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MINISTERIE VAN VOLKSHUISVESTING, RUIMTELIJKE ORDENING EN MILIEU
MINISTRY OF HOUSING, SPATIAL PLANNING AND THE ENVIRONMENT

WIMEK report / RIVM report 773201 003

Monitoring of Greenhouse Gases in the Netherlands:

Uncertainty and Priorities for Improvement

Proceedings of a National Workshop held in Bilthoven, The Netherlands, 1 September 1999

André R. van Amstel, Jos G.J. Olivier, Paul G. Ruyssenaars (editors)

Organised by the Netherlands Ministry of Housing, Spatial Planning and the Environment (VROM) in co-operation with the National Institute for Public Health and the Environment (RIVM) and the Wageningen University and Research Center, Institute for Environment and Climate Research (Wageningen UR/WIMEK).

This investigation has been performed by order and for the account of the Directorate-General for Environmental Protection, Department of Climate Change and Industry, of the Netherlands' Ministry of Housing, Spatial Planning and the Environment, within the framework of RIVM project 773301, titled 'International emission reports'.

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Abstract

A workshop was organised in the Netherlands on 1 September 1999 to improve the National System for Monitoring Greenhouse Gas Emissions. These are the Proceedings. Implementation of the *Kyoto Protocol* requires reduction of the uncertainties and improvement of the so-called *National System* for greenhouse gas emission monitoring, so that flexible strategies like emission trading and joint implementation can be introduced. It was the task of this workshop to introduce initiatives for adding substance and organisation to the monitoring programme. The starting point of this workshop was the monitoring of policy implementation in the light of uncertainties in emission data. The demands for accuracy in monitoring are a logical consequence of the *Climate Convention* and the *'legally binding commitments'* taking force as soon as the *Kyoto Protocol* is ratified.

The objectives were elaborated as follows:
1. *Per target group:* Listing the possibilities for quantitative assessment of the uncertainties of emission estimates. Overall assessment of uncertainties per sector.
2. *Per target group*: Improving the monitoring of emission reductions.
3. *Expertise for follow-up research:* Determining the institutions per sector currently equipped to carry out research on uncertainty reduction in emission estimates.
4. *Who, what and when?* Determining who is going to do what and when to reduce uncertainties in emission estimates.
5. *Plan of action:* Establishing a general plan per target group to work out the above objectives.

Contents

Summary

The national system of the Netherlands for the Kyoto protocol is described in different reports, some of which are in the Dutch language. This workshop on the monitoring of greenhouse gases in the Netherlands was organised to improve the national system and make this material available in the English language. Reporting by the Netherlands is done through the national Emission Registration project. An additional project is formulated next to the national Emission Registration to improve on the monitoring of the greenhouse gases. The recommendations from this report will be used to improve the monitoring in the Netherlands over the coming years. Current monitoring activities have resulted in reasonably accurate emission inventories and the emission estimates, methods and processes are rather well described. However, systematic review and documentation of procedures, methods and data will result in a more efficient emission compilation process and a quantitatively more accurate and qualitatively better greenhouse gas emission inventory. The next general items were recognised for further review and improvement during the workshop:

- the **reporting and documentation** on emission factors and activity data used each year to report greenhouse gas emissions and sinks.

- the **uncertainty estimates** for each subcategory in the emission inventory and to make a separate estimate for the uncertainty in the emission factor - when different from IPCC defaults - and in the activity data.

- the **quality control** on each new years estimates and on recalculations based on new methodology or better activity data and/or emission factor data and document the basis of these estimates.

- the **maintenance of time series**. For example, it should be clear for which reason and at what moment in time new methods were introduced that effected the time series. A decision may be needed on frequency and timing of recalculations: for example recalculations only after three or five years or specific criteria to be met e.g. on minimum differences between subsequent versions.

- **knowledge gaps** should be closed. Large sectoral emissions with large uncertainties should be made top priority (e.g. gas distribution leakage, agriculture, SF_6 use). Thereby improving the monitoring of emissions that can have a great impact on the time trend.

- in some cases **improved application of the *Revised IPCC Guidelines*** will produce more comparable emission estimates (e.g. in the estimates of CO_2 from feedstocks, non-CO_2 from bunker fuels and nitrous oxide from agriculture and polluted surface waters).

- the **cooperation with the target groups** to enhance the monitoring of emissions in particular when reductions are expected. It should be avoided that each target group develops its own methodologies. If measurements are commissioned, e.g. in the policy plan for the reduction of greenhouse gases, new emission factors may be developed for specific sub-sectors.

