funding by the Dutch *National Research Programme on Global Air Pollution and Climate Change,* project no. 954222, and the POET project of the Fifth Framework Programme of the European Union, no. EVK2-1999-00011, we would like to mention the Dutch *Ministry of Housing, Spatial Planning and the Environment* (VROM) for funding. This work is also part of the *International Geosphere-Biosphere Programme* (IGBP) and its *International Global Atmospheric Chemistry Programme* (IGAC), in particular the *Global Emissions Inventory Activity* (GEIA), a component of IGAC. We greatly appreciate the co-operation with various GEIA Study Groups and other persons and organisations as well as the interest in the datasets received from the IGAC modelling community at large.

References

Van Aardenne, J.A., Dentener, F.J., Olivier, J.G.J., Klein Goldewijk, C.G.M. and J. Lelieveld (2001) A High Resolution Dataset of Historical Anthropogenic Trace Gas Emissions for the Period 1890-1990. *Global Biogeochemical Cycles,* **15(4),** 909-928.

Adler, M.J. (1994) International anthropogenic methane emissions: estimates for 1990. EPA, Washington, DC (USA), EPA report no. 230-R-93-010, January 1994.

AEPA, [Australian Environment Protection Authority] (1992) Personal correspondence with F. Carnovale, 1992.

Amstel, A.R. van, Kroeze, C., Janssen, L.H.J.M., Olivier, J.G.J. and J. Van der Wal (1997a) Greenhouse Gas Accounting. Preliminary study as Dutch input to a joint International IPCC Expert Meeting/CKO-CCB Workshop on Comparison of Top-down versus Bottom-up Emission Estimates. WIMEK report / RIVM report nr. 728001 002. RIVM, Bilthoven.

Amstel, A.R. van, J.G.J. Olivier, L.H.J.M. Janssen and J.J.M. Berdowski (1997b) Comparison of bottom-up inventories, methane as an example. Discussion paper for the IPCC Expert Meeting on Methods for Assessment of Inventory Data Quality, Bilthoven, the Netherlands, November 5-7 1997.

Amstel, A.R. van, J.G.J. Olivier, L.H.J.M. Janssen (1999a) Analysis of differences between national inventories and an Emissions Database for Global Atmospheric Research (EDGAR). *Environmental Science & Policy*, 2, 275-294.

Amstel, A.R. van, L.H.J.M. Janssen, J.G.J. Olivier (1999b) Greenhouse gas emission accounting. Paper presented at *Second Symposium on Non-CO_2 Greenhouse Gases*, Noordwijkerhout, the Netherlands, 8-10 September 1999.

Amstel, A.R. van, Kroeze, C., Janssen, L.H.J.M. and J.G.J. Olivier (1999c) Greenhouse Gas Accounting 2. Update including Second National Communications. WIMEK report / RIVM report no. 773201 001. RIVM, Bilthoven.

Andreae, M. O. and P. Merlet (2001) Emission of trace gases and aerosols from biomass burning, *Global Biogeochemical Cycles*, **15**, 2001, 955-966.

Assekmann, I. and P.J. Crutzen (1989) Global distribution of natural freshwater wetlands and rice paddies, their net primary productivity, seasonality and possible methane emissions. *J. Atmos. Chem.*, **8**, 307-385.

Barbosa, P.M., Stroppiana, D., Grégoire, J.-M. and J.M.C. Pereira (1999) An assessment of vegetation fire in Africa (1981-1991): Burned areas, burned biomass, and atmospheric emissions. *Global Biogeochemical Cycles*, **13,** 933-950.

Benkovitz, C.M., M.T. Scholtz, J. Pacyna, L. Tarrason, J. Dignon, E.C. Voldner, P.A. Spiro, J.A. Logan and T.E. Graedel (1996) Global gridded inventories of anthropogenic emissions of sulfur and nitrogen, *J. Geophys. Res.,* **101**, 29239-29253.

Benkovitz, C. M., Berdowski, J. J. M., Mubaraki, M. A., and Olivier, J. G. J. (1997) Global anthropogenic sulfur emissions for 1985 and 1990. In*: Assessing Historical Global Sulfur Emission Patterns for the Period 1850-1990*, Appendix A, Report DE96-014790, U.S. Department of Energy, Washington, DC. [BNL 64596]

Benkovitz, C. M., Berdowski, J. J. M., Mubaraki, M. A., and Olivier, J. G. J. (1997) Sulfur emissions from volcanic activity. In*: Assessing Historical Global Sulfur Emission Patterns for the Period 1850-1990*, Appendix C, Report DE96-014790, U.S. Department of Energy, Washington, DC. [BNL 64597]

Berdowski, J., Olivier, J., and C. Veldt (1993) Methane from fuel combustion and industrial processes. In: A.R. van Amstel (1993) Proceedings of workshop on methane and nitrous oxide, Amersfoort, 3-5 February 1993.

Berdowski, J.J.M., Draaijers, G.P.J., Hulskotte, J.H.J., Oonk, J., Teeuwisse, S.T., Visschedijk, A.J.H., Corré, W. & M. Vosbeek (1999). Description of a detailed CH_4 emission database for the Netherlands and Northwest Europe. TNO MEP report (draft version), Apeldoorn, The Netherlands.

Berdowski, J.J.M., G.P.J. Draaijers, L.H.J.M. Janssen, J.C.Th. Hollander, M. van Loon, M.G.M. Roemer, A.T. Vermeulen, M. Vosbeek and H. Visser (1998). Independent Checks for Validation of Emission Estimates: The METDAT Example for Methane. Meeting of the IPCC/OECD/IEA Programme for National Greenhouse Gas Inventories on 'Managing Uncertainty in National Greenhouse Gas Inventories', Paris, 13-15 October 1998. TNO Publication P98/037, Apeldoorn, The Netherlands.

Berdowski, J.J.M., G.P.J. Draaijers, L.H.J.M. Janssen, J.C.Th. Hollander, M. van Loon, M.G.M. Roemer, A.T. Vermeulen, M. Vosbeek, H. Visser (1998). Independent Checks for validation of CH_4 emission estimates. In: Proceedings of the first NRP-II Symposium on Climate Change Research, Garderen, The Netherlands, 29-30 October 1998, pp. 87-96. TNO-Publication P98/039, Apeldoorn, The Netherlands.

Beurden, A.U.C.J. Van, and W.J.A.M. Douven (1999) Aggregation issues of spatial information in environmental research. *Int. J. of Geographical Information Science*, **13:5**, 513-527.

Bouscaren, R. (1990) Inventaire des Emissions de Polluants dans L'Atmosphere dans La Communate Europeenne en 1985, CITEPA, 1990. Carnovale, F., P. Alviano, C. Carvalho, G. Deitch, S. Jiang, D. Macaulay and M. Summers, Air Emissions Inventory for the Port Phillip Control Region, *Clean Air*, **26**, 134-144.

Bouwman, A.F., Van Der Hoek K.W., and Olivier J.G.J. (1995) Uncertainties in the global source distribution of nitrous oxide. *J. Geophys. Res.* **100**, 2785-2800

Bouwman, A.F., Lee, D.S., Asman, W.A.H., Dentener, F.J., Van Der Hoek, K.W. and J.G.J. Olivier (1997) A Global High-Resolution Emission Inventory for Ammonia, *Global Biogeochemical Cycles* **11:4** 561-587.

Braatz, B.V., B.P. Jallow, S. Molnar, D. Murdiyarso, M. Perdomo and J. Fitzgerald, (eds.) (1996) Greenhouse Gas Emission Inventories. Interim Results from the US Country Studies Program. Kluwer Academic Publishers. Dordrecht, Boston, London.

Brocard, D., Lacaux, C. and J.-P. Lacaux (1996) Emission from the combustion of biofuels in western Africa. In: J.S. Levine (ed.) (1996) Biomass burning and global change, MIT Press, Cambridge, Mass.

Cao, M., Gregson, K., Marshall, S., Dent, J.B. and O.W. Heal (1996) Global methane emissions from rice paddies. *Chemosphere*, **33**, 879-897.

Carnovale, F., P. Alviano, C. Carvalho, G. Dietch, S. Jiang, D. Macaulay and M. Summers (1992) Air Emissions Inventory for the Port Phillip Control Region. *Clean Air*, **26,** 134-144.

Castellan, A., Bart, J.C.J. and Cavallero, S. (1991) Industrial production and use of adipic acid. *Catalysts Today* **9**, 237-254.

Choe, J.S., Cook, P.J. and F.P. Petrocelli (1993) Developing N_2O abatement technology for the nitric acid industry. Paper presented at the *1993 ANPSG Conference*. Air Products and Chemicals Inc., Allentown, PA, USA.

Clark, J. I. and D. W. Rhind (1992). *Human Dimensions of Global Environmental Change*. Programme Report 3. International Social Science Council, Programme on Human Dimensions of Global Environment Change, UNESCO, Paris.

Cofala, J., and S. Syri (1998a) Nitrogen Oxide emissions, abatement technologies and related costs in the RAINS model database, Interim Report, International Institute for Applied System Analysis (IIASA), Laxenburg, Austria, Report no. IR-98-88/October.

Cofala, J. and S. Syri (1998b) Sulphur emissions, abatement technologies and related costs in the RAINS model database, Interim Report, International Institute for Applied System Analysis (IIASA), Laxenburg, Austria, Report no. IR-98-035/June.

Corbett, J.J. and P. Fischbeck (1997) Emissions from ships. *Science*, **278**, 823-824.

Corbett, J.J., P.S. Fischbeck and S.N. Pandis (1999) Global nitrogen and sulfur emissions for oceangoing ships. *J. Geophys. Res.*, **104:D3**, 3457-3470.

Delmas, R. (1993) An overview of present knowledge on methane emission from biomass burning. In: A.R. van Amstel (1993) Proceedings of workshop on methane and nitrous oxide, Amersfoort, 3-5 February 1993.

Delmas, R., Lacaux, J.P. and D. Brocard (1995) Determination of biomass burning emission factors: methods and results. Env. Mon. and Assessment 38, 181-204.

Denier van der Gon, H. (1999) Changes in CH_4 emission from rice fields from 1960 to 1990s 2. The declining use of organic inputs in rice farming. *Global Biogeochemical Cycles,* **13**, 1053-1062.

Denier van der Gon, H. (2000) Changes in CH_4 emission from rice fields from 1960 to 1990s 1. Impacts of modern rice technology. *Global Biogeochemical Cycles,* **14**, 61-72.

Dignon, J. (1992) NO_x and SO_x Emissions from Fossil Fuels: A Global Distribution, *Atmos. Environ*., **26A**, 1157-1163.

Doorn, M.R.J., Strait, R.P., Barnard, W.R. and B. Eklund (1997). Estimates of global greenhouse gas emissions from industrial and domestic waste water treatment. Report no. NRMRL-RTP-086. R 8/18/97. Pechan & Ass., Durham.

Doorn, M.J. and D.S. Liles (1999) Quantification of methane emissions and discussion of nitrous oxide, and ammonia emissions from septic tanks, latrines, and stagnant open sewers in the world. EPA, Washington DC, USA. EPA report EPA-600/R-99-089, October 1999.

Draaijers, G.P.J., J.J.M. Berdowski, G.C. Ypenburg, A.J.H. Visschedijk, J.H.J. Hulskotte, M. Roemer and M. van Loon (1998). Overview of greenhouse gas emission databases and validation activities in the Netherlands, EU Concerted action workshop on Biogenic emissions of greenhouse gases caused by arable and animal agriculture, Lökeberg, Sweden, July 9-10, 1998.

Dwyer, E., Pinnock, S., Grégoire, J.-M. and J.M.C. Pereira (2000) Global spatial and temporal distribution of vegetation fires determined from satellite observations, *Int. J. Remote Sensing*, **21**, 1289-1302.

EEA (1999). Environment in the European Union at the turn of the century, Chapter 3.1, Greenhouse gases and climate change (pp. 79-98). ISBN 92-9157-202-0, Copenhagen, Denmark.

EEA (2000) Environmental signals 2000. European Environment Agency regular indicator report. EEA, Copenhagen. Report no. 6.

Ellegard, A. and H. Egneus (1992) Health effects of charcoal and woodfuel use in low-income households in Lusaka, Zambia. Sockholm Environment Institute (SEI), EEDS No.14. ISBN 91 88116 51 4.

EMEP-CORINAIR (1999) Joint EMEP/CORNAIR Atmospheric Emission Inventory Guidebook. Second Ed.; S. Richardson (ed.) EEA, Copenhagen.

Elzen, M. den, Berk, M., Schaeffer, M., Olivier, J., Hendriks, C., Metz, B. (1999) The Brazilian Proposal and other Options for International Burden Sharing: an evaluation of methodological and policy aspects using the FAIR model. RIVM-report no. 728001011. October 1999, NOP-MLK, Bilthoven. 125 pp.

ERI-UC [Energy Research Institute] (1993) Personal correspondence with R.K. Dutkiewicz.

FAO (1993) Forest resources assessment 1990; Tropical countries. FAO, Rome. Report FP-112.

FAO (1995) Forest resources assessment 1990; Global analysis. FAO, Rome. Report FP 124.

FAO (1998) State of the Worlds Forests 1997. FAO, Rome.

FAO (1998b) FAOSTAT Forestry Data. Data downloaded from www.apps.fao.org on 12-3-1998.

Feng Wang, Z. Vekerdy and J.L. van Genderen (1999) Database management and implementation for coal fire detection and monitoring in the Rujigou coalfield, Northwest China. printed from: *Proceedings of the 2nd international conference on operationalisation of remote sensing, August 16-20, 1999*. ITC, Enschede.

Finn, J.T. (1993) Use of the average mutual information indix in evaluating classification error and uncertainty. *International J. of Geographical Information Systems*, **7**, 349-366.

Genderen, J.L. Van, and Guan Haiyan (1997) Environmental monitoring of spontaneous combustion in the North China coalfields. Final report to the European Commission. ITC, Enschede. ISBN 90-6164-152-7.

Gupta, S., K. Mohan, R. Prasad, S. Gupta and A. Kansal (1998) Solid waste management in India: options and opportunities. *Conservation and Recycling* **24**, 137-154.

Hall D.O., Rosillo-Calle F. and Woods J. (1994) Biomass utilization in households and industry: energy use and development, *Chemosphere* **29**, 1099-1119.

Ham, J. van, J.J.M. Berdowski, A.H.M. Versteeg, A.J.H. Visschedijk and P.Y.J. Zandveld (1996) CO2 -emissions in China; Breakdown into provinces and economic sectors, TNO-MEP - R 96/130, TNO Institute of Environmental Sciences, Energy Research and Process Innovation, Apeldoorn, The Netherlands, 1996.

Hao, W.M., and M.-H. Liu, Spatial and temporal distribution of tropical biomass burning, *Global Biogeochemical Cycles* **8**, 495-503, 1994.

Heimann, M. (1992) Modelling temporal resolution of emissions in GENEMIS. In: Proceedings of *the Global Emission Inventory Activity (GEIA) Workshop*, Lilleström, Norway, 22-24 June 1992.

Heimann, M. (1994) Description and recent activity of GENEMIS. In: G. McInnes, J.M. Pacyna, H. Dovland (eds.), Proceedings of the *first meeting of the EMEP Task Force in Emission Inventories*, London, UK, 5-7 May 1992. EMEP/CCC report 8/93, p. 281-292.

Hobbs, P.V, Reid, J.S., Herring, J.A., Nance, J.D., Weiss, R.E., Ross, J.L., Hegg, D.E., Ottmar, R.D. and C. Liousse (1996) Particle and trace-gas measurements in the smoke of prescribed burns of forest products in the Pacific Nortwast. In: J.S. Levine (ed.) (1996) *Biomass burning and global change*, MIT Press, Cambridge, MA, USA.

Houweling, S., F. Dentener, J. Lelieveld, B. Walter and E. Duglokencky (2000) The modeling of tropospheric methane: How well can point measurements be reproduced by a global model?, *Journal of Geophysical Research*, **105:D7**, 8981-9002.

IEA (1997) *Beyond 20/20, Release 4.1, Energy Balances of OECD Countries, Energy Balances of NON-OECD Countries.* Ivation DatasystemsInc. 1997.

IPCC (1995) *Climate Change 1994. Radiative forcing of Climate Change*. Cambridge University Press.

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

IPCC (2000) Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, IPCC-TSU NGGIP, Japan.

Janssen, L.J.H.M., P. van Velthoven, F. Dentener and A.R. van Amstel (eds.), 1997: Proceedings of the CKO/CCB Workshop on Bottom-up and Top-down Emission Estimates of Greenhouse Gases in Bilthoven on 27-6-1997. CCB/CKO/RIVM report 728001006. Bilthoven, The Netherlands.

Janssen, L.H.J.M., J.G.J. Olivier, A.R. van Amstel (1997) A comparison of bottom-up and top-down methane emission inventories. Discussion paper for the IPCC Expert Meeting on Methods for Assessment of Inventory Data Quality, Bilthoven, The Netherlands, November 5-7 1997.

Janssen, L.H.J.M., J.G.J. Olivier, A.R. van Amstel (1999) Comparison of CH_4 emission inventory data and emission estimates form atmospheric transport models and concentration measurements. *Environmental Science & Policy*, **2,** 295-314.

Joshi, V., Venkataraman, C. and D.R. Ahuja (1989) Emissions from burning biofuels in metal cookstoves. Env. Management 13:6, 763-772.

Kato, N. and H. Akimoto (1992) Anthropogenic Emissions of SO_2 and NO_x in Asia: Emissions Inventories (plus errata), *Atmos. Environ.,* 2**6A**, 2997-3017

Kroeze, C. (1994) Nitrous oxide (N_2O). Emission inventory and options for control in the Netherlands. RIVM, Bilthoven. Report no. 773001 004.

Lawrence, M.G., Crutzen, P.J., Rasch, P.J., Eaton, B.E., and N.M. Mahowald (1999a) A model for studies of tropospheric photochemistry: description, global distributions, and evaluation. *J. Geophys. Res.*, **104:D21,** 26245-26277.

Lawrence, M.G. and P.J. Crutzen (1999b) Influence of NO_x emissions from ships on tropospheric photochemistry and climate, *Nature*, **402**, 167-170.

Lee, D.S. and D.H.F. Atkins (1994) Atmospheric ammonia emissions from agricultural waste combustion. *Geophys. Res. Lett.,* **21**, 281-284.

Lee D.S., Köhler I., Grobler, E., Rohrer F., Sausen, R., Gallardo-Klenner L., Olivier J.G.J., Dentener F. J. and Bouwman A. F. (1997) Estimations of global NOx emissions and their uncertainties. *Atmospheric Environment* **31:12** 1735-1749.

Li, Y.-F. (1996) Global Population Distribution Database. A Report to UNEP. UNEP Sub-Project no. FP/1205-95-12, March 1996. Also described in: Li, Y. F., McMillan, A., and Scholtz, M. T. (1996) Global HCH usage with 1 degree x 1 degree longitude/latitude resolution. *Environmental Science & Technology*, **30**, 3525-3533.

Lim, B., Boileau, P., Bonduki, Y., Van Amstel, A.R., Janssen, L.H.J.M., Olivier, J.G.J. and C. Kroeze (1999) Improving the quality of national greenhouse gas inventories. *Environmental Science & Policy*, **2,** 335-346.

Lloyd, S.M.. (1993) South African Department of Health and Population Development, personal communication.

Marland, C., Boden, T.A., Brenkert, A., Andres, R.J. and J.G.J. Olivier (1998) CO_2 from Fossil Fuel Burning: Updates on the Magnitude, Distribution and Uncertainty of Emissions Estimates. *Proceedings of the 5th International Carbon Dioxide Conference*, Cairns (AUS), 8-12 September 1997. Forthcoming.

Marland, G., A. Brenkert, J.G.J. Olivier (1999) CO_2 from fossil fuel burning: a comparison of ORNL and EDGAR estimates of national emissions. *Environmental Science & Policy*, **2,** 265-274.

Mayer, M., Hyman, R., Harnisch, J., and J. Reilly (2000) *Emissions Inventories and Time Trends for Greenhouse Gases and other Pollutants.* Technical Note No. 1, July 2000. MIT Joint Program on the Science and Policy of Global Change, Cambridge MA, USA.

Mitra, A.P., and S. Bhattacharya (1998) Greenhouse Gas Emissions in India for the base year 1990 using IPCC standard methodology. Scientific Report 11, Centre on Global Change, National Physical Laboratory, New Delhi.

Neue, H.U. (1997) Fluxes of methane from rice fields and potential for mitigation. *Soil Use and Management*, **13**, 258-267.

NGCIA (2000) *Gridded Population of the World (GPW) data set*. Initial data set, GPW version 1, was produced by W. Tobler, U. Deichmann, J. Gottsegen, and K. Maloy of the National Center for Geographic Information and Analysis (NCGIA). This data set has been superceded by version 2, available at http://sedac.ciesin.org/plue/gpw: *Gridded Population of the World (GPW), Version 2*. Center for International Earth Science Information Network (CIESIN), Columbia University; International Food Policy Research Institute (IFPRI); and World Resources Institute (WRI). Palisades, NY: CIESIN, Columbia University.

Nizich, S.V. and A. Pope (1998) National air pollutant emission trends update 1970-1997. USEPA, Washington. Report no. EPA-454/E-98-007.

Olivier, J.G.J. (1995) Scenarios for global emissions from air traffic. The development of regional and gridded (5^ox5^o) emissions scenarios for aircraft and for surface sources, based on CPB scenarios and existing emission inventories for aircraft and surface sources. RIVM report no. 773002 003. RIVM, Bilthoven.

Olivier, J.G.J., Bouwman, A.F., Van der Maas, C.W.M., Berdowski, J.J.M., Veldt, C., Bloos, J.P.J., Visschedijk, A.J.H., Zandveld, P.Y.J. and Haverlag, J.L. (1996) Description of EDGAR Version 2.0: A set of global emission inventories of greenhouse gases and ozone depleting substances for all anthropogenic and most natural sources on a per country basis and on 1°x1° grid. RIVM, Bilthoven, December 1996. RIVM report nr. 771060 002 / TNO-MEP report nr. R96/119.

Olivier, J.G.J. and A.F. Bouwman (1997) A global sectoral emission inventory of N_2O and comparison with atmospheric observations. Paper presented at *CKO/CCB Workshop "Comparison of Bottom-Up and Top-Down emission inventories of greenhouse gases",* RIVM, Bilthoven, 27 June 1997.

Olivier, J.G.J., A.F. Bouwman, K.W. van der Hoek and J.J.M. Berdowski (1998) Global Air Emission Inventories for Anthropogenic Sources of NO_x, NH_3 and N_2O in 1990. *Env. Poll*. **102,** 135-148.

Olivier, J.G.J. (1998) Tiered Approach and Reporting Format for Estimating and Evaluating Uncertainty in Emission Inventories. Discussion paper prepared for the *IPCC/OECD/IEA Scoping Meeting on Managing Uncertainty in National Greenhouse Gas Inventories,* Paris, 13-15 October 1998.

Olivier, J.G.J., Berdowski, J.J.M., Peters, J.A.H.W., Bakker, J., Visschedijk, A.J.H. and J.P.J. Bloos (1999) EDGAR V.3.0: Reference database with trend data for 1970-1995. Proceedings of the *first NRP-II Symposium on Climate Change Research*, Garderen, The Netherlands, 29-30 October 1998, p. 339-343. NRP report 410200 033, NRP/RIVM, Bilthoven.

Olivier, J. (1998) Trends and uncertainties in emissions of greenhouse gases (in Dutch). *Lucht* 1**6:4,** 114-116.

Olivier, J.G.J, A.F. Bouwman, J.J.M. Berdowski, C. Veldt, J.P.J. Bloos, A.J.H. Visschedijk, C.W.M. van der Maas, P.Y.J. Zandveld (1999a) Sectoral emission inventories of greenhouse gases for 1990 on a per country basis as well as on 1° x 1°. *Environmental Science & Policy*, **2**, 241-264.