Samenvatting

Het zgn. *nationale systeem* voor monitoring van broeikasgasemissies in Nederland, dat in het kader van het Kyoto Protocol aan bepaalde eisen zal moeten voldoen, wordt beschreven in verschillende rapporten, waarvan de meeste in het Nederlands zijn. Deze workshop over het monitoren van de emissies van broeikasgassen in Nederland werd georganiseerd om het *nationale systeem* te verbeteren en de informatie die in dit kader verzameld is in het Engels beschikbaar te maken. De emissierapportage wordt in Nederland georganiseerd in het kader van het nationale Emissie Registratie-project. Een additioneel project wordt opgezet om de monitoring van de broeikasgasemissies te verbeteren. De conclusies en aanbevelingen van het verslag zullen gebruikt worden om de komende jaren deze monitoring te verbeteren. De huidige monitoringactiviteiten hebben geresulteerd in redelijk nauwkeurige emissie-inventarisaties en de emissieschattingen, berekeningsmethodieken en werkprocessen zijn redelijk goed beschreven. Niettemin kan geconcludeerd worden dat een systematische evaluatie en documentatie van procedures, methoden en data kan leiden tot een efficiënter proces van emissiecompilatie en een kwantitatief betere emissie-inventarisatie voor broeikasgassen. De volgende algemene aspecten werden op de workshop aanbevolen voor een nadere review en verbetering:

- het **rapporteren en documenteren** over en van emissiefactoren en activiteitendata die ieder jaar gebruikt worden om de emissies en sinks van broeikasgassen te rapporten.

- de **onzekerheidsschattingen** voor iedere broncategorie in de emissie-inventarisatie en het maken van separate schattingen voor de onzekerheden in de emissiefactoren - als die afwijken van de standaard IPCC-waarde - en in de activiteitendata.

- de **quality control** van de jaarlijkse nieuwe emissieschattingen en van herberekeningen die op nieuwe methoden of betere activiteitendata en/of emissiefactoren gebaseerd zijn en het documenteren van de basis van deze schattingen.

- het **onderhouden van tijdreeksen**. Het zou bijvoorbeeld duidelijk moeten zijn om welke reden en op welk moment er nieuwe berekeningsmethodieken geïntroduceerd zijn, die de gehele tijdreeks beïnvloeden. Het kan noodzakelijk om over frequentie en timing duidelijke besluitvorming te hebben: bijvoorbeeld alleen herberekeningen na drie of vijf jaar of alleen wanneer aan bepaalde criteria voldaan wordt, bijv. dat de bijstelling groter is dan een bepaalde minimumwaarde.

- **grote gaten in kennis** zouden moeten worden gedicht. Grote sectorale emissies met grote onzekerheden dienen daarbij de hoogste prioriteit te krijgen (bijv. lekkages bij de gasdistributie, landbouw, gebruik van SF_6). Hierdoor zal de monitoring verbeteren van de bronnen die een groot effect hebben op de emissietrends.

- in sommige geval zal een **verbeterde toepassing van de *Revised IPCC Guidelines*** leiden tot meer vergelijkbare emissieschattingen (bijv. de schatting van CO_2 van energiedragers gebruikt als chemische grondstof (zgn. feedstocks), niet-CO_2-emissies van bunkerbrandstoffen en N_2O uit landbouw en vervuild oppervlaktewater).

- de **samenwerking met de doelgroepen** om de monitoring van emissies te verbeteren, in het bijzonder wanneer emissiereducties worden verwacht. Voorkomen moet worden dat iedere doelgroep andere schattingsmethoden gaat ontwikkelen. Indien emissiemetingen worden uitgevoerd, bijv. in het kader van het Reductieplan Overige Broeikasgassen (ROB), zouden op basis hiervan nieuwe emissiefactoren kunnen worden ontwikkeld.

PROGRAMME

Chair:	Harry Baayen, Director, Air and Energy Directorate-General for Environmental Protection (DGM) Ministry of VROM, The Netherlands
	Introduction
9.00 – 9.30	Presentation of the workshop objectives *Paul Ruyssenaars VROM/DGM*
9.30 – 9.50	International activities *Carolien Kroeze WIMEK*
9.50 – 10.20	Target group monitoring *Pieter van der Most VROM/HIMH*
	Validation
10.50 – 11.20	General introduction and national experience with uncertainty analysis *Tinus Pulles TNO-MEP/John van Aardenne WIMEK*
11.20 – 11.35	Comparison of country reports with EDGAR/GEIA data *André van Amstel. WIMEK*
11.35 – 11.50	Fact sheets on carbon dioxide *Marianne Kuijpers-Linde RIVM/LAE*
	Verification
11.50 – 12.00	General introduction on the (im)possibilities of verifying emission estimates with atmospheric concentration measurements *Leon Janssen RIVM*
12.00 – 12.10	An example of methane measurements *Jan Berdowsk*i TNO
12.10 – 12.20	Costs for reducing uncertainties in emission estimates using monitoring results from Europe *Peter Builtjes/Jan-Willem Erisman TNO/ECN*
12.30 – 13.30	*Lunch*
	Introduction to **parallel sessions**
13.30 – 13.40	How can we achieve a strategy for reducing the uncertainties? *André van Amstel WIMEK*
13.40 – 15.30	**Parallel sessions** 1. Energy (production/distribution and stationary combustion, including feedstock) 2. Industry (process emissions, excl. feedstock emissies and CO_2 from fossil fuels) 3. Transport (combustion and process emissions - incl. bunkers) 4. Agriculture (process emissions) 5. Other (process emissions from Waste Treatment, Residential and Trade & Services)
15.30 – 16.00	*Tea break*
	Concluding session
16.00 – 17.00	Discussion and conclusions
17.00 – 18.00	*Drinks*

1. INTRODUCTION

André van Amstel [1)] and Paul Ruyssenaars [2)]

[1)] Wageningen Institute for Environment and Climate Research
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A good monitoring system for greenhouse gas emissions is essential if the Kyoto Protocol under the United Nations Framework Convention on Climate Change (*UNFCCC*) is implemented. The implementation (and credibility) of the *Climate Convention* and the *Kyoto Protocol* will stand or fall with the quality of the emission data; for this reason, this data has to be reliable and verifiable. Uncertainties in the emission figures for greenhouse gases have proven to be considerable. With a view to the public opinion on climate policy and also to give substance to the obligations in the Climate Agreement, uncertainties, both in the Climate Agreement and in the *Kyoto Protocol* must be reduced. The Ministry of VROM, in cooperation with the National Institute of Public Health and the Environment (RIVM) and the Wageningen University's Institute for Environment and Climate Research (WIMEK), therefore takes pleasure in welcoming your participation in this workshop.

Workshop objectives

The objectives for this workshop are:
1. Mapping and possibly improving information flows for the national inventories taking place annually in the context of the *Kyoto Protocol*.
2. An inventory of aspects in the current national system for determining greenhouse gas emissions that could be improved.
3. An inventory of how improvements of the national system can be achieved.

Implementation of the *Kyoto Protocol* will require reduction of the uncertainties and improvement of the so-called *National System* for greenhouse gas emission monitoring, so that flexible strategies like emission trading and joint implementation can be introduced. It will be the task of this workshop to introduce initiatives for adding substance and organisation to the monitoring programme. The starting point of this workshop is the monitoring of policy implementation in the light of uncertainties in emission data. The demands for accuracy in monitoring are a logical consequence of the *Climate Convention* and the *'legally binding commitments'* taking force as soon as the *Kyoto Protocol* is ratified.

The objectives will be elaborated as follows:
6. *Per target group:* Listing the possibilities for quantitative assessment of the uncertainties of emission estimates. Overall assessment of uncertainties per sector.
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9. *Who, what and when?* Determining who is going to do what and when to reduce uncertainties in emission estimates.
10. *Plan of action:* Establishing a general plan per target group to work out the above objectives.

We will start with a plenary morning session, followed by parallel sessions in the afternoon where working groups (according to target group) will define the general uncertainties and develop action plans for reduction.

Workshop results

The workshop should be seen as a starting point for setting up a monitoring programme to be carried out in the coming years. The workshop report will form the basis of this programme. The workshop will bring together researchers, policy-makers, and suppliers of statistical data and those who will be compiling the emission inventories.

Monitoring

This introduction overviews the state-of-the-art on emission monitoring and the quality of the emission data and sketches the (inter)national approach to improvement of emission data. It is the starting point for this meeting of those involved in the emission inventory in the Netherlands for a discussion on the implementation of the *Kyoto Protocol.* Especially the obligations for the Netherlands are addressed. The obligations for the yet to be developed so-called *National System* for the monitoring of greenhouse gas emissions are, to start with, heavy; this in consideration of the 'compliance' system to be developed, which is geared to monitoring of countries to see if they are meeting their obligations. Besides, this it is important for the application of flexible tools (Joint Implementation, Clean Development Mechanism and Emission Tradeoffs). This introduction was to serve as background information for participants to the workshop ' Monitoring greenhouse gases' held in Bilthoven, The Netherlands on 1 September 1999.