Olivier, J.G.J, J.P.J. Bloos, J.J.M. Berdowski, A.J.H. Visschedijk and A.F. Bouwman (1999b) A 1990 global emission inventory of anthropogenic sources of carbon monoxide on 1°x1° developed in the framework of EDGAR/GEIA. *Chemosphere: Global Change Science* **1**, 1-17.

Olivier, J.G.J. and J. Bakker (1999c) Historical emissions of HFCs, PFCs and SF_6 1950-1995. Consumption and emission estimates per country 1950-1995 and global emissions on 1°x1° in EDGAR V3.0. RIVM, Draft.

Olivier, J.G.J. and J. Bakker (1999d) SF_6 from Electrical Equipment and Other Uses (Draft). Information paper prepared for 'IPCC Expert Group Meeting on Good Practice in Inventory Preparation: Industrial Processes And The New Gases', Washington DC, 26-28 January 1999.

Olivier, J.G.J, N. Paciornic and J. Mangino (1999e) Conclusions on SF_6 from Electrical Equipment and Other Uses. IPCC Expert Group Meeting on Good Practice in Inventory Preparation: Industrial Processes And The New Gases, Washington DC, 26-28 January 1999.

Olivier, J.G.J. and J.A.H.W. Peters (1999f) International marine and aviation bunker fuel: trends, ranking of countries and comparison with national CO_2 emissions. RIVM report no. 773301002. RIVM, Bilthoven. July 1999.

Olivier, J.G.J., J.J.M. Berdowski, J.A.H.W. Peters, J. Bakker, A.J.H. Visschedijk and J.P.J. Bloos (1999g) *EDGAR V.30: Reference database with trend data for 1970-1995.* Poster presented at 6th IGAC Conference, 14-17September 1999, Bologna, Italy.

Olivier, J.G.J., Winiwarter, W. and J.P. Chang (1999h) Check and verification at national and international level. Background Paper #5 prepared for the *IPCC Expert Meeting on Estimating Uncertainties and Inventory Quality in Greenhouse Gas Inventories*, Culham, United Kingdom, 5-7 October 1999.

Olivier, J.G.J. and D. Cunnold (1999i) Report of the 10th GEIA Workshop, Bologna, Italy, 13 September 1999.

Olivier, J.G.J. and J.J.M. Berdowski (2001) Global emissions sources and sinks. In: Berdowski, J., Guicherit, R. and B.J. Heij (eds.) "*The Climate System*", pp. 33-78. A.A. Balkema Publishers/Swets & Zeitlinger Publishers, Lisse, The Netherlands. ISBN 90 5809 255 0.

Olivier, J.G.J. (2001) Shares and trends in greenhouse gas emissions. In: "*CO_2 emissions from fuel combustion 1971-1999*", 2001 Edition, pp. III.3-III.7. International Energy Agency (IEA), Paris. ISBN 92-64-08745-1.

Olivier, J.G.J. *et al*. (2001) CO_2, CH_4 and N_2O emissions for 1990 and 1995; Sources and Methods. In: "*CO_2 emissions from fuel combustion 1971-1999*", 2001 Edition, pp. III.9-III.29. International Energy Agency (IEA), Paris. ISBN 92-64-08745-1.

Piccot, S.D., Watson, J.J. and J.W. Jones (1992) A global inventory of volatile organic compound emissions from anthropogenic sources. *J. Geophys.Res*., **97:D9**, 9897-9912.

Reimer, R.A., Parrett, R.A. and Slaten, C.S. (1992) Abatement of N_2O emission produced in adipic acid. *Proceedings of 5th International Workshop on Nitrous Oxide emissions*, Tsukuba, Japan, July 1-3, 1992.

RIVM (1997a) *National Environmental Outlook 1997-2020* (in Dutch). Samson H.D. Tjeenk Willink Publishers. Alphen aan de Rijn.

RIVM (1997b) *Background information of the National Environmental Outlook 1997-2020* (in Dutch). Samson H.D. Tjeenk Willink Publishers. Alphen aan de Rijn.

RIVM (1997/98/99/2000a) *Environmental Balance 1997/98/99/200* (in Dutch). Samson H.D. Tjeenk Willink Publishers. Alphen aan de Rijn.

RIVM (1997/98/99/2000b) *Background information for the Environmental Balance 1997/98/99/2000* (in Dutch). RIVM, Bilthoven. For some years also or only available on the internet: http://milieu.rivm.nl/milieubalans and http://milieu.rivm.nl/milieucompendium.

RIVM (2000) *National Environmental Outlook 2000-2025* (in Dutch). Samson H.D. Tjeenk Willink Publishers. Alphen aan de Rijn.

Roelofs, G.J. and J. Lelieveld (2000) Tropospheric ozone simulation with a chemistry-general circulation model: Influence of higher hydrocarbon chemistry, *Journal of Geophysical Research*, **105:D18**, 22697-22712.

Rotty, R.M. (1987) Estimates of seasonal variation in fossil fuel CO_2 emissions. *Tellus*, **39B**, 184-101.

Saeger, M., J. Langstaff, R. Walters, L. Modica, D. Zimmerman, D. Fratt, D. Dulleba, R. Ryan, J. Demmy, W. Tax, D. Sprague, D. Mudgett and A.S. Werner (1989) *The 1985 NAPAP Emissions Inventory (Version 2): Development of the Annual Data and Modelers' Tapes*, Rep. EPA-600/7-89-012a, U.S. Environmental Protection Agency, Research Triangle Park, NC.

Sandnes, H. and H. Styve (1992) *Calculated Budgets for Airborne Acidifying Components in Europe, 1985, 1986, 1987, 1988, 1989, 1990 and 1991*, Meteorological Synthesizing Centre-West. The Norwegian Meteorological Institute, Oslo, Norway.

Smill, V. (1999) Nitrogen in crop production: an account of global flows. *Global Biochemical Cycles,* **13**, 647-662.

Smith, K.R. and J. Ramakrishna (1990) Biomass fuels and health, in: J. Lamptey *et al.* (1990) *Bioenergy*. Wiley Eastern Ltd, IDRC, Ottawa.

Smith, K.R., Khalil, M.A.K., Rasmussen, R.A., Thornloe, S.A., Manegdeg, F. and M. Apte (1993) Greenhouse gas emissions from biomass and fossil fuel stoves in developing countries: a Manila pilot study. *Chemosphere,* **26**, 479-505.

Smith, S.J., Pitcher, H. and T.M.L. Wigley (2001) Global and Regional Anthropogenic Sulfur Dioxide Emissions, *Global and Planetary Change,* **29**, 99-119.

Spiro, P.A., Jacob, D.J. and Logan, J.A. (1992) Global Inventory of Sulfur Emissions with a 1^o x 1^o Resolution *J. Geophys. Res.,* **97**, 6023-6036.

SRI (1998). Adipic acid production data 1974-1997. SRI Consulting, Menlo Park, USA. Table dated January-1998, received 30-1-1998.

Tonooka, Y. (1993) Personal correspondence, Institute of Behavioural Sciences, Japan.

Tukey, J.W. (1977) Exploratory data analysis. Addison-Wesley, Reading, MA, USA.

UN/ECE-FAO [United Nations Economic Commission for Europe & Food and Agriculture Organisation of the United Nations] (1996) Forest Fire Statistics 1993-1995, Timber Bulletin, Vol. XLIX, No. 4, ECE/TIM/BULL/49/4, United Nations, 1996.

UN (1999) UN World Population Prospects, 1996 Revision. UN Population Division, New York.

UNFCCC (1997) Second review and synthesis of first national communications. Addendum 2: Tables. UNFCCC Secretariat, Geneva. UNFCCC/CP/1997/L.7/Add.1.

USEPA (1985) *Compilation of Air Pollutant Emission Factors.* USEPA, Research Triangle Park, North Carolina. Publication No.AP-42, September 1985, 4th Edition.

Valks, P. and M.G.M. Roemer (1996) *Model calculations of ozone and other trace gases based on EDGAR/GEIA emission estimates of NMVOC* (in Dutch). TNO report R96/294, Delft, Netherlands

Veldt, C. (1992) *Updating and upgrading the PHOXA emission database to 1990.* TNO, Apeldoorn. TNO Report.

Veldt, C. and J.J.M. Berdowski (1995) *GEIA-note on the combustion of biomass fuels (Emission factors for CO, CH_4 and NMVOC).* TNO-MW, Delft. 7 February 1995. TNO-report TNO-MW-R94/218.

Wagner, J., R.A. Walters, L.J. Maiocco and D.R. Neal (1986) *Development of the 1980 NAPAP Emissions Inventory,* U.S. Environmental Protection Agency, Washington, DC, 1986.

Heng, Yao, Zhuang, Ya-Hui and Chen, Zong Liang (1996) Estimation of methane emission from rice paddies in mainland China, *Global Biogeochemical Cycles*, **10**, 641-649.

Appendix 1: Results of EDGAR user survey

First the results are presented in tables, following the structure of the survey. Subsequently, the general evaluation items discussed under C are presented graphically.

A. User Information

1. Country: France: 2; Germany: 1; Japan: 2; The Netherlands: 5; UK: 4; USA: 5

2. Type of user:

6 Research User | 1 Education User | 1 Business User
0 Home User | 1 Other

3. Do you want to be informed by e-mail when we post new inventories or other new information on the EDGAR site?

9 Notify of general changes | 5 Notify only if there are changes to inventories | 1 Do not notify me!

B. Use of EDGAR V2.0 Data

1. In what type of model, assessment or comparison study are you currently using EDGAR data?

10 Atmospheric Model | 2 Other Model | 2 Other Scientific Application
3 Policy Application | 0 Other

2. What EDGARV2.0 datasets are you currently using? (Please check all that are relevant)

1 CO_2
7 CH_4
1 N_2O
2 Halocarbons (CFC etc.)
9 NO_x
8 SO_x
4 NH_3
10 CO
10 NMVOC
3 Aircraft Emissions

3. What spatial resolution are you using in your application?

10: **1x1 degree grid**
6: **Other grid, please specify:** *4x5; 4x5; 5x5 (variable); 0.5x0.5 or 2.75x3.5; various*
2 **Country level**
0 **Other**

4. What temporal resolution are you using in your application?

8 **Annual**
6 **Seasonal**
4 **Other, please specify**: *2x monthly; 1x monthly/diurnal; 1x hourly*

C. General Evaluation of EDGAR V.2.0 Data Sets

Instructions: Please mark each item on a scale of 1 to 5. Also, please indicate which aspects of the data sets is most important for your needs, by ranking them from 1 to 5. (1=highest, 5=lowest).

1. Data retrieval is:

very easy	fairly easy		difficult		Priority: high	medium		low	
1	2	3	4	5	1	2	3	4	5
4	*6*	*2*	*2*	__	*1*	_*6*_	*6*	*1*	__

2. Data documentation on file is:

excellent	fair		poor		Priority: high	medium		low	
1	2	3	4	5	1	2	3	4	5
_*1*_	*7*	*5*	__	*1*	*6*	__*3*	*4*	__	__

Suggestions: *NMVOC doc. problems*

3. Data documentation in scientific paper is:

excellent	fair		poor		Priority: high	medium		low	
1	2	3	4	5	1	2	3	4	5
2	*2*	*1*	*4*	*1*	*4*	_*4*_	*2*	__	__

4. Description of applicability/caveats is: Priority:

excellent	fair		poor		high	medium		low	
1	2	3	4	5	1	2	3	4	5
__	*4*	*6*	*1*	*1*	*3*	_*4*	*5*	__	__

5. Available compounds/sources: Priority:

more than sufficient	sufficient	insufficient			high	medium		low	
1	2	3	4	5	1	2	3	4	5
1	*4*	*8*	__	__	*7*	*3*	*3*	__	__

6. Data generally are: Priority:

very adequate	fairly adequate	not adequate			high	medium		low	
1	2	3	4	5	1	2	3	4	5
__	*9*	*2*	*2*	__	*8*	__*3*	*1*	__	__

7. In general the appropriateness of data format is: Priority:

very good	fair	not approp.			high	medium		low	
1	2	3	4	5	1	2	3	4	5
3	*8*	*2*	*1*	__	*8*	*3*_	*1*	__	__

8. Data quality is: Priority:

excellent	fairly good	not very good			high	medium		low	
1	2	3	4	5	1	2	3	4	5
1	*5*	*4*	*2*	_____	*6*	_*5*	*5*	__	__

9. Representation of data uncertainty: Priority:

very adequate	fairly adequate	not adequate			high	medium		low	
1	2	3	4	5	1	2	3	4	5
__	*4*	*4*	*5*	*1*	_*6*	*2*	*5*	*1*	__

10. Data consistency with other comparable information: Priority:

very comparable	comparable	not comparable			high	medium		low	
1	2	3	4	5	1	2	3	4	5
1	*4*	*8*	*1*	__	*4*	_*6*_	*2*	*1*	*1*

11. Reference year(s): Priority:

sufficient/up-to-date	sufficient	insufficient			high	medium		low	
1	2	3	4	5	1	2	3	4	5
2	*3*	*7*	*2*	__	*2*	_*7*_	*4*	__	*1*

D. More Detailed Evaluation of Specific Data Sets and Needs

1. For the particular data sets that you use, do you find that the information is adequate for your use:

Data set name, reference year, units, temporal resolution, spatial resolution is adequate:

Additional information would be helpful: Y/N. If Yes, please specify: *agreement with obervations*

Additional Header Needs. If needed, please specify: *source process not always clear from heading.*

2. Which key new data would be particularly useful for your needs:

Compounds: *more NMVOC; particulates; AOT40*

New Sources: *biomass burning gaps; fires emissions; NOx from lightning*

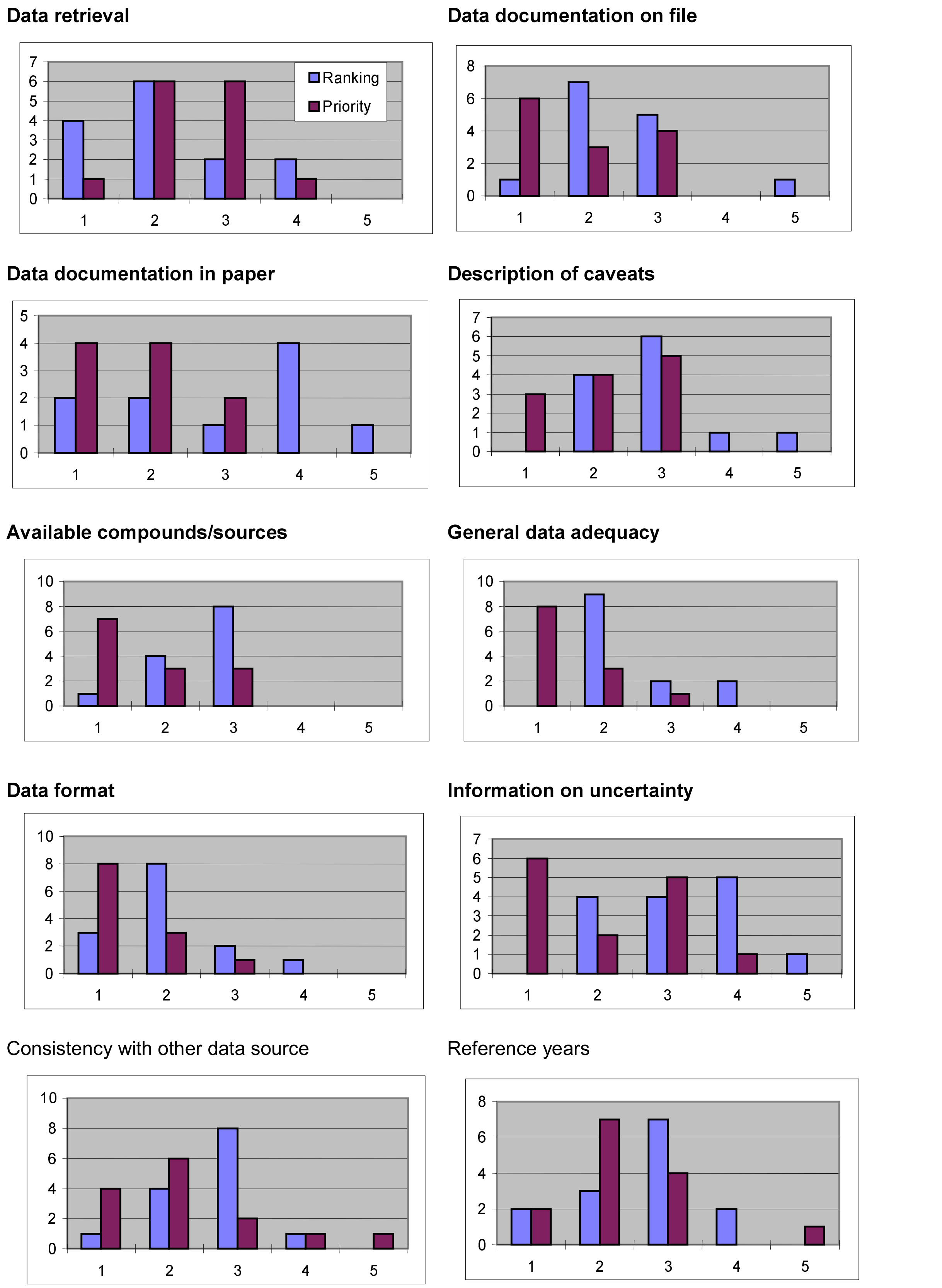
Source Split/Category: -

Reference year, other years: *95 (2x); 96; 98*

Spatial Resolution: *0.5x0.5; country data!*

Temporal Resolution: *monthly trend; monthly; monthly/daily; seasonal for CO; seasonal biomass burning (2x); seasonality; trend to scale emissions to another year*

Uncertainty qualifications: *more; description/quantification of main sources of uncertainty per proces/compound quantitatively.*



Ranking: 1 = easy/excellent/adequate/ok ; 5 =difficult/poor/inadequate/inappropriate;
Priority: 1 = high; 5 = low.

Fig.A.1.1. EDGAR survey: evaluation of general aspects

Appendix 2: Time profiles

As part of the project, available information on time profiles of anthropogenic sources was collected and listed, focussing on their monthly variation. Within GEIA, however, a full study of time profiles for all sources is in progress. The present activities of the EDGAR will feed into this larger study.

Time profiles can be defined on different temporal scales, e.g. seasonal or monthly variation, weekly patterns, or diurnal cycles. Often as a first approximation modellers distinguish natural sources from anthropogenic sources, since natural sources often depend strongly on climate, soil or water characteristics and thereby show a strong temporal variation, in seasonality, diurnal cycle or both. Thus, natural sources often have a distinctly other character than have anthropogenic sources. In particular with respect to seasonality, modellers often consider anthropogenic sources to be uniform in time. Surely this is the case when compared to natural sources. However, when taking a closer look at the scattered literature on this subject a more detailed picture shows up, also for seasonal variation of emission sources. Seasonal variation in weather and different climate conditions gives rise to different profiles for fuel combustion for space heating and for biomass burning, whereas cultural differences show up in statistics of industrial production and transportation.

Table A.2.1. Priorities for sectoral time profiles based on their contribution to emissions of various compounds.

MAIN CATEGORY	DETAILED	PRIORITY	COMPOUND				REMARK
			CO_2	CH_4	N_2O	Other	
Fossil fuel combustion	**Industry**	4	x		x		IRO-coal, culture?
	Power plants	1	x		x		HDD, avail. hydro, CDD in USA
	Other transf. sector						
	Residentials etc.	2a	CO_2		N_2O		HDD
	Road transport	?	CO_2		N_2O	x	culture?
	Other land transport						
	Air transport						
	International shipping					SO_2	
	Non-energy use						
Fossil fuel production	Coal	5a		CH_4			coal?
	Oil	5b	(x)	CH_4		(VOC)	main practices oil/gas; demand flow?
	Gas	5c		CH_4		(VOC)	main practices oil/gas; demand flow?
Biofuels	Industry						
	Residentials etc.	2b	(x)	CH_4	N_2O	x	avail. dry woodfuel; avail agr. residues
Industrial processes	Iron&steel		o				culture?
	Non-ferro					SO_2	demand flow?
	Chemicals						
	-Adipic Acid	10a			N_2O		
	- Nitric Acid	10b			N_2O		fertilizer demand flow?
	- NMVOC sources					VOC	
	Cement		(x)				demand flow?
	Glass		o				demand flow?
	Solvents					VOC	
Agriculture	Rice	6		CH_4			
	Fertiliser use	9			N_2O		
	Animals	7		CH_4	N_2O		
	Biomass burning	3	CO_2		N_2O		based on satellite data?
Waste handling	Landfills	8		CH_4			
	Incinneration						
	Agric. waste burning						
	Domestic waste burning						
Natural sources	Soils			CH_4	N_2O	x	
	Vegetation		CO_2			VOC	
	Oceans		CO_2		N_2O		

In this Appendix we focus on anthropogenic time profiles for seasonality (monthly variation). Table A.2.1 summarises the priority setting for compiling time profiles per source category in relation with their contribution to total emissions of specific compounds.

In general climatic, cultural and economic influences contributing to non-uniformity of human activities are:

space heating, influencing the demand on fuels in the residential and commercial sectors;
space cooling, affecting the demand for electricity in the residential and commercial sectors;
availability of hydropower, influencing the use of fossil fuels or electricity production;
holiday periods, influencing both road traffic intensity and manufacturing activities;
maintenance periods for large plants relating to favourable periods (e.g. due to holidays, demand drops, weather conditions), influencing the demand for fossil fuels and the activity level of industrial processes;
seasonality of agricultural production, influencing the amount of national and international transport (predominantly road and shipping, respectively);
car cooling, influencing emissions of CFCs and HFCs from mobile air conditioners.

In the LOTOS approach (Veldt, 1992) time profiles on different time scales are based on reasonable, simplified assumptions for key sources (Table A.2.2). In Figure A.2.1 the weekly and seasonal variation of these profiles is presented graphically, showing the straightforward character of these datasets.

Table A.2.2. LOTOS time profiles for estimating emissions with temporal resolution at monthly, week and daily level. Source: Veldt (1992).

Category/sector	Winter/Summer[1]	Working/Weekend day	Day-time/Night-time[1]	Temp. dependent
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 combustion sources	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
7-9 Traffic	1/1	1/1	1.8/0.2	yes
10-12 Vegetation	1/1	1/1	1/1	yes

[1] Each of each length.

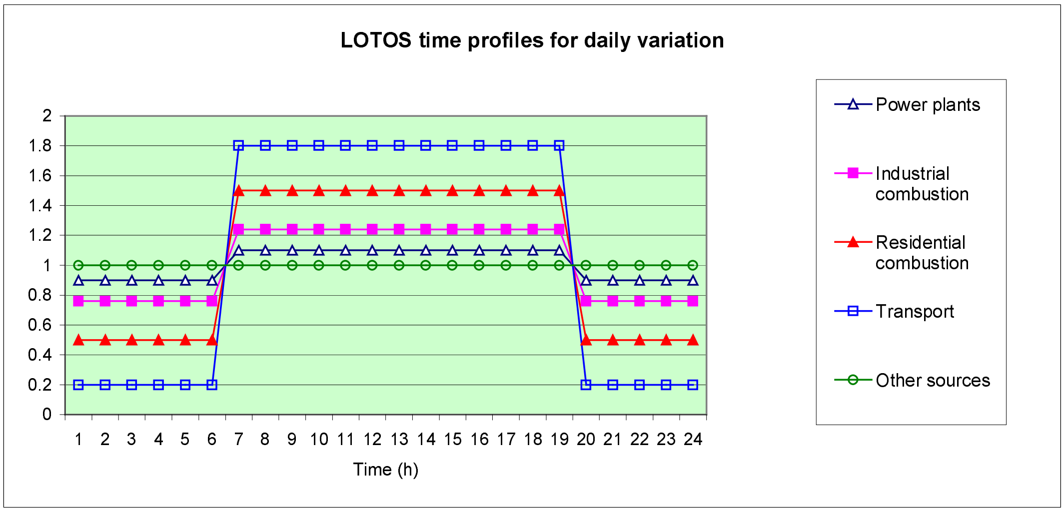
As an example of a more detailed approach, in Figure A.2.2 time profiles are presented that have been defined and used in the USA for estimating quarterly emissions of NAPAP emission inventories.