Methodology

According to international agreements the Netherlands should determine and report yearly the (trends in) greenhouse gas emissions. Reporting is done to the Conference of Parties to the Climate Convention of the UN via the secretariat in Bonn and to the European Union, which is also a Party to the Climate Convention. In this Convention it has been agreed that emissions would be established following the guidelines for greenhouse gas emission inventories of the IPCC (1997). Countries are asked to use the best available methods. If country-specific methods are used because they are better than in the IPCC Guidelines, delegates will be requested to report using a standard format. Emissions will, in general, be determined by *multiplying the activity data (fuel consumption, number of animals, production, etc.) by emission factors (emission per unit fuel, animal and productio*n). In de *Revised 1996 IPCC Guidelines* default emission factors are incorporated, which countries can choose in the absence of better figures. However, IPCC urges countries to use the best methods and emission factors. These are usually country-specific methods and emission factors. On the basis of scientific research, the Netherlands uses its own emission factors for virtually all the sources. Methods usually conform to the detailed IPCC methods. The methods used in the Netherlands were established in 1997 after consultation between different relevant institutes (RIVM, TNO, CBS, ECN, Wageningen University). The necessary data for the annual inventory were collected by TNO in the framework of the Emission Registration office. This information is then processed and reported in the Emission Report for the Supreme Inspection for the Environment of the Ministry (VROM/HIMH). RIVM reports the inventory in the trend analysis in the annual Environmental Balance. Next to this the Netherlands makes official submissions to the UN Climate Convention secretariat and the European Union in annual reports conforming to the IPCC format.

Reliability

To get a maximum public support for the climate policies it is essential that greenhouse gas emission data is reliable. Large uncertainties can affect the credibility of government policy. Willingness of target groups and the public to carry out policy measures will be limited in a situation where there is a lot of uncertainty about emission data. Certainly public support will be low if measures are being considered that achieve a reduction effect of only a few 10ths of

Mton CO2 equivalents per year, as suggested in the *Option document for emission reduction of greenhouse gases* (a preparatory report to the Ministry's Climate Policy Implementation Memorandum).

The table below, based on the judgement of RIVM experts and tested during an international workshop on this subject held in Bilthoven in November 1997, shows an estimate of the reliability for emission data. The uncertainties in the Netherlands' emission inventory with regard to specific components are a bit smaller than the international estimates; however, with respect to their magnitude they are comparable.

Table 1: Emissions in the Netherlands (base year 1990 [1995 for HFCs, PFCs and SF_6]; Mton CO_2 equivalents) and uncertainty estimates (%) on the basis of *expert judgement*

Gas/sector	Emissions 1990	Uncertainty (±)	
	(Mton CO_2-eq.)	(%)	(Mton CO_2-eq.)
CO_2 (carbon dioxide)			
Fossil fuel combustion	149.7	2%	3.0
Industrial processes/Feedstocks	11.7	25%	2.9
Land use (sinks)	*(-1.5)*	*(60%)*	
Subtotal emissions	161.4	3%*	4.2*
CH_4 (methane)			
Energy	4.5	25%	1.1
Agriculture	10.6	25%	2.7
Waste	11.9	30%	3.6
Subtotal	27.0	17%*	4.6*
N_2O (nitrous oxide)			
Energy use	2.3	75%	1.7
Industrial processes	9.8	35%	3.4
Agriculture	6.9	75%	5.2
Subtotal	19.0	34%*	6.4*
HFCs/SF_6 [95]			
Energy sector	1.4	50%	0.7
Industrial processes	5.1	50%	2.6
Subtotal	6.5	41%*	2.6*
PFCs [95]			
Industrial processes	2.4	100%	2.4
Subtotal	2.4	100%	2.4
Other sectors			
Other sectors/substances	1.0	50%	0.5
Total emissions:	218.8	4.4%*	9.6*
Objectives 2008-2012:	206		

Table based on actual emissions.

* Uncertainty ranges summed for all sectors or gases using the standard calculation for error propagation (total error is the root of the sum of squares of the error in the underlying sources). Strictly speaking, this is only valid if the uncertainties meet the following conditions: a) standard-normal division, b) 2σ smaller than 60%, c) sector to sector, substance to substance are independent.

The percentage uncertainty for CO_2 from fossil fuels as shown in the table is small (ca. 3%). These emissions arise from combustion processes, feedstocks (synthetics) and refineries. If only combustion processes are taken into account, the uncertainty in the emissions is even lower (about 2%). This can be explained by the availability in the Netherlands - just as in most of the other industrialised countries - of complete, detailed and reliable fuel statistics, for demand as well as supply. These data become available through energy supply statistics, and measured and adjusted fuel consumption and questionnaires held in the branches of industry carried out ever since the energy crisis in the 1970s. From these statistics it is possible to calculate fairly accurately how large the CO_2 emissions from the combustion processes are. The uncertainly in the total greenhouse gas emission in the Netherlands is therefore determined to a large extent by CO_2 emissions. Incidentally, the IPCC has suggested recently that the statistical uncertainty should be made explicit.

The uncertainty in the emission data of especially non-CO_2 greenhouse gases and uncertainty in CO_2 sinks is relatively large. Possible explanations follow:
- The focus on greenhouse gases other than CO_2, as an element of climate policy is recent. The trajectory followed throughout the years for obtaining reliable CO_2 emission data still has to be largely started up for these gases; of main concern here are HFCs, PFCs and SF_6, which started to gain attention after the *Kyoto Protocol*. Indeed, the emissions of these gases (primarily from industrial sources) are easily determined. The uncertainty in the estimates is due to there not yet being good statistics on their use; measurement data are also only available to a limited extent.
- Bacteriological processes in the soil and digestive tracts of cattle mainly determine methane and nitrous oxide emissions from agriculture. These emissions are dependent on many factors and are therefore variable in time and space. For this reason large samples are needed for their proper determination. There is also a lack of good, climate-policy relevant statistics.
- The same goes for emissions and sinks of CO_2 related to forests and land use. To date it has not proven possible to completely balance the carbon budget (exchange of carbon between the earth and atmosphere). However, in the Netherlands this effect is relatively small.

Three comments on Table 1:
(1) The uncertainties for the non-CO_2 greenhouse gases and sinks, as presented in the table, are based on 'expert judgement' and not on elaborate empirism and statistics. This makes these uncertainties even more uncertain.
(2) For the time being it is not certain if all the sources have been (completely) mapped out. We are not sure if still more emission categories will have to be added later. Particularly in the reduction of NO_x, conditions may arise causing the formation of nitrous oxide. Although the effect is expected to be small, further research is desirable.
(3) The uncertainties in the emissions for the base year are projected in the emissions for the budgeted period of 2008 to 2012 and the resultant reduction efforts. According to the rules for calculating the effect of uncertainties, an uncertainty margin of 17 Mton per year (34%) should be maintained if a reduction effort of 50 Mton per year is to be realised. Here the uncertainties inherent in the scenarios used (assumptions for prices, GDP growth index, etc.) are not taken into consideration. Besides, if the necessary reduction effort proves to be higher than 50 Mton per year, the reduction potential will turn out just as high.

Conclusions

Based on the above-mentioned we can conclude that:
(1) The uncertainty in the greenhouse gas emissions is relatively small (about 5%) when this is compared to the total emissions in the base year. This means that the emission ceiling for the Netherlands (*assigned amount* of 206 Mton CO_2 equivalents per year) under the *Kyoto Protocol* is, on the basis of current insights, fairly robust.
(2) The uncertainties in the emissions per gas and per sector are considerable for a number of cases. This applies in particular to HFCs, PFCs and SF_6 emitted from industry and installations, as well as emissions of methane and nitrous oxide from the agricultural sector. These are both sectors where substantial reduction potentials (ca. 7 Mton CO_2 equivalents) are expected for the period of 2008-2012. With a view to realising a credible implementation of policy, these uncertainties will have to be reduced in the coming time.

Policy commitment

The policy commitment for emission monitoring in the Netherlands for the coming years will be established through:

- the international obligations conforming to the *Climate Convention* and the *Kyoto Protocol*;
- the national climate policy (Implementation memorandum on Climate Policy).

Compliance to the *Climate Convention* and the *Kyoto Protocol*

The main obligations taken on by countries on the basis of the Climate Convention and the *Kyoto Protocol*:
- Countries are to report the progress and implementation of their policy to the secretariat of the *Climate Convention* (by means of a *National Communication*, the first due in 2001). Reporting on emission trends and projections up to 2020 will form part of this reporting.
- Countries are also obliged to *report emission data annually* to the secretariat of the Climate Convention. During the signing of the Convention in Buenos Aires the parties had decided to subject these annual reports to an international review process, similar to that for the *National Communication;*
- Countries are to develop a *National System* for emission inventories in conformance with Article 5.1 of the *Kyoto Protocol*.

Besides this, various elements in the Climate Convention are resulting at the moment in international IPCC activities directed to improving the quality of emission data (and the reports on these submitted to the Climate secretariat). Such activities are needed to substantiate themes like the compliance regime of the *Kyoto Protocol* (including the verification of the emission ceiling of countries - the ' assigned amounts'). Reliable figures are also needed as a basis for the flexible mechanisms in the *Kyoto Protocol*, such as emission trading and Joint Implementation.