Obviously there is an enormous amount of data available on economic activities at the smallest scale (plant level, city, street, individual farmers). Within Europe, comprehensive effort has been made by the GENEMIS project (Generation of European Emission Data for Episodes), which is part of EUROTRAC, to produce time profiles at a very high spatial and temporal resolution (Heymann, M, 1992; 1994)(see Table A.2..3). This approach extended and generalised the LOTOS approach discussed above. The GENEMIS project showed that the availability of high temporal resolution indicator data is limited. Some examples of this project are summarised in the Section of temporal variation in the *EMEP/CORINAIR Emission Inventory Handbook* (EMEP-CORINAIR, 1999).

Table A.2.3. Indicator data used for the GENEMIS database on time profiles. Source: IER (EMEP-CORINAIR, 1999).

Sector	Indicator data		
	Monthly resolution	Daily resolution	Hourly resolution
Power plants	fuel use	load curves	
Industrial combustion	fuel use, temperature, degree days, production	working times, holidays	working times
Small combustion	degree days	user behaviour	user behaviour
Refineries	production	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	traffic counts
Air traffic	LTO cycles, number of fleights	LTO cycles, number of fleights	LTO cycles, number of fleights
Biogenic emissions	temperature, radiation	temperature, radiation	temperature, radiation

Data sources:
production indices OECD, EUROSTAT, UN, CERES; energy consumption: EUROSTAT, Statistisches Bundesamt, CERES; traffic counts: BaSt, University of Thessaloniki, PSI Switzerland, CERES, national experts; meteorological data: Wetterdienst, Klimarechenzentrum, EUMAC; time zones: GENEMIS, EUMAC; user behavior: SANA, VDI, CERES; working times: GENEMIS, PEF, TRACT; holidays: GENEMIS, CERES geographical data: GENEMIS, EUROSTAT, EUMAC.



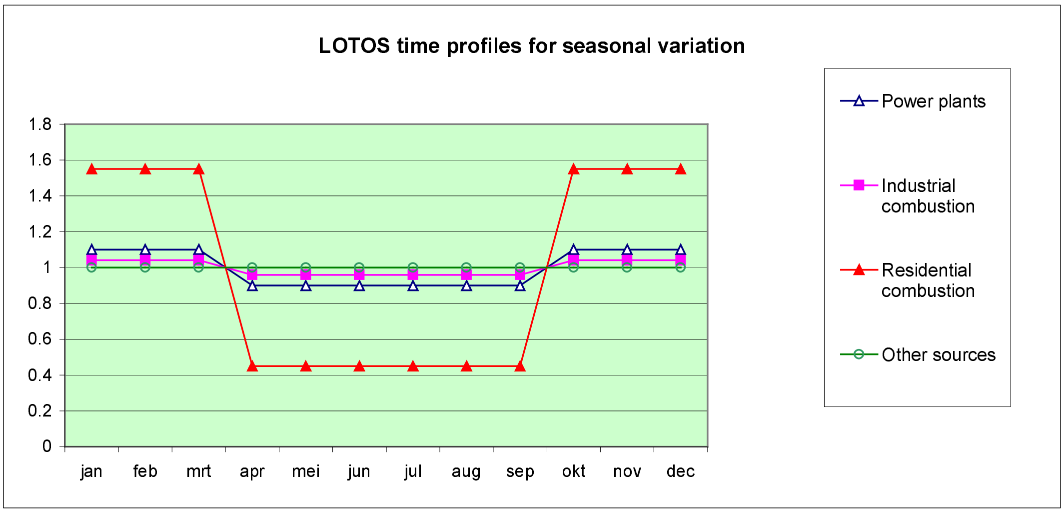
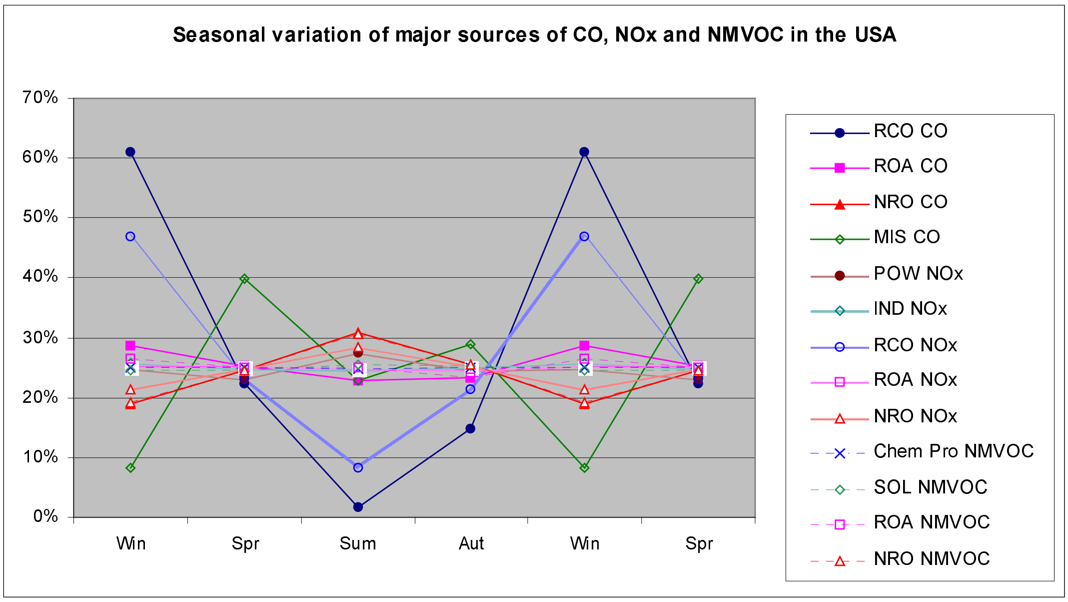


Fig A.2.1 LOTOS time profiles for estimating emissions with temporal resolution at monthly and daily level (source: Veldt, 1992).



Note: RCO = residentials etc.; ROA = Road transport; NRO = Non-road tra sport ; MIS = Miscellaneous; POW = Power generation; IND = Industry; SOL = Solvent use

Fig. A.2.2. Seasonal variation of major sources of CO, NO_x and NMVOC in the USA. Source: EPA, 1995.

Although the information of this project has been used to generate European emission inventories with high time and space resolution, it was not possible to receive sectoral time profiles aggregated to the country level. Nevertheless, many data sources are available as indicator for monthly variation. This provides a good sense for the variability of anthropogenic emissions. However, regarding monthly indicator data for specific economic sectors at country level, however, data are not so easily available, in particular with global coverage. In general one can say that for OECD countries more statistics are available than for non-OECD countries.

In the remainder we will summarise data sources by presenting a selection of available seasonal profiles for the main anthropogenic emission sources: fossil fuel combustion, industrial production, agriculture and biomass burning. When using these datasets to compile time profiles on a global scale one should keep in mind that actual seasonality may differ from year to year, so when constructing an average profile one should preferably use multi-year datasets to average out these differences and to be able to estimate the uncertainty in these profiles when applying them for a specific year.

Fossil fuel combustion

Based on reported fossil fuel consumption data, supplemented by data on heating-degree days, Rotty (1987) analysed seasonal variation of fuel consumption in the 21 largest fuel consuming countries. Figure A.2.3 shows the difference for global total fuel consumption per fuel type. It clearly shows that gas is has a higher share in consumption for space heating than coal and oil. In Figure A.2.4 per fuel type the different seasonal pattern of six world regions are presented. These graphs illustrate clearly the opposite cycles of temperate regions in the Northern and Southern Hemisphere as well as the higher seasonality in temperate regions compared to tropical regions.

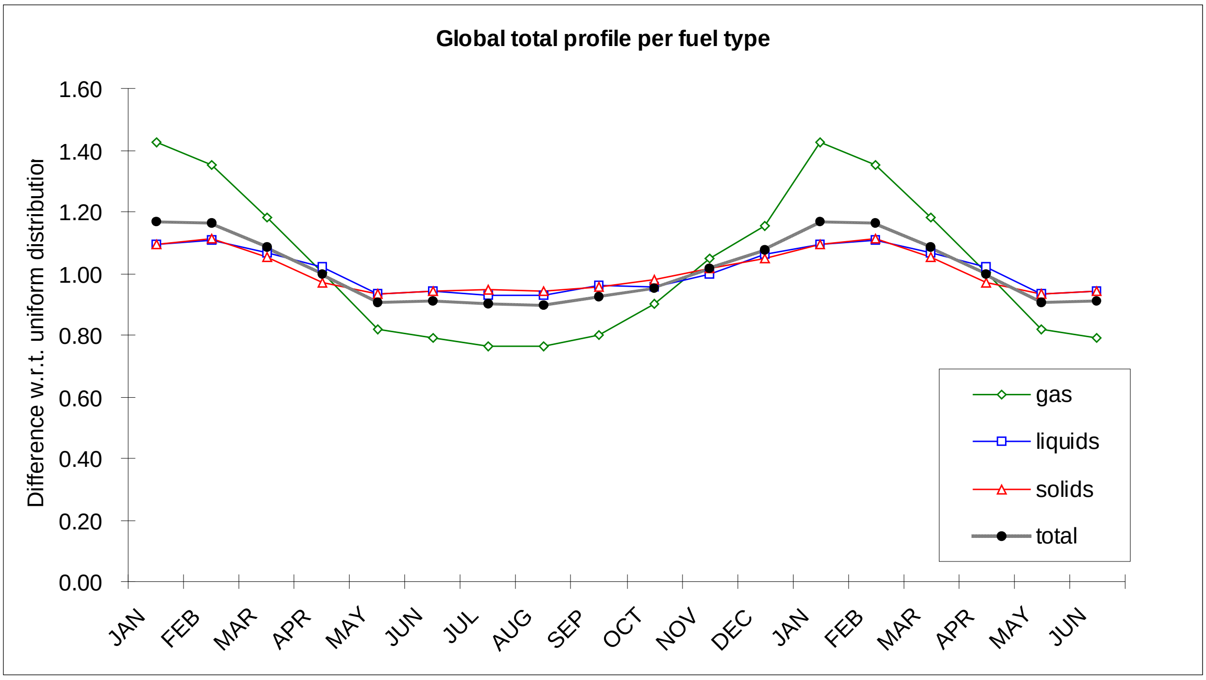


Fig.A.2.3. Monthly variation in global total fossil fuel combustion per fuel type. Source: Rotty, 1987.

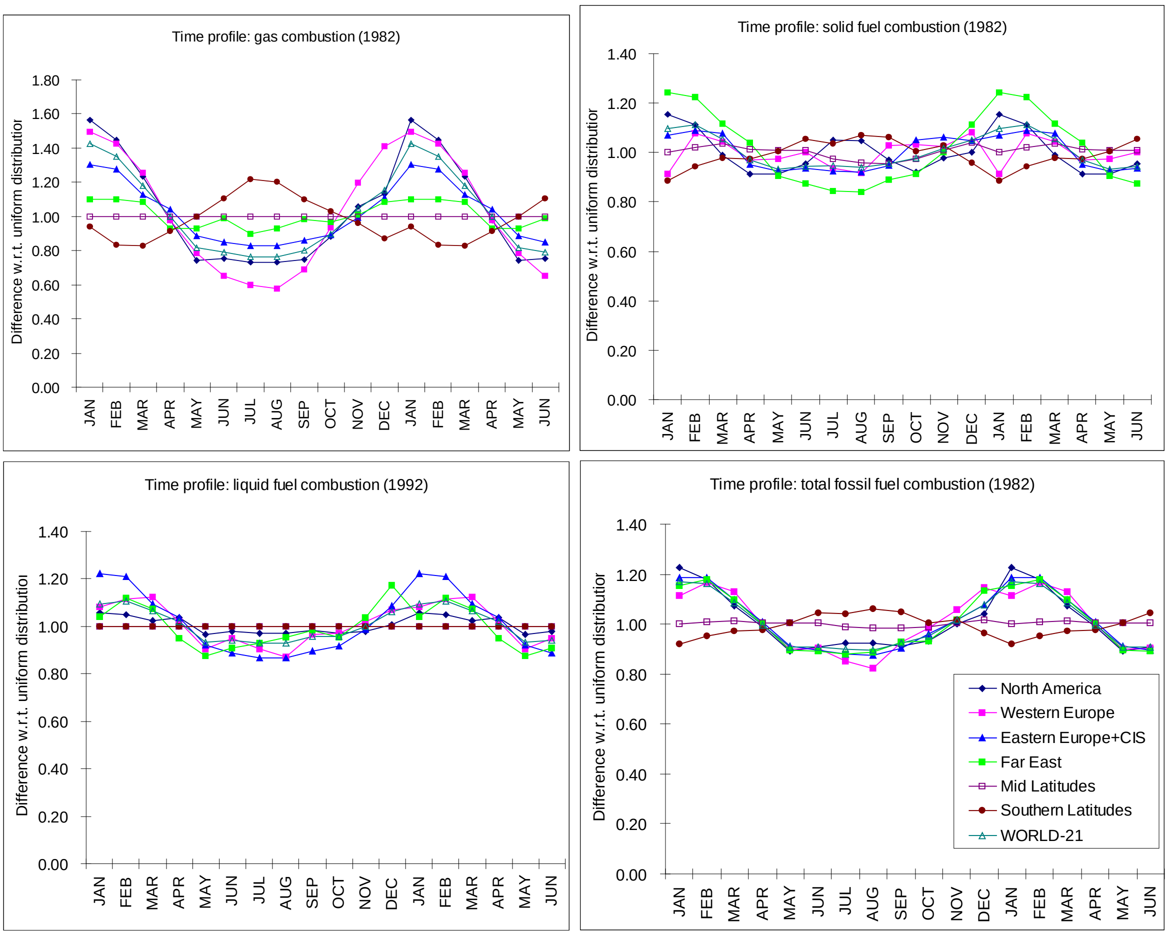


Fig. A.2.4. Monthly variation in fossil fuel combustion per fuel type per world regions and in the som of 21 analysed countries. Source: Rotty, 1987.

Air traffic

Cultural aspects are visible in the patterns for air transport presented in Figure A.2.5, based on an analysis by Mortlock (1994) of monthly Offical Airline Guide (OAG) traffic data for the period 1976-1991. Most of the interregional and intraregional flights are rather uniform in time, with two clear exceptions. North Atlantic flights between Europe and North America are more frequent in summer and autumn months and flights within Europe which show a clear peak during July and August, probably representing a peak in holiday traffic. These profiles were aggregated to a more simple profile for application in a Dutch aircraft policy study by Olivier (1995), while maintaining these noted exceptions (Fig. A.2.6).

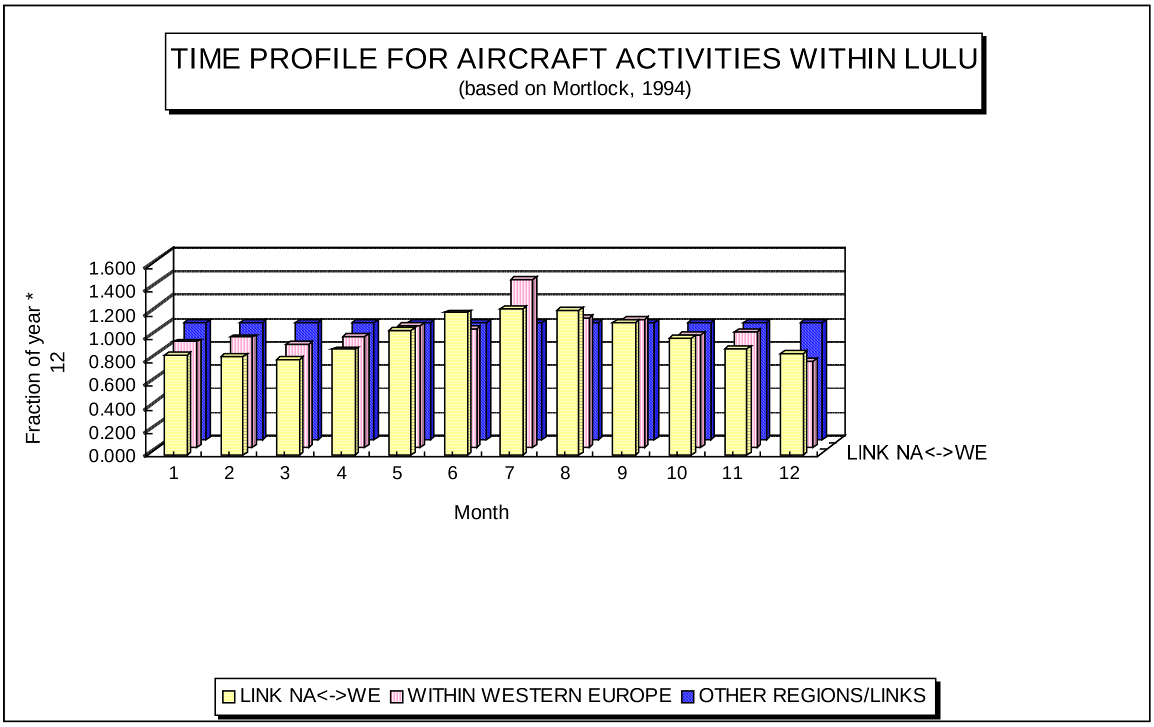
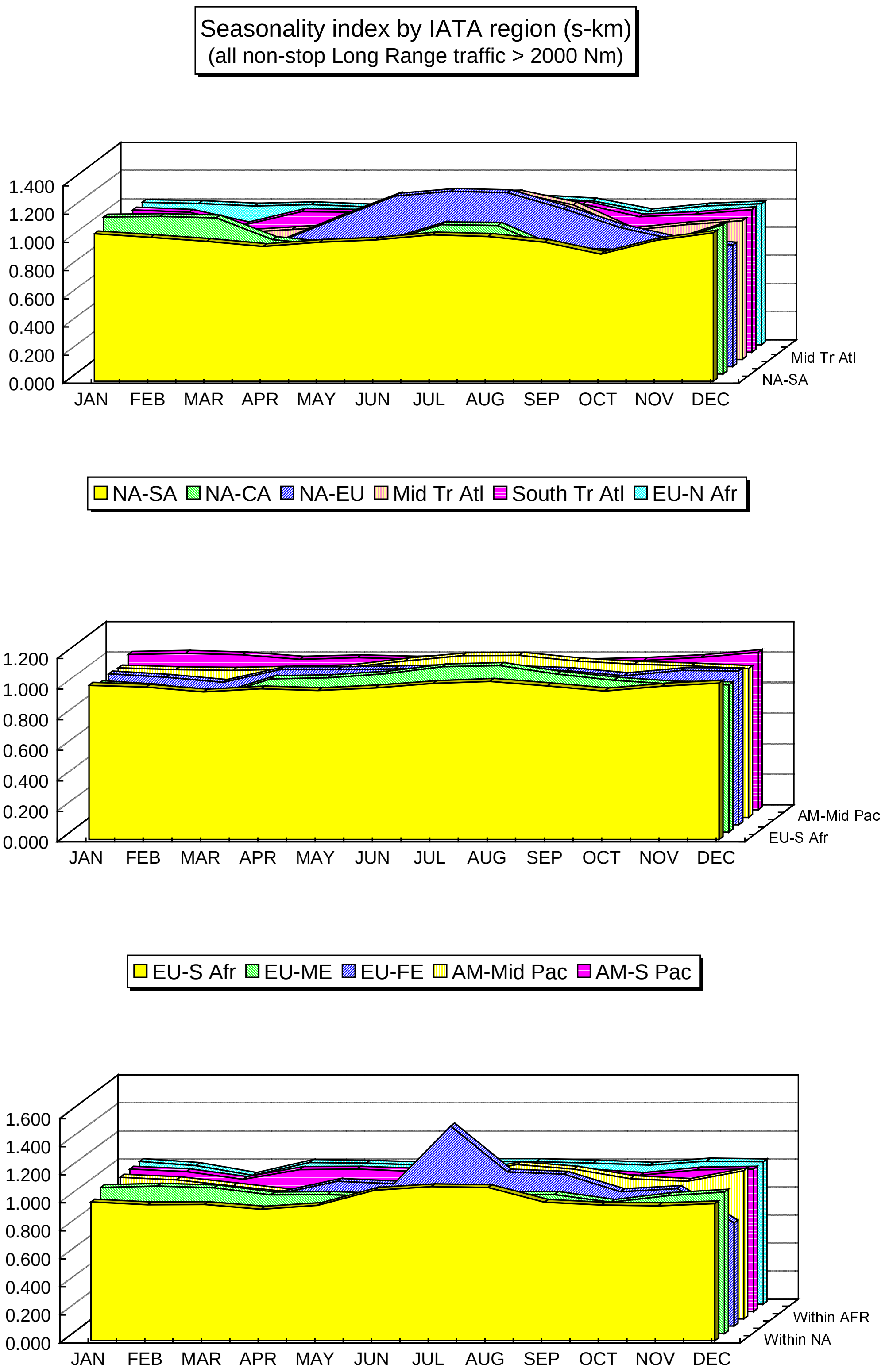


Fig. A.2.6. Simplified time profile for aircraft activities used within the LULU project. Source: Olivier, 1995.



Note:

NA = North America
CA = Central America
SA = South America
AM = Americas

EU = Europe, incl. former USSR (West of Urals)
ME = Middle East
FE = Far East, incl. former USSR (East of Urals)
MISC = Miscellaneous

Fig. A.2.5. Seasonal variation of air traffic by region/flow based on scheduled OAG passenger air traffic data from 1976 through 1991. (Source: Mortlock, pers. communication, 1994).

Industrial production

Data from the International Iron and Steel Institute (IISI) illustrate some other aspects to consider when compiling time profiles for global application. First in Figure A.2.7 seasonal variation in crude steel production is shown for 1993. At first impression it looks quite uniform for most countries/regions. However, when analysing multi-annual datasets it clearly shows that European countries show a distinct non-uniform pattern with dips in August and December, possibly related to planned maintenance periods during holiday months, not visible in other regions (see Figure A.2.7 for EU, USA and Japan). This proves the value of analysing seasonal data for more than one year only.