Considering the above-mentioned, one of the bodies under the *Climate Convention*, the *Subsidiary Body for Scientific and Technical Advice (SBSTA)* has asked the IPCC to develop guidelines for determining and communicating uncertainties, and for the manner in which uncertainties should be dealt with; these are the so-called *'Good Practice Guidelines'*. The Climate secretariat is currently working on improvements in the manner of reporting under the Climate Convention (and later the *Kyoto Protocol*). For emission reporting countries will - in conformance with a Conference of the Parties decision in Kyoto – need to follow the guidelines developed by the IPCC (*Revised 1966 IPCC Guidelines*).

For the further development of these guidelines and the co-ordination of international activities in emission inventories, the IPCC (in cooperation with the IEA and OECD in Paris) has developed the *National Greenhouse Gas Inventories Programme.* The secretariat of this Programme is transferred to Japan in 1999, while a recently established IPCC Technical Support Unit in Japan will tackle the further implementation of this programme.

The emphasis of the programme at the moment is on the development of the above-mentioned *'Good Practice Guidelines'* for determining and addressing the (international) uncertainties for greenhouse gas emissions. The guidelines to be developed will be concerned with the way in which emissions are reported and - ultimately - possibly reduced. Scientists from various Dutch institutes with expertise in this area are taking part in this Good Practice effort. Wageningen University organised an IPCC Expert Meeting from 23-26 February 1999 to investigate the uncertainties in agricultural sources. Within the *National Greenhouse Gas Inventories Programme* there is also special focus on CO_2 sinks through agricultural use, and soils and forests. The uncertainties in these categories are extremely large, while (on the global level) and depending on the manner in which the *Kyoto Protocol* is interpreted, the contribution of sinks to the net emission reduction for some countries (USA, Russia) can be, mathematically in any case, considered as extremely large.

National policy

The current Dutch emission data meet the guidelines as presently upheld by the IPCC. For this reason there is no reason to adapt Dutch emission figures to the Implementation Memorandum for Climate Policy.

The Netherlands must, however, meet the future obligations proposed via the *Climate Convention*. This means that the Netherlands must have a national system at its disposal for establishing the emissions of greenhouse gases that will stand up to the test of international criticism. The requirements that such a national system will ultimately have to meet have, however, not yet been established.

Keeping in mind the uncertainties of the current emission data of especially the other greenhouse gases, efforts will be needed to reduce these uncertainties. Besides the earlier argument of the carrying capacity of target groups, similar efforts will be necessary to be able to determine exactly what the effect (in terms of emission reductions) will be of the measures taken in the framework of the *Implementation Memorandum for Climate Policy.*

With a view to this the Implementation Memorandum will announce the setting up and execution of a monitoring programme. The substantial and process design of this programme will be worked out in cooperation with and on the basis of insights of experts and policy-makers.

1.1. INTERNATIONAL ACTIVITIES ON NATIONAL GREENHOUSE GAS EMISSION INVENTORIES

Carolien Kroeze

Environmental Systems Analysis, Wageningen University

Introduction

The IPCC/OECD/IEA Programme for National Greenhouse Gas Inventories includes two activities that are relevant for the topic of this workshop: the development of the *IPCC Guidelines for National Greenhouse Gas Inventories* and, related to that, the development of *Good Practice Guidelines for Inventory Preparation.*

IPCC Guidelines for National Greenhouse Gas Inventories

The IPCC Guidelines for National Greenhouse Gas Inventories have been developed in order to assist countries in estimating their national emissions. The IPCC Guidelines consist of methods for the quantification of greenhouse gas emissions from energy, industry, solvent and other product use, agriculture, land use change and forestry and waste. For each of the relevant emissions an estimation method including default emission factors is given, that is applicable to any world country on the basis of readily available statistics on human activities. Countries are, however, not obliged to estimate their emissions following the default methods included in the IPCC Guidelines. Instead, they may report alternative estimates, based on country-specific information.

Nitrous oxide (N_2O) from agriculture as an example

The IPCC method for estimating N_2O emissions from agriculture was developed by an expert group in 1995, reviewed in 1996 and published in the revised IPCC Guidelines in 1997 (IPCC, 1997). The expert group consisted of more than 30 scientists from different countries. The group was subdivided into 3 subgroups, focussing on (1) emissions from agricultural fields, (2) emissions associated with animal production and (3) indirect emissions (e.g. from polluted surface waters). The subgroups developed draft calculation methods which were finalized at a meeting. The method is described in detail in Mosier et al. (1998). Countries can estimate their agricultural N_2O emissions following this method, on the basis of information that can be obtained from FAO databases. The method includes a nine-step procedure to estimate national emissions from this information. On a global scale, the method results in emission estimates that are consistent with trends in atmospheric N_2O (Kroeze et al., 1999). However, this does not necessarily indicate that the method provides good quality estimates on the national level. For several countries the IPCC method results in higher estimates than reported in their National Communications. This is partly a result of missing sources in the National Communications, and partly a result of different estimation methods used by countries, based on country-specific information.