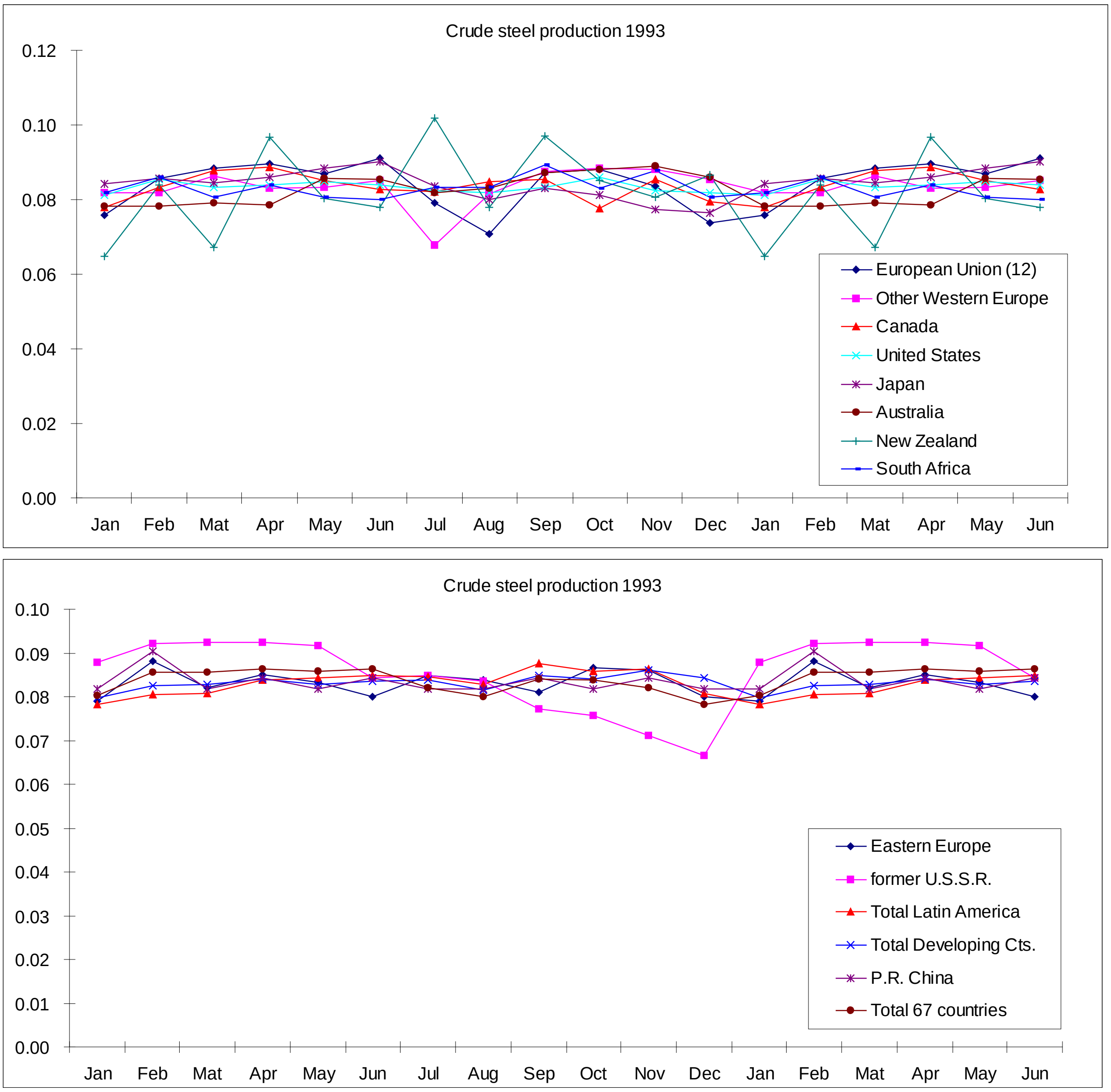
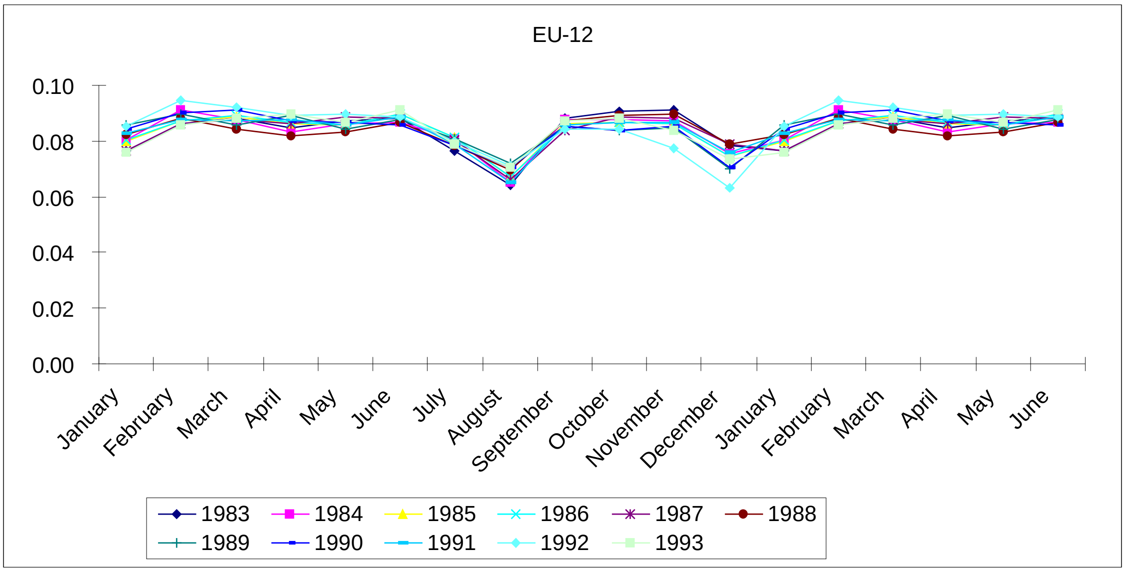
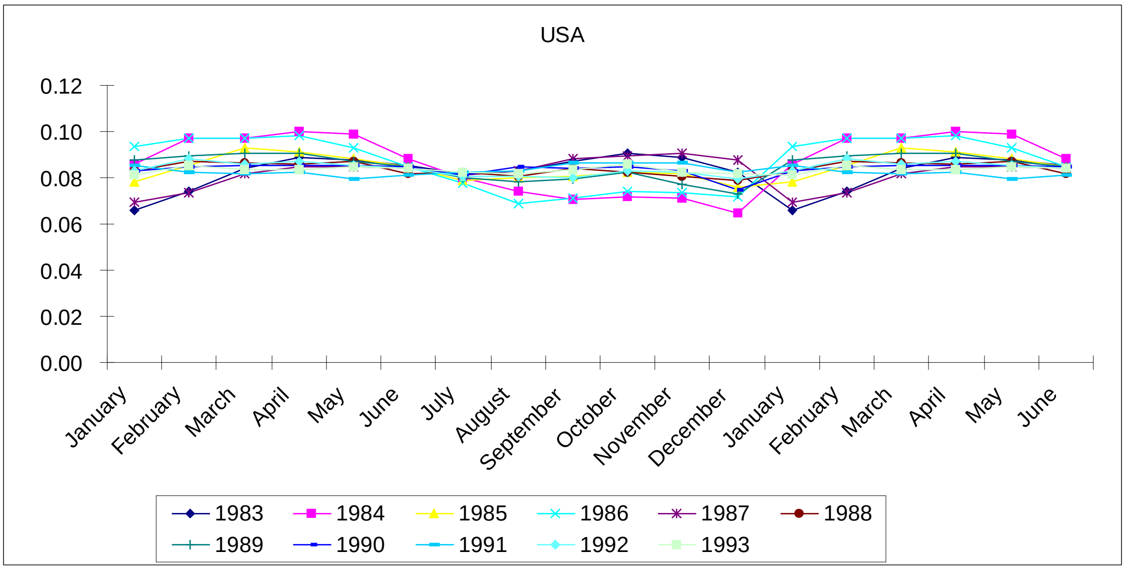


Fig. A.2.7. Monthly time profile of crude steel production in 1993 (normalized months): a. OECD countries; b. non-OECD countries. Source: IISI, 1996.





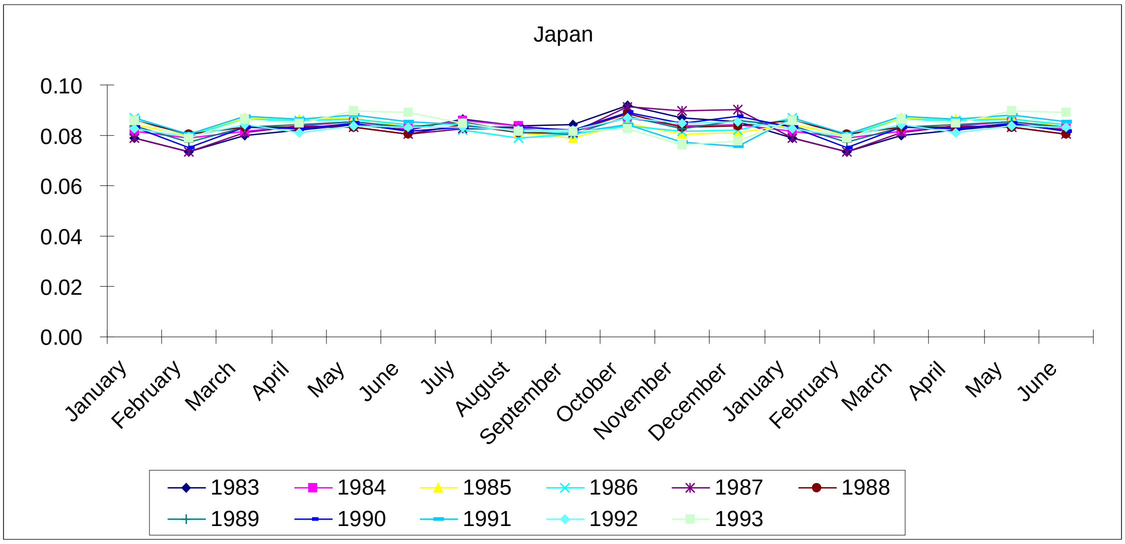


Fig. A.2.8. Multi-year monthly time profiles for crude steel production (1983-1993) in EU-12, USA and Japan (normalized months). Source: IISI, 1996.

Agriculture: CH_4 from rice cultivation

Methane emissions from rice cultivation are known to be highly seasonal. From the many publications on this subject we present a few graphs in which the seasonality is presented and compared from a number of model studies. In Figure A.2.9 the seasonality in emissions from three world regions is presented as modelled by Cao *et al.* (1996). Apparently, the seasonality is the strongest in the northern regions. In the north 75% of annual CH_4 from rice paddies is emitted between June and October, whereas in the south 90% was emitted between November and March; in the near-equator region emission show much less seasonality (Cao *et al*., 1996). In Figure A2.10 the results of Cao are compared with results presented by Asselmann and Crutzen. Both seasonal variation patterns look rather similar. Finally, in Figure A.2.11 the seasonal variation of CH_4 emissions from rice paddies in China is presented for different latitudes.

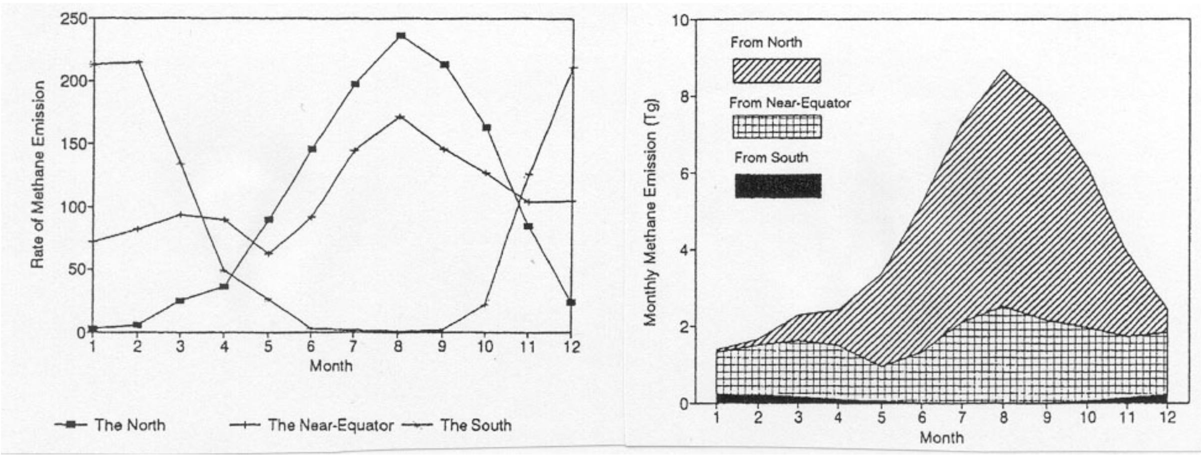


Fig. A.2.9 Seasonal variation in methane emissions from rice paddies in northern, near-equatorial and southern regions: (a) in the rate (kg/m^2/day); (b) in monthly total methane emissions from rice paddies. Source: Cao et al., 1996.

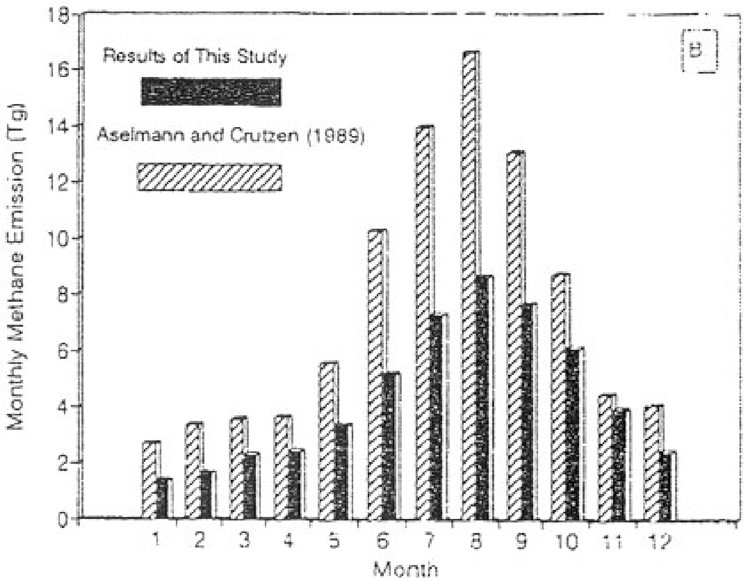


Fig. A.2.10. Comparison of seasonal variation of methane emissions from rice paddies in Cao et al. (1996) and Asselmann and Crutzen (1989).

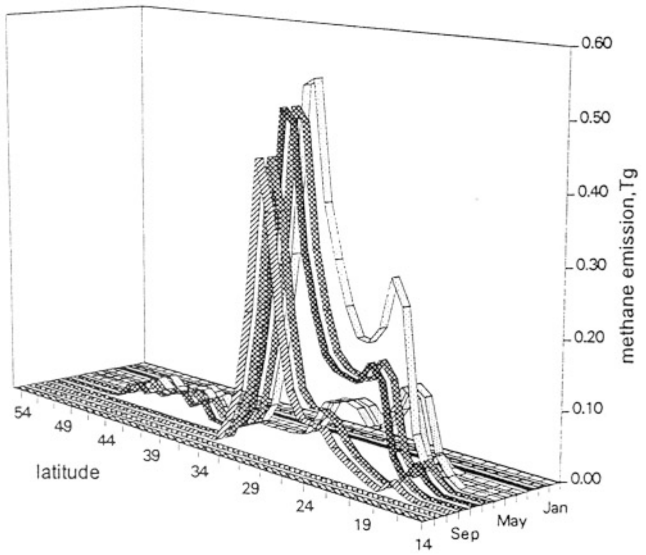


Fig. A.2.11 Seasonal variation of methane emissions from rice paddies in China and their dependence on the latitude.

Biomass burning

Biomass burning (deforestation, savannah burning, field burning of agricultural wastes) is limited to the dry season, therefore showing very clear seasonal patterns (Fig. A.2.12). However, it is very difficult to get accurate seasonal profiles, since this seasonal pattern may differ substantially between years (Fig. A.2.13) and regions (Fig. A.2.14).

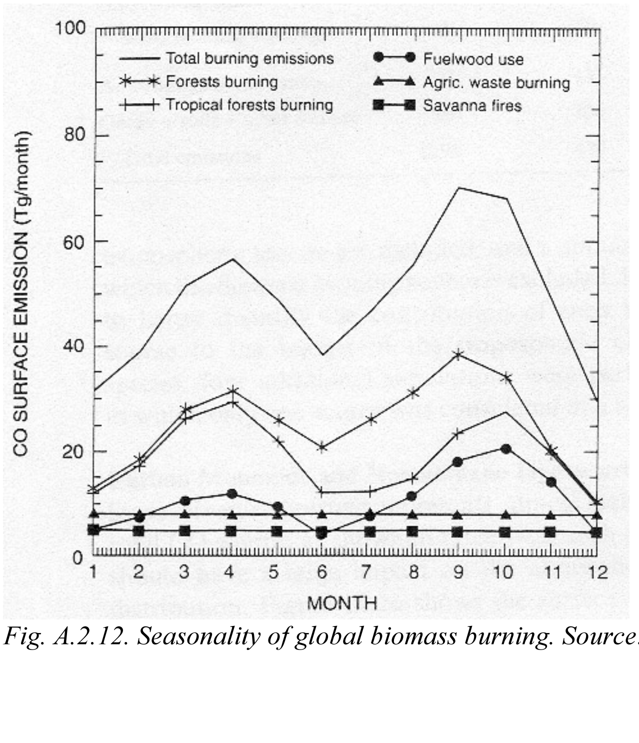


Fig. A.2.12. Seasonality of global biomass burning. Source: Hao and Liu, 1994.

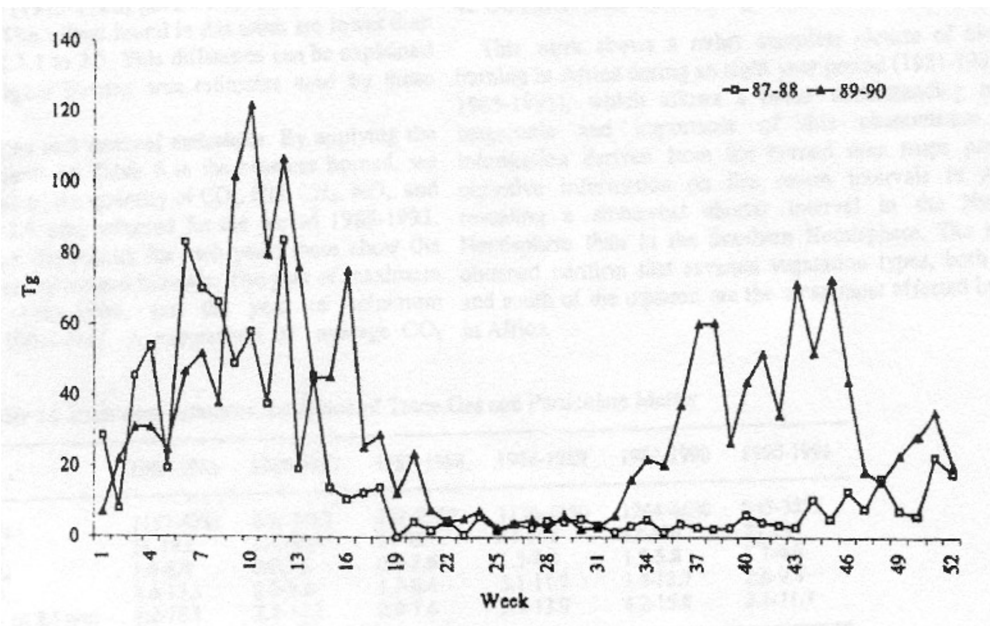


Fig. A.2.13. Seasonality of biomass burning in Africa in two subsequent years Source: Barbosa et al., 1999.

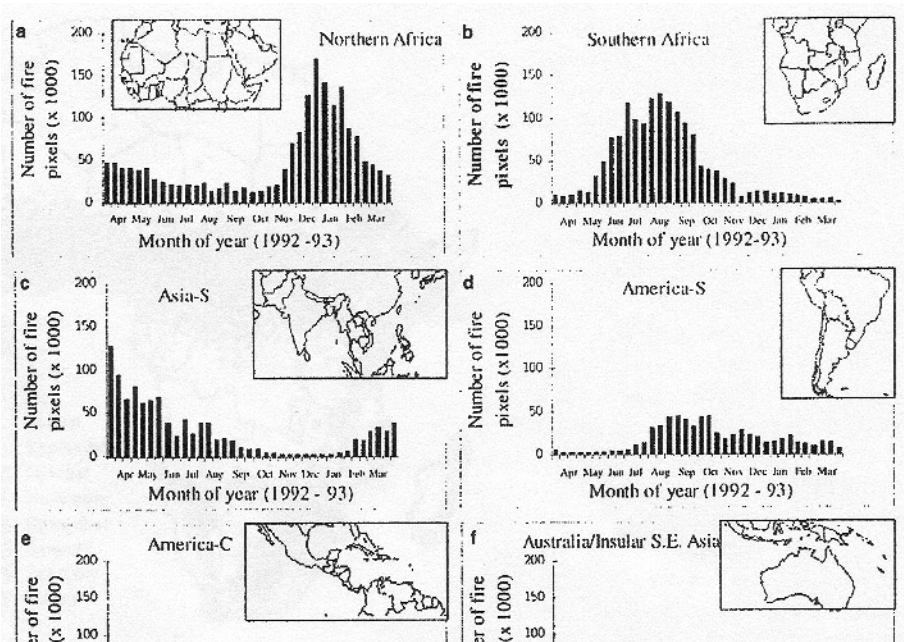


Fig. A.2.14. Seasonality of regional biomass burning. Source: Dwyer et al., 2000.

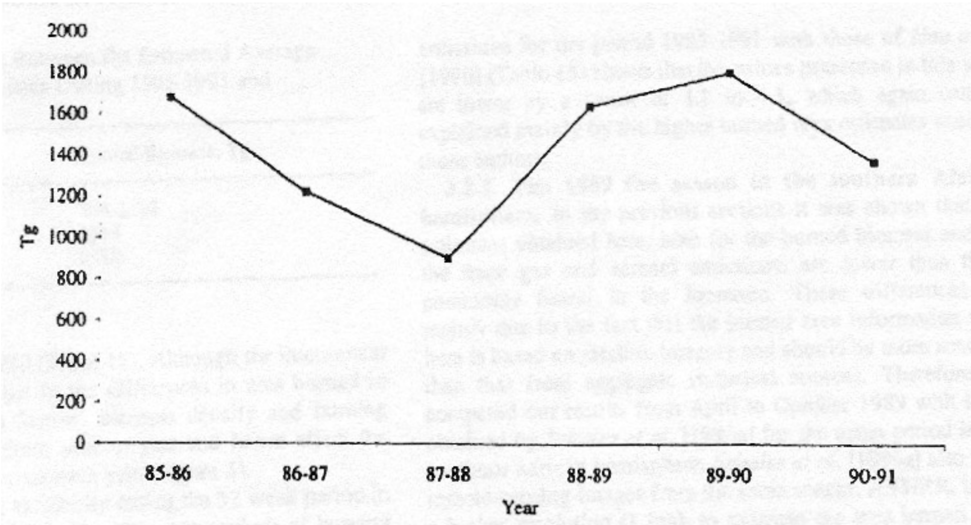


Fig. A.2.15. Interannual variation of vegetation fires in Africa. Source: Barbosa et al., 1999.

An additional problem for this source is that available data are often limited to one or a few years and that the also the extent of burning often substantially differs between years (Fig. A.2.15). Using the counts of satellite observations of so-called hot-spots to identify the seasonal patterns of biomass burning (e.g. Fig. A.2.16), is also not straightforward. In Fig. A.2.17 the results of two algorithms for identifying hotspots for biomass burning are compared. Although the two patterns look similar the deviations from the uniform distribution are rather different.

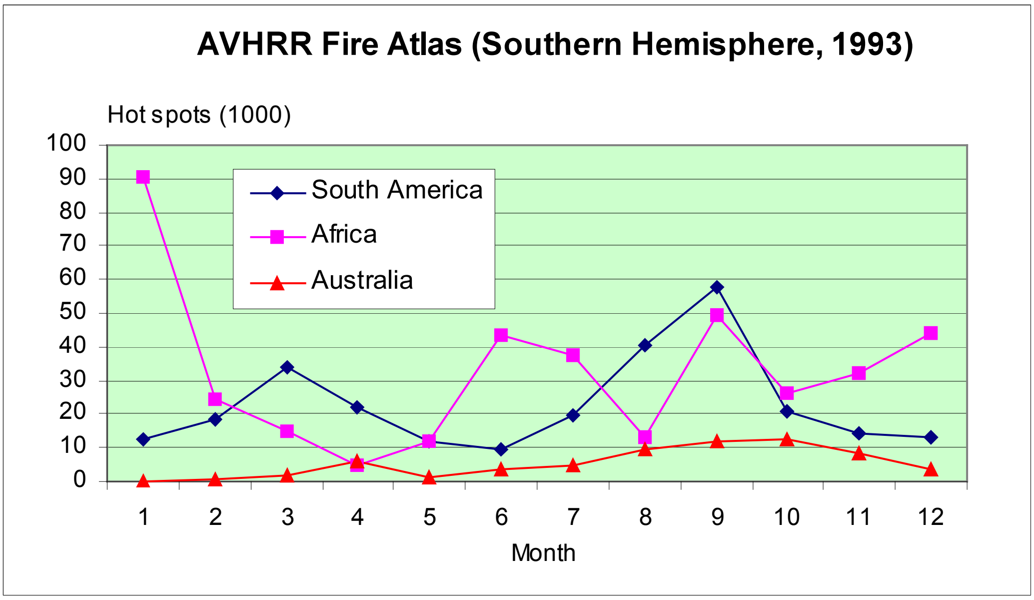


Fig. A.2.16. Seasonality of biomass burning in the AVHRR Fire Atlas (Southern Hemisphere). Source: ESA/ESRIN, Frascati, Italy

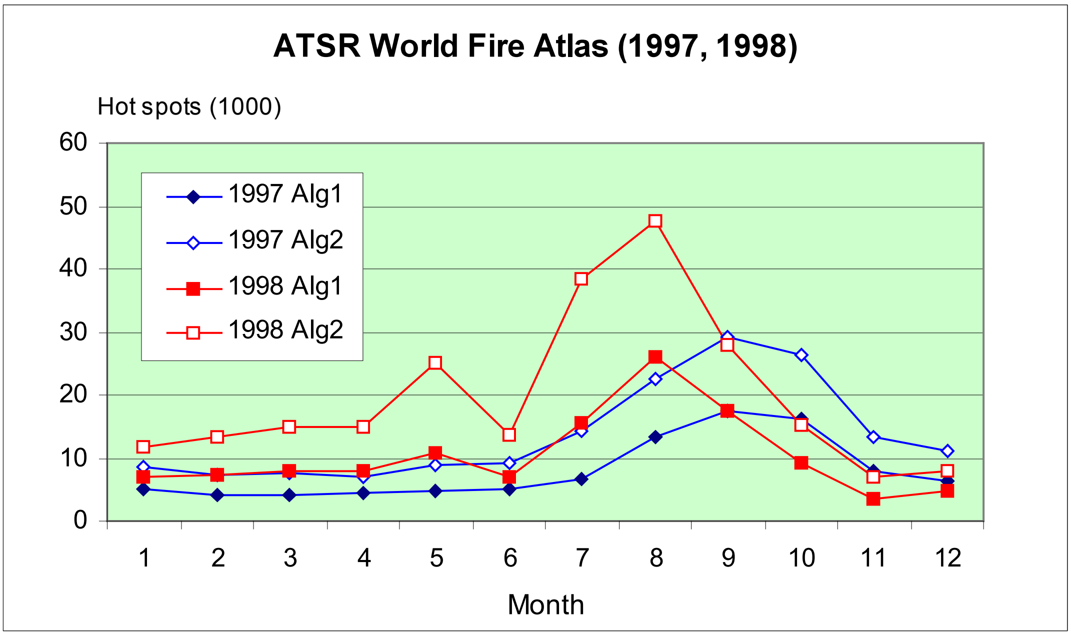


Fig. A.2.17. Differences in hotspot numbers in the ATSR World Fire Atlas in using different algorithms for identifying biomass burning. Source: ESA/ESRIN, Frascati, Italy

Appendix 3: Construction of the total, urban and rural human population maps in EDGAR 3.2

A.3.1. Selection of total population map

At present, several gridded population map are publicly available, such as the 1°x1° maps from Harvard/Logan (Logan, 1993, pers. comm.), NASA-GISS (www.giss.nasa.gov/data/landuse/people.html), two maps at 10'x10' NGCIA (2000), and the GEIA map on 1°x1° by Li (1996). In EDGAR 3 we use the Li map (see Fig. A.1) since it is the only map available at 1°x1° which has the following qualifications:

- a uniform spatial quality for all countries - in contrast with the NGCIA maps, which are based on sub-national census data that have in many cases a very high spatial resolution, but also include several countries - e.g. the Russian Federation - of which the smallest units are much larger then a 1°x1° grid cell;
- a detailed rural population distribution due to the inclusion of small towns to the size of 10,000 inhabitants and compiled for a recent year - in contrast with the NASA-GISS and Harvard/Logan maps, which were compiled for an older year and using less details for the rural area;
- it locates population in the proper grid cell - whereas allows taking account of border cells, which include areas of more than one country/sea area.

For these reasons the map compiled by Li was selected by GEIA as the default GEIA population map for new inventories. Therefore, we also decided to use this map, although the EDGAR software presently does use the multi-country/sea feature provided in the dataset. We combined the Li map with the NASA-GISS one grid cell-to-one-country relation table for distributing national total emissions of a particular source to the grid cells allocated to the countries. Moreover, due to the more detailed spatial resolution in the rural areas, the Li map is better suited for splitting into urban and rural sub-maps.

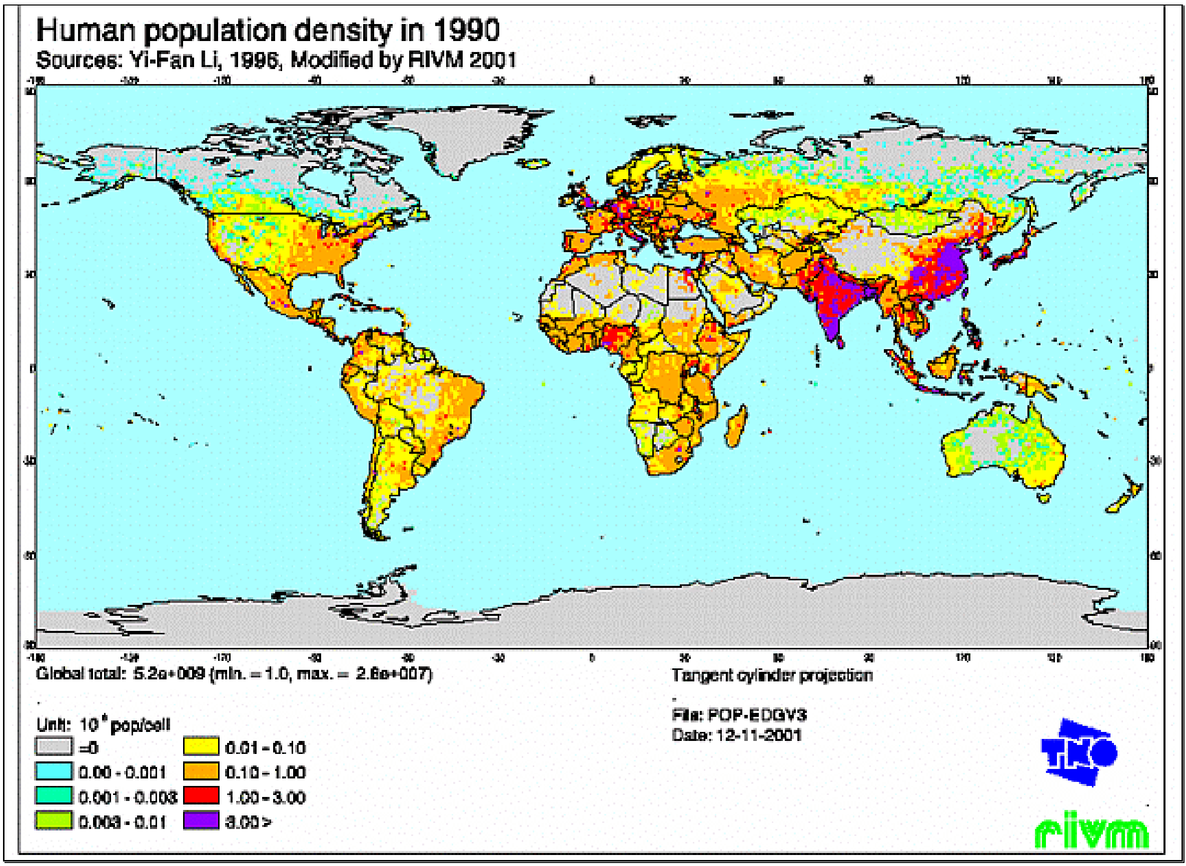


Fig. A.1. GEIA map of total human population density in 1990 (Li , 1996).

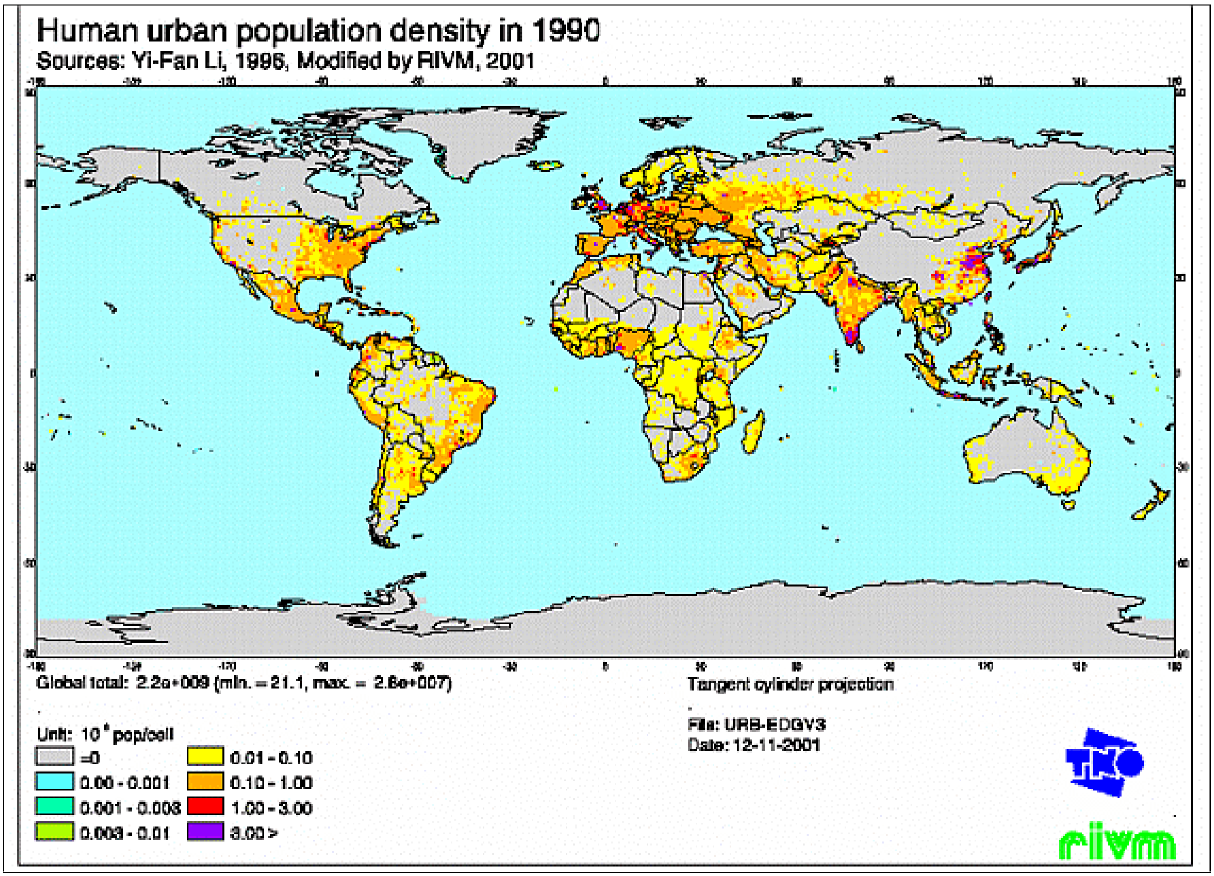


Fig. A.2. EDGAR 3 map of urban population density in 1990.

A.3.2. Construction of separate urban and rural population maps

The reason for compiling separate maps for urban and rural population from the total human population map of Li at 1°x1° was to be able to restrict emissions from large scale activities, e.g. from industry and power generation, to the urban population areas when no source-specific map is available. In this way we can avoid that a fraction of the emissions of these sources is also allocated to distant, rural areas. Although that share would have been small (say up to 10-20% in most cases) and sometimes distributed over many cells, in absolute levels it may be a substantial amount, thus increasing rural emissions significantly. This effect has now largely been eliminated from the previous spatial distribution used e.g. in EDGAR 2. We believe that for some atmospheric model applications this may prove to be a sensitive issue.

The ***urban population map*** has been used for the following sources (when source-specific maps were not available, instead of total population:

Power generation; industrial combustion; industrial processes (non-combustion); energy transformation of fossil fuels (coke ovens, oil refineries), including charcoal production; CO_2 from non-energy/feedstock use of energy carriers

Commercial sector (fuel combustion by commercial and public services)

Usage of N_2O, HFCs, PFCs and SF_6

Ethanol in road transport

Hazardous waste disposal sites

The urban fraction of uncontrolled waste burning, of human wastewater disposal/treatment, and industrial WWTP.

In addition, the ***rural map*** has been applied for the following sources:

Fossil fuel and biofuel combustion in the agricultural sector

Biofuel combustion of bagasse, dung and vegetal waste in the residential and commercial sectors

The rural fraction of uncontrolled waste burning and of human wastewater disposal/treatment.

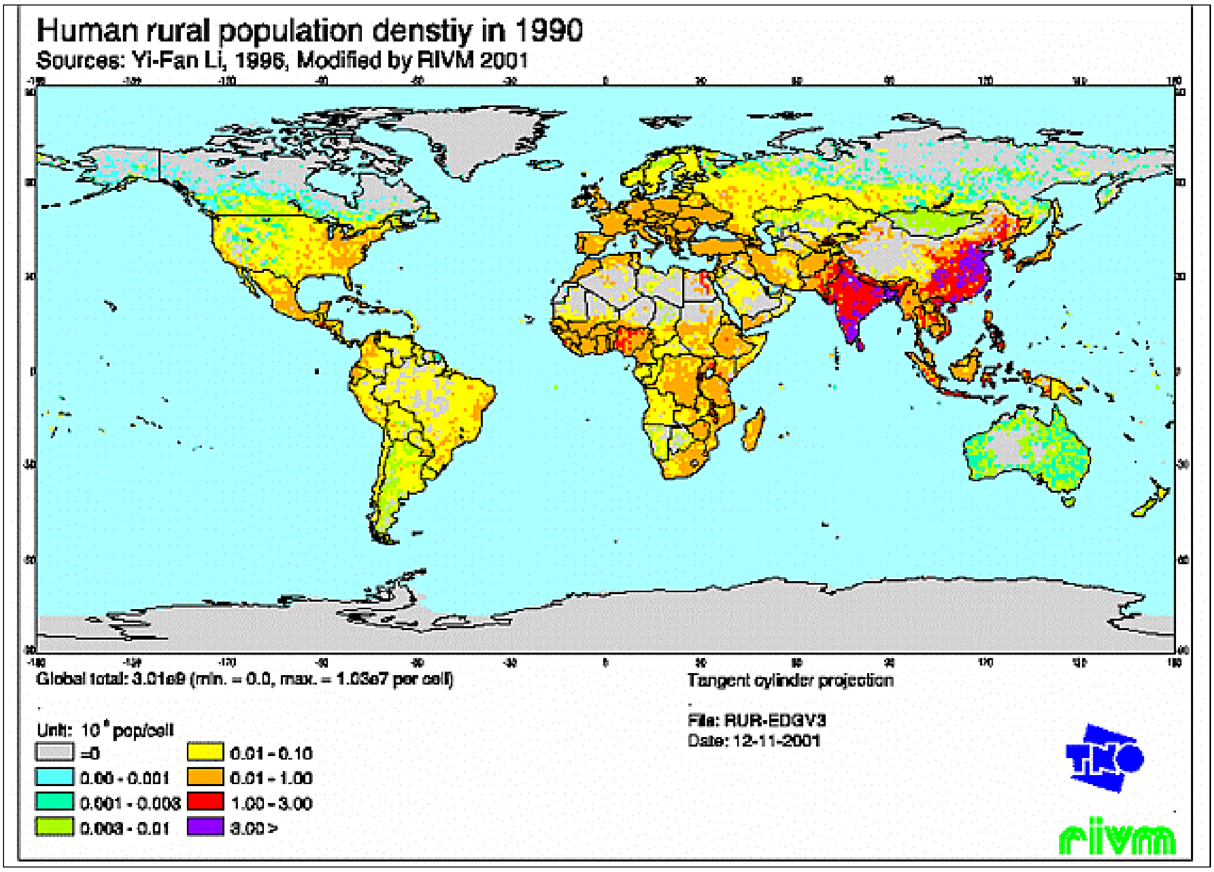


Fig. A.3. EDGAR 3 map of rural population density in 1990.

A.3.3. Construction of urban and rural population maps for EDGAR 3 from the GEIA/Li total population map

There is no generally agreed definition of 'rural' and 'urban' population or 'rural' and 'urban' area (Clark and Rind, 1992). Sometimes the distinction is between settlements smaller or larger than 10,000 inhabitants living in a built-up area. However, then the question is what is a built-up area: are these households living all adjacent to each other, or are they (partly) distributed over a large area with distances between houses of 100s or 1000s of metres? Also the definitions that countries use in reporting their national fraction of urban and rural population to the UN Population Statistics Division differ in practice, often to an unknown extent.

Therefore we decided to use a pragmatic approach in separating out the area and population in the country that is living in smaller units, e.g. smaller than 10,000. Since the grid cells at $1^o x 1^o$ can be as large as the order of 100x100 km near the equator, many rural communities may live in one grid cell. So taking a cut-off of 10,000 persons per grid cell would be a too simple approach. Instead we made the following argument:

make the spatial distinction into rural and urban areas within a country only for the larger ones, since for the smaller ones the spatial redistribution effects will be much smaller;

use a default urban population density (in pers/km^2) for continuously built-up urban areas based on data for a selection of European type of cities;

if the population density of a grid cell is higher than is this urban cut-off value, we assume the cell to be 100% urban;

if the population density is less than a selected rural cut-off density, we assume the cell to be 100% rural;

also if the *total* population of a grid cell is lower is than 10,000, we assume the cell to be 100% rural;

for all intermediate cells, i.e. grid cells with a population density between the urban and rural cut-off values, we ranked the grid cells per country in order of decreasing population density and applied an algorithm for allocating fractions of urban/rural population per grid cell in such a way that the national urban and rural population fractions were equal to the fractions published in the 1990 population statistics of the UN (1999).

The resulting maps have been compared with high-resolution urban and rural population maps for China, where urban population was based on a cut-off density per high-resolution grid cell. Both visual inspection of the spatial pattern as well as the shape of the urban and rural population density distributions (number of grid cells ranked according to decreasing densities) showed good agreement.

The results of this algorithm are shown in *Figures A.2* and *A.3*, where we show the urban and rural maps, respectively, using the same classification as in the total population map of *Figure A.1*. Visual inspection clearly shows that the urban map is not extending in thin populated areas in larger countries such as the northern part of Canada, mid-west of the USA, remote areas of the Russian Federation, western and north-eastern parts of China, and mid Australia.

Appendix 4: EDGAR 3.2: sources, regions, results

A.4.1. SOURCE GROUPING IN SUMMARY TABLES

This grouping basically follows the definition of IPCC source categories 1 to 6:

Fossil fuel (EDGAR category 'F'):

Fossil fuel combustion (IPCC 1A)
Fossil fuel production, handling, transmission and distribution (IPCC 1B)
Energy transformation of fossil fuels (coke ovens, oil refineries) (IPCC 1B)
CO_2 from non-energy/feedstock use of energy carriers (IPCC 1A or 2, 3, 6)

Biofuel (EDGAR category 'B'):

Combustion of fuelwood, charcoal, vegetal waste and other non-commercial biomass fuels (IPCC 1A)
Combustion of wood/wood waste in industry and power generation (for energy purposes) (IPCC 1A)
Production of charcoal (IPCC 1B)

Industrial processes (EDGAR category 'I'):

Non-combustion processes in industry (IPCC 2)
Solvent use in all sectors (IPCC 3)

Agriculture (EDGAR category 'L'):

Animal breeding: enteric fermentation and animal waste handling) (IPCC 4A and 4B, respectively)
Arable land: fertiliser use (synthetic and animal waste used as fertiliser) (IPCC 4D)
Rice cultivation (IPCC 4C)
Other crops (N-fixing crops, crop residues on/in soil, histosoils) (IPCC 4D)
Agricultural waste burning (field burning) (IPCC 4F)
Savannah burning (IPCC 4E)
Indirect N_2O sources (IPCC 4D)

Biomass burning (EDGAR category 'L'):

Deforestation (IPCC 5)
Temperate vegetation fires (IPCC 5)

Waste handling (EDGAR category 'W'):

Landfills (IPCC 6A)
Waste water treatment (IPCC 6B)
Human waste water disposal (IPCC 6B)
Waste incineration (uncontrolled residential burning, controlled non-energy burning) (IPCC 6C)
Hazardous waste handling (IPCC 6D)

Production and use of halocarbons and other fluorinated gases (EDGAR category 'H'):

Production of halocarbons (CFCs, halons, HCFCs, methyl bromide, etc.) and other F-gases (IPCC 2E)
By-product emissions from HCFC-22 manufacture (IPCC category 2E)
By-product emissions from primary aluminium production (IPCC category 2C)
Use of halocarbons and other F-gases in all sectors (HFCs, PFCs, SF_6) (IPCC categories 2C and 2F)

Other (EDGAR category 'F'):

Fossil fuel fires

A.4.2. SOURCE GROUPING IN COUNTRY SUMMARY TABLES (e.g. IEA TABLES)

For carbon dioxide:

"Fuel combustion" refers to fossil fuel combustion and non-energy/feedstock use (IPCC category 1A);

"Fugitive" refers to flaring and venting of associated gas in oil and gas production (IPCC category 1B);

"Industry" refers to cement production (IPCC category 2); and

"Others" refers direct emissions from tropical forest fires plus 10% of biofuel combustion emissions, which is the fraction assumed to be produced unsustainably (IPCC category 5).

For methane:

"Energy" comprises production, handling, transmission and combustion of fossil fuels and biofuels (IPCC category 1A and 1B);

"Agriculture" comprises animals, animal waste, rice production, agricultural waste burning (non-energy, on-site) and savannah burning (IPCC category 4);

"Waste" comprises landfills, wastewater treatment, human wastewater disposal and waste incineration (non-energy) (IPCC category 6);

"Others" include industrial process emissions and tropical and temperate forest fires (IPCC categories 2 and 5).

For nitrous oxide:

"Energy" comprises combustion of fossil fuels and biofuels (IPCC category 1A and 1B);

"Agriculture" comprises fertiliser use (synthetic and animal manure), animal waste management, agricultural waste burning (non-energy, on-site) and savannah burning (IPCC category 4);

"Waste" comprises human sewage discharge and waste incineration (non-energy) (IPCC category 6);

"Others" include industrial process emissions, N_2O usage and tropical and temperate forest fires (IPCC categories 2, 3 and 5).

For carbon monoxide, nitrogen oxides, NMVOC and sulphur dioxide:

"Fuel combustion" refers to fossil fuel combustion and evaporation of NMVOC in road transport (part of IPCC category 1A);

"Biofuel combustion" refers to traditional biofuels as well as to wood waste, paper, ethanol, etc. (part of IPCC category 1A);

"Fugitive" comprises flaring and venting of associated gas in oil and gas production, handling / transmission losses of oil and charcoal production (IPCC category 1B);

"Industry" refers to non-combustion industrial processes, excluding solvent use (IPCC category 2);

"Solvent use" refers to solvent use in industry and non-industry sectors (IPCC category 3);

"Agriculture" comprises agricultural waste burning (non-energy, on-site) and savannah burning (IPCC category 4);

"Waste" comprises waste incineration (non-energy) (uncontrolled residential burning and controlled non-residential burning) and hazardous waste handling (IPCC category 6);

"Others" comprises tropical forest fires and temperate forest fires (IPCC category 5A).