Approaches to assess the quality of national emission inventories

National greenhouse gas inventories are preferably accurate, complete, comparable, transparent and of good quality. However, no clear guidance exists as yet on how to meet these requirements. November 1997, an IPCC Expert meeting was held focussing on the quality of greenhouse gas inventories (Van Amstel et al., 1999). At this meeting, four

different approaches to assess the quality of an inventory were discussed (Lim and Boileau, 1999):
- Inventory quality assurance
- Comparison of emission inventories
- Comparison of emission estimates with atmospheric model results
- Direct emission measurements

Good practice in inventory preparation

Currently, an activity within the IPCC/OECD/IEA Programme for National Greenhouse Gas Inventories focuses on the development of guidelines for good practice in inventory preparation. The objectives of this activity are
- To examine good practice in inventory preparation
- To outline procedures for establishing completeness, comparability, transparency and quality of inventories
- To develop guidance on specific methodological and reporting issues
- To examine issues related to uncertainty assessment

These issues are discussed at four IPCC Expert Meetings, focussing on industry, agriculture, energy and waste. In addition, a meeting will be held focusing on uncertainty assessment. One of these meetings was organized at the Wageningen University, and focused on greenhouse gas emissions from agriculture (IPCC Expert Meeting on Good Practice in Inventory Preparation: Agriculture, February 1999).
Some of the issues discussed at this meeting included
- Good practice decision trees
- Consistency of activity data
- Assessment of the nitrogen cycle in inventories
- Interrelations between estimates of methane, nitrous oxide, ammonia and nitrogen oxide emissions
- How to take into account temporal variation
- Guidance towards collection of country-specific information

Monitoring of emission reduction

The IPCC Guidelines were primarily developed to quantify present-day emissions, which does not necessarily mean that they can be used for the monitoring of all possible emission reduction strategies. There may be policy options, for which the methodologies included in the IPCC Guidelines may not be sufficiently detailed to assess their effects. It would be useful, therefore, to take this into account when evaluating the IPCC Guidelines in the future.

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1.2. NATIONAL POLLUTANT EMISSION REGISTER IN THE NETHERLANDS

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[Paper also submitted to the Pangovernmental meeting "Development of an Environmental Monitoring System in the European Region". December 8-9, 1999. Moscow. Russian Federation.]

Abstract

Since 1974 an integrated database of emissions and supporting information is present in The Netherlands. This database has developed into the national register containing all information about emissions that all actors in the field have agreed upon. This national Pollutant Emission Register is the equivalent of the national Pollutant Release and Transfer Register (PRTR) in The Netherlands. The Pollutant Emission Register is one of the main tools in the monitoring of target groups and is the main source of information about emissions on a regional, national and international level. The emission data in the central national database are disseminated to all interested parties including the public by means of reports using also CD-ROM and Internet.

Introduction

The national Pollutant Emission Register (PER) comprises the registration, analysis, localisation and presentation of emission data of both industrial and non-industrial sources in The Netherlands. The PER is used as the national instrument to monitor the emissions from all source categories to all compartments on a (sub-) national scale [1]. Emissions are gathered from all source categories, being industry, public utilities, traffic, households, agriculture and natural sources. Agreement about definitions, methods and emission factors, based on reports by expert groups, is achieved in the Coordination Committee for the Monitoring of Target Groups (CCDM).

The emission data are updated every year. The results are reported yearly in a joint publication with the other actors in the field and stored in the central national database, from which information for policy or research applications is provided. The aim of the emission inventory is to support the environmental policy of the government and to monitor the progress of environmental policy. The annual update of the emission data enables the user to analyse trends in the emission data and to assess in what respect environmental targets are achieved. These environmental targets have been set in the National Environmental Policy Plan that will be revised in 2000 [2].

The Inspectorate for Environmental Protection (IMH) is owner of the Pollutant Emission Register (PER) and is responsible for the overall management and co-ordination of all activities with respect to the PER. Part of the operational activities has been commissioned to other institutes. The Organisation for Applied Scientific Research (TNO) collects emission data of the large point sources and carries out the processing and publication of the emission data. The National Institute for Public Health and Environment (RIVM) carries out the maintenance of the information systems. Both TNO and RIVM are contractors in commission of the Inspectorate.

All activities by the Inspectorate, TNO and RIVM are subject to a quality system according to ISO 9001. This quality system has been introduced in 1997 to ascertain the quality of the monitoring process related to the PER. The function of the quality system is assessed periodically.