A.4.3. SOURCE GROUPING IN F-GAS SUMMARY TABLES

For HFCs:

HCFC-22 manufacture (by-product emissions) (IPCC category 2E)

HFC usage (refrigeration, fire extinguishers, semiconductor manufacturing, miscellaneous use) (IPCC categories 2E and 2F)

For PFCs:

Primary aluminium production (by-product emissions) (IPCC category 2C)

HFC usage in semiconductor manufacturing (IPCC category 2E)

PFC usage (semiconductor manufacture, refrigeration, fire extinguishers, aerosols, foam blowing, accelerators (high energy physics), solvents, miscellaneous) (IPCC category 2F)

For SF_6:

Electrical equipment Manufacture (OEM) (manufacture, on-site erection of GIS (*Gas Insulated Switchgear*), circuit breakers etc.) (IPCC category 2F)

Electrical equipment use (maintenance/leakage of GIS (*Gas Insulated Switchgear*), circuit breakers etc.), in accelerators (high energy physics) and unknown applications through sales to utilities (IPCC category 2F)

Magnesium industry (primary production and die casting) (IPCC category 2C)

Semiconductor manufacture (IPCC category 2F)

Adiabatic property applications (use in car tires, soles of sport shoes, etc.) (IPCC category 2F)

Miscellaneous use (soundproof windows, aluminium degassing, other use excluding Russia and China) (IPCC categories 2C and 2F)

Miscellaneous use by Russia and China (IPCC categories 2C and 2F)

A.4.4. REGIONS IN EDGAR 3: CHANGES COMPARED WITH VERSION 2

Renaming

The regional subdivision has been adjusted to the RIVM's new regional subdivision (Kreileman *et al.,* 1998), which is also used by other global projects such as IMAGE 2.1. EDGAR 3 uses these regional definitions, with aggregations for Latin America and Africa, which in the basic subdivision are divided into 2 and 4 smaller regions, respectively. In practice, the largest changes have occurred in the EDGAR 2.0 regions "India region", "China regions" and "East Asia", which have been *renamed* as "South Asia", "East Asia" and "Southeast Asia", respectively. In *Figure 1* these regions and the corresponding EDGAR 3 regions are shown on a world map.

Change in definitions

In order to comply with the standard RIVM regional subdivision, the definition of the three Asian regions has been changed as follows:

Afghanistan (AFG):	moved from 10 (H) to 11 (South Asia)
Korea (South) (KOR):	moved from 13 (K) to 12 (East Asia)
Papua New Guinea (PNG):	moved from 13 (K) to 04 (Oceania)
Cambodia (KHM):	moved from 12 (J) to 13 (Southeast Asia)
Laos (LAO):	moved from 12 (J) to 13 (Southeast Asia)
Vietnam (VNM):	moved from 12 (J) to 13 (Southeast Asia)

Furthermore, since the former DDR and the BRD have been merged into Germany (United), which is part of the "OECD Europe" region, compared with EDGAR 2.0 the following change was made:

Former DDR (DDR):	moved from 6 (F) to 03 (OECD Europe)

Besides these changes between regions, the following major changes occurred within regions:

Former USSR [07 (G)]:	split into 15 new countries
Former Yugoslavia [06 (F)]:	split into 5 new countries
Former Czechoslovakia [06 (F)]:	split into 2 new countries
Former Ethopia [09 (D)]:	split into 2 new countries

Finally, a number of small countries/islands have been added to the old regional definitions.

Reordering

In addition, the order of regions in EDGAR 3 has been changed; now the OECD, Economies-In-Transition (EIT) and Less Developed Countries (LDC) regions have been grouped together, respectively. These three regional clusters are somewhat homogeneous with respect to the development of the national statistical systems and the emission factors for a number of source categories.

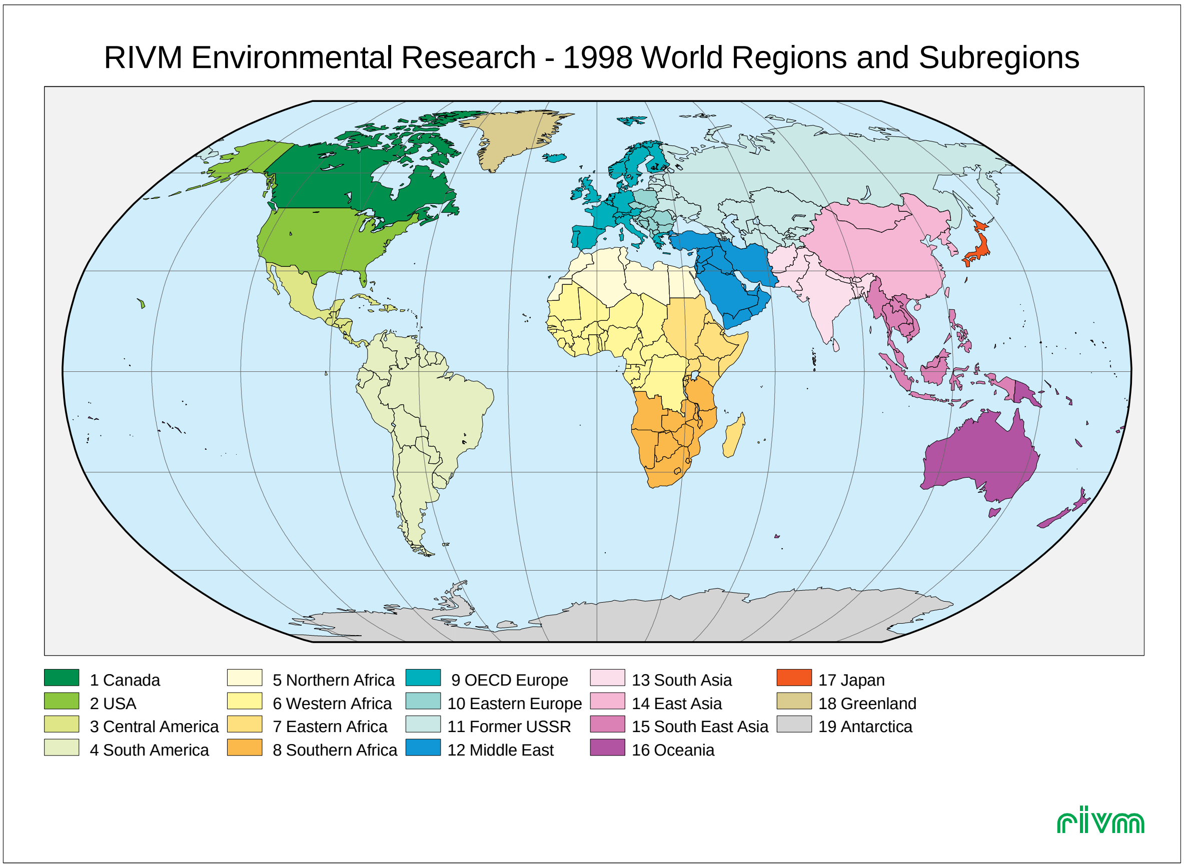


Figure : Regional subdivision of the world in IMAGE 2 and EDGAR 3

EDGAR 3 regions: *

01-Canada (IM1)
02-USA (IM2)
03-OECD Europe (IM9)
04-Japan (IM17)
05-Oceania (IM16)

06-Eastern Europe (IM10)
07-Former USSR (IM11)

08-Latin America (IM3+4)
09-Africa (IM5+6+7+8)
10-Middle East (IM12)
11-South Asia (13)
12-East Asia (14)
13-Southeast Asia (15)

14-Greenland (IM18)
15-Antarctica (IM19)
16-Oceans (IM--)

* Corresponding IMAGE regions between brackets.

A.4.5. SUMMARY RESULTS OF EDGAR 3.2 FOR 1995: GLOBAL AND REGIONAL EMISSIONS

Note: Totals may not equal the sum of components because of independent rounding.

Table A.4.1. Sources and regional contribution of emissions of CO_2 in 1995 (Tg CO_2)

	Global total	Canada	USA	OECD Europe	Oceanica	Japan	Eastern Europe	Former USSR	Latin America	Africa	Middle East	South Asia	East Asia	South East Asia
Fossil fuel	**24027**	503	5507	3618	341	1237	978	3056	1188	741	1087	976	4146	649
Biofuel	**532**	1	30	9	2	2	3	14	30	109	6	146	111	69
Industrial processes	**716**	5	38	91	4	45	20	27	49	27	55	38	275	44
Agriculture	**13**	0	1	2	3	4	5	6	7	8	9	10	11	12
Biomass burning	**1664**	0	5	1	51	1	0	0	1776	797	12	73	36	1048
Waste handling	**13**	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**26965**	**509**	**5582**	**3721**	**400**	**1289**	**1006**	**3102**	**3049**	**1682**	**1169**	**1243**	**4579**	**1821**

Table A.4.2. Sources and regional contribution of emissions of CH_4 in 1995 (Tg)

	Global total	Canada	USA	OECD Europe	Oceanica	Japan	Eastern Europe	Former USSR	Latin America	Africa	Middle East	South Asia	East Asia	South East Asia
Fossil fuel	91.1	2.1	21.5	4.3	1.3	0.8	4.7	24.0	3.4	3.5	6.0	1.9	13.5	4.0
Biofuel	13.9	0.0	0.3	0.1	0.0	0.0	0.1	0.3	0.5	3.6	0.2	4.0	2.9	1.8
Industrial processes	0.8	0.0	0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.2	0.0
Agriculture	134.1	1.0	7.5	7.7	4.2	0.4	2.2	7.8	21.8	14.5	2.2	28.2	23.9	12.7
Biomass burning	6.5	1.5	0.2	0.1	0.1	0.0	0.0	0.1	2.0	1.0	0.0	0.1	0.0	1.3
Waste handling	55.7	1.2	10.3	5.0	0.6	1.6	1.2	3.7	7.2	4.1	1.5	8.1	7.6	3.5
Total	**301.9**	**5.8**	**39.8**	**17.4**	**6.3**	**2.9**	**8.2**	**36.0**	**35.1**	**26.7**	**9.9**	**42.3**	**48.2**	**23.3**

Table A.4.3. Sources and regional contribution of emissions of N_2O in 1995 (Tg N_2O)

	Global total	Canada	USA	OECD Europe	Oceanica	Japan	Eastern Europe	Former USSR	Latin America	Africa	Middle East	South Asia	East Asia	South East Asia
Fossil fuel	0.29	0.01	0.11	0.04	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.05	0.01
Biofuel	0.18	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.00	0.05	0.03	0.02
Industrial processes	0.74	0.04	0.19	0.29	0.00	0.03	0.07	0.02	0.02	0.02	0.01	0.01	0.02	0.01
Agriculture	9.65	0.13	1.06	0.89	0.44	0.04	0.21	0.46	1.51	1.24	0.40	1.12	1.74	0.40
Biomass burning	0.39	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.17	0.08	0.00	0.01	0.00	0.11
Waste handling	0.27	0.00	0.16	0.08	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Total	**11.5**	**0.2**	**1.5**	**1.3**	**0.5**	**0.1**	**0.3**	**0.5**	**1.7**	**1.4**	**0.4**	**1.2**	**1.8**	**0.5**

Source: EDGAR 3.2

Table A.4.4. Global trend in sources of F-gases HFCs, PFCs and SF_6 in 1995 (Tg CO_2-eq.)

	1970	1975	1980	1985	1990	1995
PFC Aluminium production	73.9	83.3	92.5	84.4	73.5	69.3
PFC Semiconductor manufacturing	0.0	0.0	0.1	1.1	3.5	17.0
PFC Solvent use	0.0	0.0	0.0	0.0	3.3	10.6
PFC Other	0.0	0.0	0.1	0.4	0.9	2.7
HFC from HCFC-22 production	15.7	22.0	39.1	50.2	74.2	84.8
HFC from 134a use	0.0	0.0	0.0	0.0	0.0	26.6
HFC Other use	0.0	0.0	0.0	0.0	0.0	13.6
SF6 Electricity sector	15.2	27.5	54.1	67.8	82.4	119.7
SF6 Magnesium production	1.1	2.9	7.7	10.4	9.2	10.5
SF6 Semiconductor manufacturing	0.2	0.3	0.4	0.5	3.3	7.8
SF6 Other use	0.9	2.9	4.9	6.5	12.4	21.3
Total	**107.0**	**138.9**	**198.7**	**221.4**	**262.8**	**384.0**

Source: EDGAR 3.3

Table A.4.5. Sources and regional contribution of emissions of CO in 1995 (Tg)

	Global total	Canada	USA	OECD Europe	Oceanica	Japan	Eastern Europe	Former USSR	Latin America	Africa	Middle East	South Asia	East Asia	South East Asia
Fossil fuel	278.3	6.0	76.7	36.2	4.2	6.9	8.8	26.9	27.2	11.2	16.6	5.1	42.6	10.0
Biofuel	231.6	0.4	5.6	2.1	0.6	0.1	1.2	5.8	9.6	56.3	2.7	68.4	49.2	29.6
Industrial processes	31.8	0.4	2.4	5.8	0.4	4.4	1.6	5.0	1.8	0.4	0.4	1.0	8.0	0.2
Agriculture	16.4	0.2	1.0	0.8	0.6	0.1	1.3	1.9	2.9	2.2	2.2	0.6	0.4	2.2
Biomass burning	298.9	45.7	4.9	2.8	12.8	0.1	0.0	2.3	83.3	114.4	0.4	2.2	1.4	28.5
Waste handling	3.8	0.1	1.3	0.2	0.1	0.5	0.1	0.2	0.3	0.2	0.1	0.3	0.4	0.1
Total	**860.8**	**52.7**	**91.9**	**47.9**	**18.7**	**12.0**	**13.1**	**42.2**	**125.1**	**184.8**	**22.3**	**77.6**	**101.9**	**70.7**

Source: EDGAR 3.2

Table A.6.6. Sources and regional contribution of emissions of NO_x in 1995 (Tg NO_2)

	Global total	Canada	USA	OECD Europe	Oceanica	Japan	Eastern Europe	Former USSR	Latin America	Africa	Middle East	South Asia	East Asia	South East Asia
Fossil fuel	**83.5**	1.9	19.8	13.0	1.5	2.9	2.4	9.1	5.7	3.2	4.5	4.1	12.2	3.1
Biofuel	**7.7**	0.0	0.5	0.1	0.0	0.0	0.0	0.2	0.5	1.5	0.1	2.3	1.5	0.9
Industrial processes	**6.1**	0.1	0.5	0.9	0.0	0.4	0.2	0.4	0.4	0.2	0.4	0.3	2.0	0.3
Agriculture	**0.7**	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.1
Biomass burning	**13.0**	1.8	0.2	0.1	0.7	0.0	0.0	0.1	3.3	6.0	0.0	0.1	0.1	0.7
Waste handling	**0.1**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**111.3**	**3.8**	**21.0**	**14.2**	**2.3**	**3.4**	**2.8**	**9.9**	**10.1**	**11.1**	**5.1**	**6.7**	**15.9**	**5.1**

Source: EDGAR 3.2

Table A.4.7. Sources and regional contribution of emissions of NMVOC in 1995 (Tg)

	Global total	Canada	USA	OECD Europe	Oceanica	Japan	Eastern Europe	Former USSR	Latin America	Africa	Middle East	South Asia	East Asia	South East Asia
Fossil fuel	**79.0**	2.4	10.7	10.1	1.4	3.0	1.4	13.5	8.4	4.8	11.5	2.0	5.5	4.5
Biofuel	**28.0**	0.0	0.8	0.3	0.1	0.0	0.1	0.7	1.4	6.9	0.3	8.1	5.9	3.5
Industrial processes	**25.4**	0.5	6.6	5.4	0.3	2.6	0.9	2.6	1.6	0.8	0.6	0.8	1.9	0.9
Agriculture	**2.0**	0.0	0.1	0.1	0.1	0.0	0.2	0.2	0.3	0.3	0.3	0.1	0.0	0.3
Biomass burning	**22.4**	6.1	0.7	0.4	0.9	0.0	0.0	0.3	4.9	7.4	0.0	0.1	0.1	1.5
Waste handling	**2.7**	0.1	0.7	0.5	0.0	0.3	0.1	0.3	0.2	0.1	0.1	0.1	0.2	0.1
Total	**159.6**	**9.2**	**19.5**	**16.8**	**2.8**	**5.9**	**2.7**	**17.6**	**16.8**	**20.1**	**12.7**	**11.1**	**13.7**	**10.8**

Source: EDGAR 3.2

Table A.4.8. Sources and regional contribution of emissions of SO_2 in 1995 (Tg SO_2)

	Global total	Canada	USA	OECD Europe	Oceanica	Japan	Eastern Europe	Former USSR	Latin America	Africa	Middle East	South Asia	East Asia	South East Asia
Fossil fuel	**111.2**	2.2	17.1	11.4	1.0	1.5	8.9	13.0	4.9	3.8	5.1	5.4	34.0	3.0
Biofuel	**2.9**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.6	0.0	1.5	0.5	0.1
Industrial processes	**25.0**	0.4	1.0	5.0	0.5	0.6	1.6	3.0	4.4	1.3	0.5	0.5	5.7	0.5
Agriculture	**0.2**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass burning	**2.5**	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.7	1.1	0.0	0.0	0.0	0.2
Waste handling	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**141.9**	**2.8**	**18.1**	**16.5**	**1.7**	**2.2**	**10.5**	**16.0**	**10.1**	**6.9**	**5.7**	**7.5**	**40.2**	**3.8**

Source: EDGAR 3.2

Table A.4.9. Sources and regional contribution of emissions of CO_2, CH_4 and N_2O in 1995 (Tg CO_2-equivalent)

	Total	Canada	USA	OECD Europe	Oce-ania	Japan	Eastern Europe	Former USSR	Latin America	Africa	Middle East	South Asia	East Asia	SE Asia
CO_2														
Fossil fuel	24027	503	5507	3618	341	1237	978	3056	1188	741	1087	976	4146	649
Biofuel	532	1	30	9	2	2	3	14	30	109	6	146	111	69
Industrial	716	5	38	91	4	45	20	27	49	27	55	38	275	44
Agriculture	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biomass burning	3801	0	5	1	51	1	0	0	1776	797	12	73	36	1048
Waste handling	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sub-total	*29075*	*509*	*5581*	*3719*	*397*	*1285*	*1001*	*3096*	*3042*	*1674*	*1160*	*1233*	*4568*	*1809*
CH_4														
Fossil fuel	1912	44	451	91	27	17	99	505	71	73	127	40	284	84
Biofuel	291	0	7	3	1	0	2	7	11	75	3	83	61	37
Industrial	16	0	1	3	0	2	1	2	1	0	0	1	5	0
Agriculture	2816	20	158	161	89	8	46	163	458	305	47	593	501	267
Biomass burning	136	32	3	2	3	0	0	2	43	21	0	2	1	28
Waste handling	1169	26	215	105	13	34	25	77	152	86	31	171	160	73
Sub-total	*6341*	*123*	*836*	*365*	*133*	*61*	*172*	*756*	*736*	*561*	*209*	*889*	*1012*	*488*
N_2O														
Fossil fuel	90	2	33	11	2	5	3	7	3	2	2	3	15	2
Biofuel	56	0	3	1	0	0	0	2	4	11	1	16	11	8
Industrial	230	12	60	90	1	9	22	7	8	5	4	3	8	2
Agriculture	2991	41	328	276	136	14	65	142	468	385	123	346	539	123
Biomass burning	121	5	1	0	2	0	0	0	51	25	0	2	0	33
Waste handling	83	1	48	23	0	3	1	1	4	0	0	0	0	0
Sub-total	*3571*	*62*	*473*	*402*	*140*	*30*	*91*	*158*	*538*	*429*	*130*	*371*	*573*	*168*
Grand Total	38987	693	6890	4486	670	1376	1264	4011	4316	2664	1499	2492	6153	2466

Source: EDGAR 3.2

Appendix 5: Project description

PROJECT DESCRIPTION FORM NATIONAL RESEARCH PROGRAMME ON GLOBAL AIR POLLUTION AND CLIMATE CHANGE

Project: Applications of EDGAR:

the Emission Database for Global Atmospheric Research

A. Rationale

The central objective is, by using the analytical structure of EDGAR, to serve both policy makers and atmospheric modellers by providing (a) materials supporting international policy development and (b) the IMAGE 2 model with up-to-date emission data to calculate regional emissions and other modellers with emissions on grid. In support of serving these key target groups three types of activities have been defined:

1. Validation and uncertainty analysis:
- with European inventories
- with national inventories prepared for the FCCC (including recommendations to IPCC)
- with GEIA inventories

2. Monitoring and integration:
- annual assessment of emission trends (direct greenhouse gases [GHG] only)
- periodic updates of the inventories (including recent activity data, country specific emission estimates (CORINAIR, FCCC), NRP results)
- evaluation of key sources/regions in the (updated) inventories and ad hoc advice to policy makers
- provide inventory data to the IMAGE 2 model, other (NRP) projects, IPCC and to GEIA.

3. Improvement and extension of EDGAR:
- time profiles
- new compounds
- improved source estimates (e.g. biofuels, biomass burning)
- software modifications

The rationale of these activities will be described below.

A.1 Validation and uncertainty analysis

At present EDGAR inventories are mainly different from those developed by the Global Emission Inventory Activity (GEIA), in that the EDGAR inventories are more consistent with respect to reference year, across sectors and across compounds. Inventories of GEIA, which is part of the International Global Atmospheric Chemistry (IGAC) project of the International Geosphere-Biosphere Programme (IGBP), are currently merely joints of regional emission maps, without any structural detail on the sources. Because of its structured approach, EDGAR facilitates: (a) the extraction of emission factors aggregated over major sources or specific regions, and (b) the construction of future and historic emissions scenarios by linkage with a scenario model like IMAGE. EDGAR will remain faster than GEIA in generating comprehensive emissions data for modellers.
The current version of EDGAR has been validated by comparing global total and regional total emissions with other estimates, notably those reviewed by the Intergovernmental Panel on Climate Change (IPCC). One way of validating EDGAR is by comparison of EDGAR/GEIA data with regional inventories such as of CORINAIR/EMEP and with greenhouse gas (GHG) inventories submitted to the secretariat of the Framework Convention on Climate Change (FCCC). This will result in a mutual validation of both EDGAR/GEIA and FCCC national inventories as well as of

calculation methods. By first validating and then calibrating European emissions to the CORINAIR'90 inventory EDGAR will achieve comparable regional emissions for global and continental atmospheric models, and will be consistent with emission figures used for continental air pollution issues such as acidification. Another way of validating the data is by comparison with independently developed inventories of the Global Emission Inventory Activity (GEIA) project. A number of GEIA inventories are compilations of databases produced elsewhere, while EDGAR uses activity levels and emission factors whenever possible. Differences between the two approaches will highlight uncertainties in specific regions of the world, and may lead to corrections in the EDGAR and/or GEIA approach. Another method of validation is to investigate sources and sinks by atmospheric modelling using a forward or inverse modelling approach. Both types require good a-priori emission estimates of all sources.

Furthermore, for model application as well as for policy development, there is a need to assess (roughly) the uncertainties in emissions inventories: to determine the uncertainty in calculated concentrations, in regional or sectoral contributions to global emissions and in emission scenarios as well as in the effectiveness of policy options. There is controversy about the relative importance of sources such as landfills, wet rice fields and natural wetlands in the global CH4 budget; the sources in the N2O budget are even more uncertain. For other (indirect) greenhouse gases uncertainties are also quite large, in particular for emissions in developing countries. Each global inventory has its specific uncertainty, related to the quality of data or to the method of extrapolation.

A.2 Monitoring and integration

Monitoring of emission trends, which is important for science and policy applications, is done by (a) annually estimating the development of key sources of direct GHGs based on new data, and (b) periodically updating the inventories by using recent activity level data, national GHG emission estimates, NRP results and new emission calculation methodologies.

The results will be used for an evaluation of the key regions/countries, sectors and compounds which determine the global growth of GHG emissions. Also, national emission inventories prepared for the FCCC and the UNEP secretariat to the Montreal Protocol may be used, but these do not cover all countries nor do they cover all sources and gases. Such an analysis will identify areas where reduction policies appear to be most effective and whether improved calculation methodologies lead to a shift in policy planning with respect to key regions and key source categories. Ad hoc advice to the government, IPCC/FCCC or GEIA on emissions, calculation methodology and the effectiveness of reduction options is also possible, using the analytical structure of EDGAR as a bridge between science and policy makers.

Results of NRP 1 and 2 will yield new insights for a number of emission source categories. However, to determine the applicability for emission factors, time profiles and temporal distributions *on a global scale* is often not straightforward. Results of NRP may help to evaluate the state of knowledge in specific fields.

In general, the dissemination of cross sections of (updated) emissions data to other NRP projects will enlarge the integration within the NRP and thus enhance the comparability of NRP results. Results from EDGAR will be provided to the IMAGE 2 model to improve and its emission calculation module. Standard data of current inventories are available to other (NRP) projects; updates of inventories will be provided to GEIA.

A.3 <u>Improvement and extension of the EDGAR database and its software</u>

Remarks of NRP participants and the results of the validation of EDGAR as developed in NRP 1 showed an apparent need for some additions to improve the applicability for policy and scientific purposes:

- *Temporal distribution* of the annual data. Many atmospheric models have specific requirements in terms of a temporal distribution of the annual emissions data, e.g. the seasonally or monthly variation within a calendar year. In other words, there is a need for compilation of time profiles suitable for application in conjunction of the annual sectoral emission files extracted from EDGAR.

- *Extension with other compounds* (or NMVOC compound groups), e.g. ammonia and aerosols:
  - A global inventory of *ammonia* (NH_3) will enable improved estimates of atmospheric N2O formation from NH3 and of deposition of NH3 and effects on N_2O formation in soils. This is related to and will affect the break-down of the global N_2O budget.
  - *Atmospheric aerosols* are considered important players in the atmospheric radiative balance: they may counterbalance greenhouse warming. Climate change models should, therefore, include estimates for aerosols. So far no comprehensive inventories have been made for aerosols and *their precursors* (e.g. DMS) with a global coverage.
  - Estimates for NM-VOC may be complemented with *more detailed VOC profiles*, separating out most of the highly reactive species. Most atmospheric models require estimates of the composition of NM-VOC for proper modelling of the chemistry of the *mix* of compounds.
- *Improve data on specific sources,* such as biofuel use, biomass burning, oceans, volcanoes. Currenty emissions estimates for these sources are either very weak or absent. The quality of assessments of anthropogenic emissions will increase substantially when these estimates are improved.
- *Software modifications* to improve the performance of update facilities and data retrieval options, e.g. for VOC profiles and comparisons of emission results of different datasets.

Finally, by a soft-link of EDGAR files with the User Support System of the IMAGE model, consistent emission scenarios on grid can be provided using gridded emissions files from EDGAR to put regional emission projections created by the IMAGE 2 model on a $1^o x 1^o$ grid (NRP project "IMAGE Model Contributions to International Climate Policy and Science", User Support System). These topics are not yet covered in the GEIA programme. Partially, the results will be Dutch contributions to GEIA.

B. Objectives and expected results/products

B.1 Validation and uncertainty analysis

The objectives of this topic are:

(1) to *harmonise* the emissions of European countries with those recently published as CORINAIR'90;
(2) to *enhance the quality* of the EDGAR inventories by incorporating results from the validation in future updates described under B.2;
(3) to provide policy makers with *key information* needed for developing the most effective and robust policies (regions/sectors);
(4) to give *recommendations* to IPCC on improved national calculation methodologies, e.g. default aggregated emission factors;
(5) to improve our understanding of the *uncertainty* involved in global extrapolations such as those made for CH_4 and N_2O. The latter objectives are preconditions to meet the first one.

Comparison of EDGAR data with independently developed GEIA inventories will highlight differences in specific sectors or regions of the world, and may lead to corrections in either the EDGAR approach or the GEIA inventories, or to revisions of uncertainty estimates. Target of the comparison of EDGAR data and national GHG inventories is an evaluation of the independently selected data sources and calculation methodology, resulting in *recommendations to the Dutch government and to the FCCC secretariat* for improving default methods and default emission factors for estimation of national GHG emissions. Compilation of an indication of the uncertainty in emissions, both by source and by region, will identify the areas in which additional policy or additional research may be more or less effective. The conclusions of these activities will be summarised in reports for policy makers and the scientific community.

B.2 Monitoring and integration

Based on new data, in particular on activities, in the context of the annual Environmental Balance co-ordinated by RIVM, *annually assessments* of recent emission trends of direct greenhouse gases will be made on a regional basis. These will include a brief description of developments in key sectors

and regions and of the underlying causes. An important application will be to provide ad hoc *support to national and international policy planning*, based upon conclusions drawn from the inventories and the monitoring of developments in anthropogenic emissions. On request of the *Ministry of Environment (DGM) and others (IPCC/FCCC)*, ad hoc advice or special assessment reports can be written based on data retrieved from the EDGAR system. Foreseen is the preparation of aggregated emission factors that can be used by IPCC Expert Groups to determine default factors for revised IPCC guidelines for national GHG inventories.
Results from EDGAR will be provided to the *IMAGE 2 model* to improve and its emission calculation module. If prepared, updates of current inventories will be provided to *GEIA*.
Furthermore, aiming at fixed, well calibrated datasets, *periodic updates* of the EDGAR database - including gridded inventories - will be produced. Therefore, this will be done not too frequently, only if major changes of insights or base years can be incorporated, e.g. on the basis of:

- changed activity levels and changed emission factors or spatial allocation functions;
- national GHG emission inventories submitted to the FCCC;
- GEIA inventories that replace or update EDGAR work or that are not represented in EDGAR;
- relevant results of NRP 1 and 2 projects and comments from users of EDGAR inventories.

To include NRP results, consultancy with key NRP participants will be organised to exchange information on specific topics. Also, standard *emission files* will be made publicly available, in particular aiming at NRP participants, through anonymous FTP.

B.3. Improvement and extension of EDGAR and its software

This topic involves aspects and inventories that are not yet in EDGAR and that are not yet covered by the GEIA programme:

- Time profiles on a monthly basis, supplementary to the annual gridded emissions files which are made available for the major sources. When possible, existing profiles of similar source categories will be used as preliminary profiles;
- Extensions with new compounds:
  - Global inventory of NH_3; this will also be a contribution to GEIA;
  - Others, depending on data availability, e.g. emission of aerosols and precursors of aerosols (amongst others DMS), including effects of volcanic eruptions; if necessary preliminary inventories may be used;
  - Include other VOC profiles in the inventory of NM-VOC emissions; this will also be a contribution to GEIA.
- Improvement for specific sources. Depending on data availability, updates of global emissions - such as from biofuel use, biomass burning, oceans, volcanoes - will be made available. This will be done through the periodic update of the inventories described under B.2.

New inventories will be made available to other NRP projects and other users in a standardised form. This includes one or more emissions scenarios on 1^ox1^o grid, created by a soft-link between gridded emission files for 1990 from EDGAR and the IMAGE 2 User Support System. Key NRP modellers are: Janssen, Builtjes, Eggink, Kelder, Lelieveld, Vermeulen, using most or all compounds, present and new. To support policy development, for all inventories developed a short assessment report will be made of policy relevant issues.
Foreseen contributions of this project to GEIA are:

- advice on how GEIA inventories can meet the needs of policy makers;
- advice on development of an integrated and consistent suite of emissions inventories;
- advice on the construction of emission scenarios on grid;
- updates of inventories of N_2O (A+N) , VOC (A), and of NO_x (N) and NH_3 (A+N), if any;
- inventories of CH4 from fossil fuel production;
- advice on data management and, possibly, act as Dutch data dissemination centre.

In reverse, new GEIA inventories may improve the structured datasets currently used in EDGAR and co-operation with GEIA participants may supply supplementary information needed to advice the Dutch government or international environmental bodies such as IPCC or the FCCC secretariat. Modifications with respect to compounds and sources will also be subject of discussion with participants of other NRP projects. Also, extensions may be incorporated, when new data become readily available in the format required for EDGAR inventories.

C. Relevance and use for science and policy making

C.1. The results of *validation and uncertainty analysis* will help to improve our scientific understanding of the regional importance of a number of sources of CH_4 and N_2O and of other GHGs. In addition to pure scientific understanding, this has also policy relevance, since it may change ideas on where and how to develop most effective control policies. The results of this work can be also used:

(1) to provide recommendations for improving the default methodology for preparing national inventories,
(2) to assist the secretariat to the FCCC in evaluating and validating national inventories, and
(3) to test compliance of regional or national emissions with agreements in the FCCC.

C.2. *Monitoring and integration* relates to integration efforts and exchange of information between NRP projects and international research groups, regarding fluxes to and from the atmosphere and radiative forcing. Also, the EDGAR team, by its contacts with the two groups, plays a key role as intermediate between the scientific level (GEIA, NRP) and the policy level (Dutch government, IPCC/FCCC). Aggregated emission factors from EDGAR will be very useful for IPCC Expert Groups to determine default factors which are certified to be in line with current estimates of global emission. Annual evaluation of changes in time of emission patterns, by country or region, sector or compound will contribute to most effective environmental policy planning, both at the national and as well as at the international level. In addition, it may contribute to planning of policy relevant future research directions on emissions and atmospheric modelling.

C.3. *Improved estimates* of radiative forcing of climate produced from the global aerosols inventory are important both from a policy and a scientific point of view. The other improvements and extensions of EDGAR have various uses. Inventories for other compounds and representative time profiles will increase the value of results of atmospheric models and their assessment of which are the most policy relevant emissions. In general, inventories for the mentioned compounds are required to decide - partly on the results of atmospheric models using these data as inputs - whether or not additional policies are needed, and if so, which and where they are most effective.

D. International relevance

D.1. *Validation and uncertainty analysis* is of concern for both policy making and modellers. About 40 institutes from all over the world showed an interest in using both GEIA and EDGAR inventories during the 8th CACGP Symposium/2nd Scientific Conference of IGAC held in Fuji-Yoshida (JPN) in 1994, amongst others: NCAR, Boulder; prof. G. Brasseur; MPI Hamburg; MPI Mainz, prof. P. Crutzen; various working groups of Global Emission Inventories Activity (GEIA), of the International Global Atmospheric Chemistry Programme (IGAC) of IGBP, and contributors such as CDIAC at Oak Ridge National Laboratory (ORNL) and Environment Canada; Secretariat to the INC/FCCC, dr. J. Swager; Netherlands Energy Research Foundation (ECN), prof.dr. J. Slanina; Royal Netherlands Meteorological Institute (KNMI), dr. H. Kelder, dr. P.F.J. van Velthoven. GEIA working groups notably on CO_2 of Marland c.s. and on SO_x/NO_x of Benkovitz c.s., and Brasseur are also interested in cooperation on uncertainty estimates and time profiles. Validation results will be used for improving default methodology and default emission factors of the IPCC guidelines for preparing national inventories. In support of the FCCC, to contribute to the development of IPCC guidelines for national GHG inventories, Berdowski and Olivier are leading or participating into IPCC expert groups on emissions.

D.2. *Monitoring and integration* activities will be performed in co-operation with key NRP projects involving flux measurements, regional extrapolation and validation. Furthermore, information will be exchanged with participants within GEIA and the IPCC National Emission Inventory Methodology projects. In addition, contacts will be maintained with other institutes analysing national inventories submitted to the FCCC. Results of the assessment of global emission developments may also be communicated to the secretariat to the FCCC.

D.3. Part of the *improvement and extension of EDGAR* contributes to the Global Emission Inventory Activity (GEIA) project, which is part of the International Global Atmospheric Chemistry (IGAC) Programme of IGBP (convenor: dr. T.A. Graedel). Dr. J.J.M. Berdowski co-ordinates the GEIA project on VOC (A). Drs. J.G.J. Olivier is member of the GEIA groups on CO_2 and on Data Management, and co-operates with the Biomass User's Network (BUN) office in London in analysing biofuel use and related emissions, which will feed into the inventories of N2O, CO, VOC and of biomass burning. The global NH_3 inventory is a GEIA project, co-ordinated by dr.ir. A.F. Bouwman, in collaboration with AEA, LUW, Academia Sinica, and the Danish Nat. Env. Res. Inst. He also co-ordinates the working group, in charge of producing and updating N_2O and NO_x (N) inventories.
GEIA working groups on CH_4 [Matthews c.s.] and N2O [Bouwman c.s.] are interested in using specific results from EDGAR activities (see B.3). The collaboration with GEIA further consists of distribution of common databases and of the inventories produced among the GEIA members, assessment of the quality of certain basic data, and assisting in extensions such as emission scenario construction, producing historical inventories, creating consistent and complete inventories, etc. The inventories produced will also be included in updates of the IMAGE model, particularly the global aerosol inventory, which is used in various international programmes and in applications for policy making all over the world.

E. Relation to Dutch and European research programmes
This project uses the results of periodical updates made for the annual Environmental Balance co-ordinated by RIVM. Updates of methodologies and emission estimates are included in the IMAGE 2 model; a soft-link between EDGAR grid files for 1990 and the IMAGE 2 model will be used to generate emission scenarios on grid. Historical emissions from 1970 as included in EDGAR were used for compiling the 100 Year IMAGE Database (HYDE).
Inventories for aircraft emissions, developed by ECAC/ANCAT in the framework of the EC project AERONOX, may be included or analysed in EDGAR, whereas other EDGAR data will be used in assessments of the impact of aircraft emissions by KNMI, NLR and Resource Analysis commissioned by the Dutch Ministry of Transport (RLD). Results of studies on biofuel use will be incorporated in the relevant IMAGE 2 NRP projects. Other Dutch (NRP) projects will use EDGAR data, not only atmospheric modellers, but also policy oriented projects such as "Emission reduction of non-CO2 greenhouse gases" in Theme III by Ecofys, TNO and LUW (De Jager c.s.) and projects on energy-related emissions by ECN (Kram c.s.). Within the Dutch Climate Centre activities the gridded inventories of EDGAR play a pivotal role in providing inputs for the atmospheric models.
In particular, regarding co-ordination with the NRP tender "Sources, regional scaling and validation of CH4 emissions from the Netherlands and Northwest Europe" of Berdowski (TNO), in a concerted action improved emission factors, time profiles and uncertainty estimates for sources categories will be made. Also the results of the different validation methods can be compared as well as the applicability of global inventories for regional assessments. This may give insight in the level of detail and uncertainty required for continental assessments. Through the activities of TNO for CORINAIR (Berdowski c.s.) and of RIVM for UN-ECE (Smeets c.s.) a personal link is realised between EDGAR/GEIA activities and EU/ECE activities, which will enable a efficient exchange of information and experiences.

F. Relevant expertise / experience of involved scientists

Relevant expertise in the research group can best be illustrated on the basis of a selected number of publications produced during the EDGAR project in NRP 1:

Berdowski, J.J.M., J.G.J. Olivier, C. Veldt, **Methane emissions from fuel combustion and industrial processes.** in: R.A. van Amstel (ed.), Proceedings of the *International Workshop Methane and Nitrous Oxide: Methods in National Emission Inventories and Options for Control*, Amersfoort, The Netherlands, February 3-5, 1993, pp. 131-141.

Berdowski, J.J.M., L. Beck, S. Piccot, J.G.J. Olivier, C. Veldt, **Working Group Report. Methane emissions from fuel combustion and industrial processes.** in: R.A. van Amstel (ed.), Proceedings of the *International Workshop Methane and Nitrous Oxide: Methods in National Emission Inventories and Options for Control*, Amersfoort, The Netherlands, February 3-5, 1993, pp. 231-237.

Bouwman, A.F., K.W. van der Hoek and J.G.J. Olivier (1995) **Uncertainty in the global source distribution of nitrous oxide**. *Journal of Geophysical Research*, **100:D2**, 2785-2800.

Bouwman, A.F. (1995) **Compilation of a global inventory of emissions of nitrous oxide**. Thesis, Agricultural University, Wageningen.

Kreileman, G.J.J. and A.F. Bouwman (1994) **Computing landuse emissions of greenhouse gases**. *Water, Air and Soil Pollution,* **76**, *231-258.*

Olivier, J.G.J. (1993) **Nitrous oxide emissions from industrial processes**, In: R.A. van Amstel (ed.), Proceedings of the *International Workshop Methane and Nitrous Oxide: Methods in National Emission Inventories and Options for Control*, Amersfoort, The Netherlands, February 3-5, pp. 339-341.

Olivier, J.G.J. (1993) **Working Group Report. Nitrous Oxide Emissions from Fuel Combustion and Industrial Processes. A Draft Methodology to Estimate National Inventories**, In: R.A. van Amstel (ed.), Proceedings of the *International Workshop Methane and Nitrous Oxide: Methods in National Emission Inventories and Options for Control*, Amersfoort, The Netherlands, February 3-5, pp. 347-361.

Olivier, J.G.J., A.F. Bouwman, C.W.M. van der Maas and J.J.M Berdowski (1994) **Emission Database for Global Atmospheric Research (EDGAR).** *Environm. Monitoring and Assessment,* **31**, 93-106. Also published in: Van Ham, L.J.H.M. Janssen and R.J. Swart (eds.), 1994. **Non-CO2 greenhouse gases: why and how to control?**, Proceedings of an International Symposium, Maastricht, 13-15 december 1993. Kluwer Academic Publishers, Dordrecht.

Olivier, J.G.J. (1994), **Biofuel combustion and greenhouse gas emissions**. Paper prepared for the *International Conference Bioresources '94*, Bangalore (IND), 3-7 October 1994. Draft.

Olivier, J.G.J., C. Kroeze, A.C.J.M. Matthijsen en H.J. van der Woerd (1994), *Scenarios for global and Dutch use of hydrofluorocarbons (HFCs) and their consequences for global warming*. In: J. van Ham, L.J.H.M. Janssen and R.J. Swart (eds.), **Non-CO_2 Greenhouse Gases: Why and how to control?**, Proceedings of an International Symposium, Maastricht (NL), 13-15 December 1993, pp. 533-542. Kluwer Academic Publishers, Dordrecht.

Olivier, J.G.J., Bouwman, A.F., Van der Maas, C.W.M., Berdowski, J.J.M., Veldt, C., Bloos, J.P.J., Visschedijk, A.J.H., Zandveld, P.Y.J. and Haverlag, J.L. (1995) **Description of EDGAR Version 2.0: A set of global emission inventories of greenhouse gases and ozone depleting substances for all anthropogenic and most natural sources on a per country basis and on 1ox1o grid**. RIVM/TNO report nr. 771060 002. RIVM, Bilthoven, December 1995.

Van der Maas, C.W.M., Berdovski, J.J.M., Olivier, J.G.J., and A.F. Bouwman (1995) **EDGAR: Emission Database for Global Atmospheric Research. Background report.** RIVM, Bilthoven. RIVM/TNO report no. 776001011.

Vries, H.J.M. de, J.G.J. Olivier, R.A. van den Wijngaart, G.J.J. Kreileman and A.M.C. Toet (1994) Model for Calculating Regional Energy Use, Industrial Production and Greenhouse Gas Emissions for Evaluating Global Climate Scenarios. *Water, Air and Soil Pollution*, **76**, 79-131.

G. Relation to long term research strategy of the institute

The EDGAR database is the global component in the RIVM-LAE RIM+ database, that further includes a national and a European database. One of the particular tasks of EDGAR is to supply data and calculations to the IMAGE project and to exchange emissions data to other scientific institutes (NRP participants and others), and to support national and international policy planning. Moreover, EDGAR contributes to other laboratories of RIVM and TNO and other national model groups active in atmospheric modelling. RIVM also contributes to the activities of the IPCC in the field of development of methodologies for national inventories, whereby the role of EDGAR is the comparison of pure national estimates with global approaches developed in GEIA and EDGAR.
At TNO, tropospheric ozone and radiative forcing have been studied on a regional and global scale for a long period. Apart from specific measurements and data analysis, the development of regional and atmospheric chemistry models forms a structural part of these studies. For that purpose, TNO has been developing emission databases on national, regional and global scale for over a decade.

H. Research plan

There are 3 major components (man years and person responsible are shown between brackets):

H.1. Uncertainty analysis and validation (0.65 my)

1.1 Validation of emission inventories:

1.1.1 By comparison with European inventories. By first validating and then calibrating to the CORINAIR'90 inventory the update of EDGAR will produce comparable regional emissions on the sector and country level. (0.25 my; Smeets)

1.1.2 By comparison of EDGAR data with inventories prepared for the FCCC. This will result in a mutual validation of key inventories (0.3 my; Olivier).

1.1.3 By comparison with inventories produced by working groups of GEIA: CO_2, SO_x/NO_x, CH_4, CO, CFCs (others are developed by TNO and RIVM) (0.05 my; Berdowski)

1.2 Assessment of the uncertainty for each compound and source (0.05 my; Berdowski)
From literature review on activity data, applicability of emission factors and spatial allocation functions an estimate of the uncertainty of emissions per major source category will be made.

H.2. Monitoring and integration (1.45+0.9=2.35 my)

2.0 Basic maintenance of the software and hardware [backups of system and data, including minor adaptations for parts 1. and 3.] (0.9 my; Van der Maas)

2.1 Annual assessment of emission trends of direct GHGs (0.6 my; Olivier)

2.2 Integration of results of NRP-1 and 2 for updating EDGAR inventories, for which key participants of NRP will be consulted (e.g. in the form of a workshop). (0.05 my; Berdowski)

2.3 Updating the base year of the inventories using new statistical data, national GHG inventories prepared for the FCCC, concrete NRP results, results of the validation performed under B.1, and monitoring of emissions development. The priority in updates will be at compounds, sources and regions which are crucial for supporting environmental policy planning (0.4 my; Olivier)

2.4 Evaluation of key sources/regions of updated inventories and ad hoc advice to policy makers (0.1 my; Olivier)

2.5 Provide inventory data to IPCC Expert Groups, the IMAGE 2 model, to other (NRP) projects, and to GEIA (0.3 my; Olivier, except GEIA: Berdowski):

2.5.1 Aggregated emission factor to IPCC Expert Groups on Fuel Combustion and Industrial Processes

2.5.2 Updated emission factors and other emissions data to the IMAGE 2 model

2.5.3 Standardized emissions data files to other NRP projects.

2.5.4 Updates to GEIA, when applicable.

[N.B. The preparation of special data files in other formats is not part of this project.]

H.3. Improvement and extension of EDGAR and its software (0.75 my)

3.1 Compilation of temporal distributions (time profile for 12 months) for all sources and species (0.15; Olivier)
As for the uncertainties, from literature review on activity data an estimate of the monthly distribution of emissions per major source category will be made.
First a preliminary version will be developed; then a final version.

3.2 Compilation of global inventories for new compounds (0.25 my; Berdowski):

3.2.1 Version 1 of NH3 inventory (also for GEIA)

3.2.2 Other compounds or VOC compound groups

3.3 Improvement of global inventories for a number of sources (0.2 my; Berdowski)
The focus is expected to be on biofuel use and biomass burning. When readily available, also estimates for natural emissions will be included (e.g. ocean and volcano emissions)

3.4 Limited software modification, in particular to enhance to data retrieval options (0.15 my; Olivier)

Specification: time schedule, products, milestones, dates

1. Uncertainty analysis and validation

1.1 Validation of emission inventories: January 1996-July 1997.

1.1.1 Comparison with the European CORINAIR'90 inventory is scheduled for the 4^{th} quarter of 1996; harmonisation will be done in a separate dataset, to be merged into the next release of the database (see 2.).

1.1.2 Comparison with national inventories for FCCC (or US Country Study Programme) will be done when they become available. This will be limited by the extent in which the data can be easily processed into the database. These activities will be focused at the end of 1996/first half of 1997. The result will be an assessment report on FCCC and EDGAR inventories. Conclusions with respect to national inventories will also aim at irregularities and improvement of default emission factors as well as methodologies. Further work on FCCC inventories depends on the time schedule of IPCC and the capacity made available for these activities.

1.1.3 Comparison with GEIA inventories will be done when they become available. These activities will be focused in the first half of 1997. The result will be an assessment report on EDGAR and GEIA inventories.

1.2 A new assessment of the uncertainties per compound and source: January 1997-July 1997.
Conclusions from this exercise will be distributed among interested parties (policy makers and users of the atmospheric models).

2. Monitoring and integration

2.0 Basic maintenance activities of the hardware and software will run during the whole project.

2.1 Annual assessment of emission trends of direct GHGs will result in a summary publication in scheduled for October of each year.

2.2 Integration of results of NRP-1 and 2 for updating EDGAR inventories, for which key participants of NRP will be consulted in the middle of 1996 and of 1997 in the form of an informal workshop. The discussion will focus on the following topics:
- Temporal distributions, scaling, species and uncertainties;
- Integration of results of NRP 1, and of results of modelling efforts by NRP 2 tenders (Theme I), in particular possible inputs from transportation or industry, agriculture and natural vegetation.

2.3 A new release V3.0 of the EDGAR inventories: February 1998.
This will include updating the base year of the inventories using new statistical data (aiming at 1995, possibly 1994 for industrial and agricultural sources). Data from national GHG inventories prepared for the FCCC, concrete NRP results provided by NRP participants and results of the validation performed under 1.1 will also be included, as well as GEIA inventories that replace or update EDGAR work or that are not represented in EDGAR. Additional

inventories for new compounds or natural sources may be added as they are available for external distribution. Together with new releases, concise documentation files on will be prepared.

2.4 *Recommendations to policy makers*. Evaluation of key sources/regions of updated inventories in V3.0 are scheduled for September 1996 and for the beginning of 1998. Ad hoc advice to policy makers may be given at any time during the project.

2.5 *Providing inventory data to the IMAGE 2 model, other (NRP) projects, IPCC Expert Groups and to GEIA:*
(1) aggregated emission factors to be used by IPCC Expert Groups for determining default factors for revised IPCC guidelines is scheduled for February 1996; (2) data for IMAGE 2 model will be included in the time schedule of updates of IMAGE 2; (3) updated versions of emissions data will be made available as standardised emissions data files at RIVM's anonymous FTP site in the 1st quarter of 1998; and (4) updates to GEIA will be submitted, when applicable.

3. Improvement and extension of EDGAR and its software

3.1 *Compilation of temporal distributions: July 1996-December 1996. Update in December 1997.*
Based on literature data for all sources and species a time profile for 12 months will be compiled. First a preliminary version will be developed; then a final version.

3.2 *Compilation of global inventories for new compounds*.
Version 1 of an NH3 inventory (also for GEIA) is scheduled to be ready by October 1996. For other compounds or VOC compound groups we aim at incorporation in the release of V3.0, which is scheduled for February 1998.

3.3 *Improvement of global inventories for a number of sources.*
Data on biofuel use and biomass burning will be improved in co-operation with GEIA groups working on these topics and incorporated in V3.0. On these sources a summary report will be written. When they become available, also estimates for natural emissions will be included in the database and made available through the FTP site.

3.4 *Limited software modification* will focus in 1996 on enhancing data retrieval and dataset comparison options.

Appendix 6: List of project publications

Van Aardenne, J.A., Dentener, F.J., Olivier, J.G.J., Klein Goldewijk, C.G.M. and J. Lelieveld (2001) **A High Resolution Dataset of Historical Anthropogenic Trace Gas Emissions for the Period 1890-1990.** *Global Biogeochemical Cycles* ***Global Biogeochemical Cycles,*** **15(4),** 909-928.

Amstel, A.R. van, Kroeze, C., Janssen, L.H.J.M., Olivier, J.G.J. and J. Van der Wal (1997) **Greenhouse Gas Accounting. Preliminary study as Dutch input to a joint International IPCC Expert Meeting/CKO-CCB Workshop on Comparison of Top-down versus Bottom-up Emission Estimates.** WIMEK report / RIVM report nr. 728001 002. RIVM, Bilthoven.

Amstel, A.R. van, J.G.J. Olivier, L.H.J.M. Janssen and J.J.M. Berdowski (1997) **Comparison of bottom-up inventories, methane as an example**. Discussion paper for the IPCC Expert Meeting on Methods for Assessment of Inventory Data Quality, Bilthoven, the Netherlands, November 5-7 1997.

Amstel, A.R. van, J.G.J. Olivier, L.H.J.M. Janssen (1999) **Analysis of differences between national inventories and an Emissions Database for Global Atmospheric Research (EDGAR).** *Environmental Science & Policy*, **2,** 275-294.

Amstel, A.R. van, L.H.J.M. Janssen, J.G.J. Olivier (1999) Greenhouse gas emission accounting. Paper presented at *Second Symposium on Non-CO_2 Greenhouse Gases*, Noordwijkerhout, the Netherlands, 8-10 September 1999.

Amstel, A.R. van, Kroeze, C., Janssen, L.H.J.M., and Olivier, J.G.J. (1999) **Greenhouse Gas Accounting 2. Update including Second National Communications.** WIMEK report / RIVM report nr. 773201 001. RIVM, Bilthoven.

Benkovitz, C. M., Berdowski, J. J. M., Mubaraki, M. A., and Olivier, J. G. J. (1997**) Global anthropogenic sulfur emissions for 1985 and 1990**. In*: Assessing Historical Global Sulfur Emission Patterns for the Period 1850-1990*, Appendix A, Report DE96-014790, U.S. Department of Energy, Washington, DC. [BNL 64596]

Benkovitz, C. M., Berdowski, J. J. M., Mubaraki, M. A., and Olivier, J. G. J. (1997) **Sulfur emissions from volcanic activity**. In*: Assessing Historical Global Sulfur Emission Patterns for the Period 1850-1990*, Appendix C, Report DE96-014790, U.S. Department of Energy, Washington, DC. [BNL 64597]

Berdowski, J.J.M., G.P.J. Draaijers, L.H.J.M. Janssen, J.C.Th. Hollander, M. van Loon, M.G.M. Roemer, A.T. Vermeulen, M. Vosbeek and H. Visser (1998). **Independent Checks for Validation of Emission Estimates: The METDAT Example for Methane.** Meeting of the IPCC/OECD/IEA Programme for National Greenhouse Gas Inventories on 'Managing Uncertainty in National Greenhouse Gas Inventories', Paris 13-15 October 1998.TNO Publication P98/037, Apeldoorn, The Netherlands.

Berdowski, J.J.M., G.P.J. Draaijers, L.H.J.M. Janssen, J.C.Th. Hollander, M.van Loon, M.G.M. Roemer, A.T. Vermeulen, M. Vosbeek and H. Visser (1998). **Independent Checks for validation of CH_4 emission estimates.** In: Proceedings of the first NRP-II Symposium on Climate Change Research, Garderen, The Netherlands, 29-30 October 1998, pp 87 - 96. TNO-Publicatie P98/039, Apeldoorn, The Netherlands.

Berdowski, J.J.M., Draaijers, G.P.J., Hulskotte, J.H.J., Oonk, J., Teeuwisse, S.T., Visschedijk, A.J.H., Corré, W. & M. Vosbeek (1999). Description of a detailed CH4 emission database for the Netherlands and Northwest Europe. TNO MEP report (draft version), Apeldoorn, The Netherlands.

Berdowski, J.J.M., Draaijers, G.P.J., Hulskotte, J.H.J., Oonk, J., Teeuwisse, S.T., Visschedijk, A.J.H., Corré, W. and M. Vosbeek (1999). **Description of a detailed CH_4 emission database for the Netherlands and Northwest Europe**. TNO MEP report (draft version), Apeldoorn, The Netherlands.

Draaijers, G.P.J., J.J.M. Berdowski, G.C. Ypenburg, A.J.H. Visschedijk, J.H.J. Hulskotte, M. Roemer and M. van Loon (1998). **Overview of greenhouse gas emission databases and validation activities in the Netherlands**, EU

Concerted action workshop on Biogenic emissions of greenhouse gases caused by arable and animal agriculture, Lökeberg, Sweden, July 9-10, 1998.

Bouwman, A.F., Lee, D.S., Asman, W.A.H., Dentener, F.J., Van Der Hoek, K.W. and J.G.J. Olivier (1997) **A Global High-Resolution Emission Inventory for Ammonia**, *Global Biogeochemical Cycles* **11:4** 561-587.

EEA (1999). Environment in the European Union at the turn of the century, Chapter 3.1, Greenhouse gases and climate change (pp. 79 - 98). ISBN 92-9157-202-0, Copenhagen, Denmark.

Elzen, M. den, Berk, M., Schaeffer, M., *Olivier, J.,* Hendriks, C., Metz, B. (1999) **The Brazilian Proposal and other Options for International Burden Sharing: an evaluation of methodological and policy aspects using the FAIR model.** RIVM-report no. 728001011. October 1999, NOP-MLK, Bilthoven. 125 pp.

Van Heyst, B. J. , M. T. Scholtz, A. W. Taylor, A. Ivanoff, C. M. Benkovitz, A. Mubaraki, J. G. J. Olivier, J. M. Pacyna. **The development of a 1990 global inventory for SOx and NOx on a 1° 1° latitude-longitude grid**. BNL Paper 66473. Presented at the *AWMA Emission Inventory Conference* ,Raleigh NC, USA, 26-28 October 1999.

Marland, C., Boden, T.A., Brenkert, A., Andres, R.J. and J.G.J. Olivier (1998) **CO_2 from Fossil Fuel Burning: Updates on the Magnitude, Distribution and Uncertainty of Emissions Estimates**. *Proceedings of the 5th International Carbon Dioxide Conference*, Cairns (AUS), 8-12 September 1997. **Forthcoming.**

Janssen, L.J.H.M., P. van Velthoven, F. Dentener and A.R. van Amstel (eds.), 1997: Proceedings of the CKO/CCB Workshop on Bottom-up and Top-down Emission Estimates of Greenhouse Gases in Bilthoven on 27-6-1997. CCB/CKO/RIVM report 728001006. Bilthoven, the Netherlands.

Janssen, L.H.J.M., J.G.J. Olivier, A.R. van Amstel (1997) A comparison of bottom-up and top-down methane emission inventories. Discussion paper for the IPCC Expert Meeting on Methods for Assessment of Inventory Data Quality, Bilthoven, the Netherlands, November 5-7 1997.

Janssen, L.H.J.M., J.G.J. Olivier, A.R. van Amstel (1999) **Comparison of CH_4 emission inventory data and emission estimates form atmospheric transport models and concentration measurements.** *Environmental Science & Policy*, **2,** 295-314.

Lee D.S., Köhler I., Grobler, E., Rohrer F., Sausen, R., Gallardo-Klenner L., Olivier J.G.J., Dentener F. J. and Bouwman A. F. (1997) **Estimations of global NOx emissions and their uncertainties.** *Atmospheric Environment* **31:12** 1735-1749.

Lim, B., P. Boileau, Y. Bonduki, A.R. van Amstel, L.H.J.M. Janssen, J.G.J. Olivier, C. Kroeze (1999) **Improving the quality of national greenhouse gas inventories.** *Environmental Science & Policy*, **2,** 335-346.

Marland, G., A. Brenkert, J.G.J. Olivier (1999) **CO_2 from fossil fuel burning: a comparison of ORNL and EDGAR estimates of national emissions.** *Environmental Science & Policy*, **2,** 265-274.

Olivier, J.G.J. and A.F. Bouwman**: A global sectoral emission inventory of N_2O and comparison with atmospheric observations.** Proceedings of the *CKO/CCB Workshop on "Bottom-Up and Top-Down Emission Estimates of Greenhouse Gases, Bilthoven on 27-6-1997", p. 79-92.* RIVM report 728001 006. RIVM, Bilthoven.

Olivier, J.G.J., A.F. Bouwman, K.W. van der Hoek and J.J.M. Berdowski (1998) **Global Air Emission Inventories for Anthropogenic Sources of NO_x, NH_3 and N_2O in 1990**. *Env. Poll.* **102,** 135-148.

Olivier, J.G.J. (1998) **Tiered Approach and Reporting Format for Estimating and Evaluating Uncertainty in Emission Inventories.** Discussion paper prepared for the *IPCC/OECD/IEA Scoping Meeting on Managing Uncertainty in National Greenhouse Gas Inventories,* Paris, 13-15 October 1998.

Olivier, J.G.J., J.J.M. Berdowski, J.A.H.W. Peters, J. Bakker, A.J.H. Visschedijk and J.P.J. Bloos (1998) **EDGAR V.30: Reference database with trend data for 1970-1995.** Proceedings NOP-MLK Symposium, 1998, Garderen, The Netherlands.

Olivier, J. (1998) **Trends and uncertainties in emissions of greenhouse gases.** *Lucht* 1**6:4,** 114-116. (in Dutch)

Olivier, J.G.J., J.A.H.W. Peters (1999) **International marine and aviation bunker fuel: trends, ranking of countries and comparison with national CO_2 emissions.** RIVM report no. 773301 002. RIVM, Bilthoven. July 1999.

Olivier, J.G.J., J. Bakker (2000) **Historical emissions of HFCs, PFCs and SF_6 1950-1995. Consumption and emission estimates per country 1950-1995 and global emissions on 1^ox1^o in EDGAR V3.0**. RIVM, Draft.

Olivier, J.G.J. and Bakker, J. (1999) **SF_6 from Electrical Equipment and Other Uses (Draft).** Information paper prepared for '*IPCC Expert Group Meeting on Good Practice in Inventory Preparation: Industrial Processes And The New Gases'*, Washington DC, 26-28 January 1999.

Olivier, J.G.J, N. Paciornic, J. Mangino (1999) **Conclusions on SF_6 from Electrical Equipment and Other Uses.** IPCC Expert Group Meeting on *Good Practice in Inventory Preparation: Industrial Processes And The New Gases,* Washington DC, 26-28 January 1999. Meeting report in prep.

Olivier, J.G.J, A.F. Bouwman, J.J.M. Berdowski, C. Veldt, J.P.J. Bloos, A.J.H. Visschedijk, C.W.M. van der Maas, P.Y.J. Zandveld (1999) **Sectoral emission inventories of greenhouse gases for 1990 on a per country basis as well as on 1^o x 1^o**. *Environmental Science & Policy*, **2**, 241-264.

Olivier, J.G.J, J.P.J. Bloos, J.J.M. Berdowski, A.J.H. Visschedijk, A.F. Bouwman (1999) **A 1990 global emission inventory of anthropogenic sources of carbon monoxide on 1^ox1^o developed in the framework of EDGAR/GEIA.** *Chemosphere: Global Change Science* **1**, 1-17.

Olivier, J.G.J., J.A.H.W. Peters (1999) **International marine and aviation bunker fuel: trends, ranking of countries and comparison with national CO_2 emissions.** RIVM report no. 773301 002. RIVM, Bilthoven. July 1999.

Olivier, J.G.J., J.J.M. Berdowski, J.A.H.W. Peters, J. Bakker, A.J.H. Visschedijk and J.P.J. Bloos (1999) **EDGAR V.30: Reference database with trend data for 1970-1995.** Poster presented at 6th IGAC Conference, September 1999, Bologna, Italy.

Olivier, J.G.J., Winiwarter, W., Chang, J.P. (1999) **Check and verification at national and international level.** Background Paper #5 prepared for the for the *IPCC Expert Meeting on Estimating Uncertainties and Inventory Quality in Greenhouse Gas Inventories*, Culham, United Kingdom, 5-7 October 1999.

Olivier, J.G.J. and D. Cunnold (1999) Report of the 10th GEIA Workshop, Bologna, Italy, 13 September 1999.

Olivier, J.G.J. and J.J.M. Berdowski (2001) **Global emissions sources and sinks**. In: Berdowski, J., Guicherit, R. and B.J. Heij (eds.) "*The Climate System*", pp. 33-78. A.A. Balkema Publishers/Swets & Zeitlinger Publishers, Lisse, The Netherlands. ISBN 90 5809 255 0.

Olivier, J.G.J. (2001) **Shares and trends in greenhouse gas emissions**. In: "*CO_2 emissions from fuel combustion 1971-1999*", 2001 Edition, pp. III.3-III.7. International Energy Agency (IEA), Paris. ISBN 92-64-08745-1.

Olivier, J.G.J. *et al*. (2001) **CO_2, CH_4 and N_2O emissions for 1990 and 1995; Sources and Methods**. In: "*CO_2 emissions from fuel combustion 1971-1999*", 2001 Edition, pp. III.9-III.29. International Energy Agency (IEA), Paris. ISBN 92-64-08745-1.

Olivier, J.G.J. and J.A.H.W. Peters (2001) **CO_2 from Non-Energy Use of fuels: a global, regional and national perspective based on the IPCC Tier 1 approach.** Paper presented at the ***Third NEU-CO_2 Workshop Non-Energy Use and CO_2 emissions*,** International Energy Agency (IEA), Paris, 7-9 November 2001.

Olivier J.G.J., J. Bakker, J.J.M. Berdowski, A.J.H. Visschedijk and A.F. Bouwman (2001) **Assessment of global methane emissions in EDGAR 3.2: 1970-1995 trends and uncertainty estimates.** Paper presented at the workshop '***Reliability of Greenhouse Gas Emission Estimates***', Wageningen, October 12-13, 2000.

Valks, P. and M.G.M. Roemer (1996). **Model calculations of ozone and other trace gases based on EDGAR/GEIA emission estimates of NMVOC** (in Dutch). TNO-report R96/294, Delft, Netherlands.

Vries de, B., J. Bollen, M. den Elzen, A. Gielen, M. Janssen, E. Kreileman, J. Olivier (1998) **IMAGE-based scenarios of greenhouse-gas emissions for the IPCC Special Report on Emissions Scenarios,** Interim Report, April 1998, RIVM, Bilthoven, the Netherlands.

Appendix 7: Coordination with other projects and programmes

EDGAR activities were done in cooperation with numerous other activities, including:

IMAGE (emission factors, activity data, sources, maps)
GEIA (inventories, data management, time profiles, uncertainties)
IPCC (emission factors, sources, descriptions, uncertainties)
ORNL/CDIAC (CO_2)
CORINAIR/EMEP (emission factors, sources, descriptions)
IGAC (biomass burning, rice)
NRP (possible users)

Appendix 8: Attendance at national and international meetings

These include:

- GEIA
- IGAC
- IMAGE
- NRP-MLK
- IPCC
- FCCC
- National Workshop on Monitoring Greenhouse Gas Emissions

Below we list the meetings attended that are related with to this project:

Olivier, J.G.J. *: 25th IOLG (IPCC-OECD Liaison Group),* 19 October 1996, Paris. Presentation of discussion paper on RIVM initiative for an IPCC workshop on comparison of Top-Down and Bottom-Up greenhouse gas inventories.

Olivier, J.G.J., Berdowski, J.J.M., Bloos, J.P.J., Visschedijk, and J.A.H.W., Peters: *RIVM/NOP-MLK Workshop "EDGAR: use of Version 2 and wishes for Version 3*", RIVM, Bilthoven, 14 February 1997.

Olivier, J.G.J. *: Greenhouse gas Inventory Liaison Group (GILG)* of IEA/OECD/IPCC, 17 June 1997, OECD, Paris. Presentation on linking top-down and bottom-up emission inventories.

Olivier, J.G.J. : *CKO/CCB Workshop "Comparison of Bottom-Up and Top-Down emission inventories of greenhouse gases*", RIVM, Bilthoven, 27 June 1997.

Olivier, J.G.J. : presentation on EDGAR Version 2.0 at *US-EPA (Barbour c.s.),* 2 September 1997, Washington DC, USA.

Olivier, J.G.J. : presentation on EDGAR Version 2.0 *at CDIAC/ORNL (Marland c.s.),* 4 September 1997, Oak Ridge TN, USA.

Olivier, J.G.J. : presentation on EDGAR Version 2.0 at *Brookhaven National Laboratory (BNL) (Benkovitz c.s),* 15 September 1997, Upton NY, USA.

Olivier, J.G.J. : *UNFCCC secretariat*, Bonn (D), 10 October 1997. Presentation on EDGAR: structure, data sets, results, planned activities.

Olivier, J.G.J. , J.J.M. Berdowski and J.P.J. Bloos*, 8th International Workshop of the Global Emissions Inventory Activity (GEIA),* 3-4 November 1997, RIVM, Bilthoven. Various contributions.

Olivier, J.G.J. and J.J.M. Berdowski*: IPCC Expert Group Meeting 'Methods for the Assessment of the Inventory Data Quality',* 5 - 7 November 1997, RIVM, Bilthoven. Various contributions.

Olivier, J.G.J. : '*Nitrogen, the Confer-N-s***'**, 23-27 March 1998, Noordwijkerhout, the Netherlands.

J.P.J. Bloos: *IEA Expert Workshop on Biomass Energy: Data, Analysis and Trends*, 23-24 March 1998, Paris.

Olivier, J.G.J. : *IPCC Steering Group Meeting* on 'Assessment of National Feedback on the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories', Paris (F), 20-21 April 1998.

Olivier, J.G.J. ***:** IPCC Steering Group Meeting* on 'Managing uncertainties in National Greenhouse Gas Inventories', Paris (F), 22 April 1998.

Olivier, J.G.J., Berdowski, J.J.M., Bloos, J.P.J., Visschedijk, and J.A.H.W., Peters**:** *NOP-MLK-II Symposium*, Garderen, the Netherlands, 29-30 November 1998. Poster presentation.

Olivier, J.G.J. : *IPCC Expert Group Meeting on Good Practice in Inventory Preparation: Industrial Processes And The New Gases,* Washington DC, USA, 26-28 January 1999. Olivier co-chair of session on SF_6 in electrical equipment and other uses.

Van Amstel, A.R., *Second Symposium on Non-CO_2 Greenhouse Gases,* Noordwijkerhout, 8-10 September 1999. presentation on 'Greenhouse Gas Accounting 2'.

Berdowski, J.J.M.: Independent checks for validation and verification of methane estimates. Key note paper presented at National Workshop *Monitoring of Greenhouse Gases in the Netherlands: Uncertainty and Priorities for Improvement,* Bilthoven, The Netherlands, 1 September 1999.

Berdowski, J.J.M. and A. J.H. Visschedijk: National Workshop *Monitoring of Greenhouse Gases in the Netherlands: Uncertainty and Priorities for Improvement,* Bilthoven, The Netherlands, 1 September 1999.

Olivier, J.G.J.: co-organiser of National Workshop *Monitoring of Greenhouse Gases in the Netherlands: Uncertainty and Priorities for Improvement,* Bilthoven, The Netherlands, 1 September 1999; co-author of discussion paper and chair of session on Energy.

Olivier, J.G.J.: 1st GAMeS workshop of IGBP/GAIM on 'Global Atmospheric Methane Synthesis' (GAMeS), Bologna (Italy), 13 September 1999**.** Presentation of the activities on methane emissions carried out for EDGAR V3.0 for the period 1970-1995 and within the framework of EDGAR-HYDE for the period 1890-1990.

Olivier, J.G.J. (1999) 10th GEIA workshop of IGBP/IGAC on 'Global Emission Inventory Activiy' (GEIA), Bologna (Italy), 13 september 1999**.** Organised and chaired by Olivier as co-convenor of GEIA.

Olivier, J.G.J.: *6th Scientific Conference of the International Global Atmospheric Chemistry programme (IGAC)*, Bologna (Italy), 14-17 September 1999. Poster presented on EDGAR/GEIA.

Olivier, J.G.J.: *IPCC Good Practice Expert Group Meeting* 'Cross-Sectoral Methodologies for Uncertainty Estimation and Inventory Quality', Culham (UK), 5-7 October 1999.

Olivier, J.G.J.: *IPCC Good Practice Guidance Wrapup Meeting*, Sydney, Australia, 28 Feb-1 March 2000. Cochair on Industrial Processes for finalising the IPCC report on Good Practice Guidance on Emission Inventories and Uncertainty Management.

Olivier, J.G.J.: *UNFCCC workshop on Art. 5,7,8* (in particular National System), Bonn, 13-15 March 2000.

Olivier, J.G.J.: *Kick-off meeting of EU project POET* ('Precursors of Ozone in the Troposphere'), no. EVK2-1999-00011, 7 March 2000, Paris (F).