Objectives of the monitoring system

The objectives of the Pollutant Emission Register (PER) are the following:

- to monitor annually the emissions of air and water pollution as well as the waste flows from all sources on a (sub-) national scale;
- to verify the progress of environmental policy;
- to provide the official emission data to national and international bodies;
- to disseminate the emission data to the public and to pollution transport models.

To fulfil its objectives the monitoring system of the PER has the following tasks:

- to collect and diagnose all emissions to air, water and soil from both industrial and non-industrial sources in The Netherlands and to store the emission data in a central database; in the near future waste data will be included too;
- to analyse the emission data with respect to pollutant, target group and industrial branches, to environmental theme and to the location of the sources;
- to assess the effects of environmental policy and to evaluate to what extent policy targets for emission reduction are achieved;
- to ascertain trends in the emission data by evaluating the results for the subsequent inventory years;
- to provide emission data to national (e.g. provinces) and international (e.g. ECE) authorities and to other interested parties and the public.

The monitoring system of the PER comprises two connected information systems:

- the individual system (IEI), containing emissions to air, water and soil for industrial large point sources. These industries are registered individually based upon detailed information of each individual site;
- the collective system (CEI), which is a geographical information system (GIS), containing spatial resolved emission data. This system includes emissions from all sources, industrial as well as non-industrial including the IEI data in aggregated form. The emissions of the small and medium-sized enterprises as well as non-industrial diffuse sources are calculated collectively with statistical data on specific activity rates and emission factors.

Position within monitoring

The progress of emission reductions, as mentioned in the National Environmental Policy Plan, is controlled by monitoring the emissions of the different source categories or target groups. This process is monitored by target group oriented expert groups and coordinated by the Coordination Committee for the Monitoring of Target Groups (CCDM). Annually the CCDM establish the list of pollutants to be incorporated in the target group monitoring programme. For each target group an expert group is elaborating the procedures and methods of the complete monitoring process into a protocol. All parties involved have to agree on the content of that protocol.

The CCDM is the national co-ordination committee for the activities of expert groups dedicated to the following source categories:
- Agriculture, including non-anthropogenic sources.
- Traffic and transport, including road, rail and air traffic and shipping.
- Facilities, including industrial sites and small and medium-sized enterprises, power plants, oil refineries and waste incinerators.
- Waste disposal sites or landfills.
- Consumers, including all residential-related emissions.
- Other small source categories, e.g. drinking-water companies, sewage treatment plants, research institutes, trade and government.
- International aspects, concerning the supply of monitoring data to the European Union and other international bodies.

Each expert group formulates a protocol for the monitoring process with respect to its specific target group. The monitoring process comprises the following five steps:

1. Data collection : the information flow from the stakeholders to the regulatory bodies or the competent authorities is described. This description includes details about the nature of the data.

2. Data validation: the quality of the data is verified. This includes the quality assurance by the supplying party as well as the quality control by the regulatory bodies or other competent authorities.

3. Data storage the Inspectorate for Environmental Protection makes appointments with all suppliers of information about polluting sources and gathers the required data. These data are implemented into the central database of the Emission Inventory System containing the national emission data.

4. Data management in close cooperation with the competent authorities the Inspectorate for Environmental Protection handles the emission data in such a way, that presentation on different levels of aggregation is possible to fulfil the requirements of the stakeholders or other users.

5. Data dissemination data from the central national database is publicly available and is reported in the annual National Emission Report, edited by the Inspectorate for Environmental Protection. Furthermore the effort is aimed at the dissemination of emission data to the public on CD-ROM as well as by using the technical possibilities of datawarehousing to provide data to the Internet.

Act on environmental reporting

The purpose of the monitoring system is to support the environmental policy of the government, comprising the monitoring of the progress of environmental policy. The yearly update of the emission data enables to analyse trends in the emission data and to test in what respect environmental targets are achieved.

The greater part of the emissions of toxic substances from industrial sources is controlled by licenses granted by the competent authorities. These regulatory bodies are in most cases provinces, water board authorities or municipalities. Until now the Department for Monitoring and Information management of the Inspectorate for Environmental Protection has been provided yearly with the nation-wide emission data of about 500 major facilities (with altogether about 2100 plants) on a voluntary basis. As a result of the act on environmental reporting reduction of the emissions is controlled by covenants between industrial sectors and government. Based on these covenant agreements environmental business reports are drawn up for individual industrial sites. The information about the industrial emission data from these environmental business reports is imported into the central national database.

A close connection exists between target group monitoring and the annual environmental reports that the large industrial sites will have to produce. These annual reports are part of the legal framework and will be made public before April 1st of each year. About 320 most polluting companies in the country have to produce environmental reports. This obligation will be mandatory from the reporting year 1999 onwards.

In the environmental report a facility is obliged to report yearly on its environmental performance as well as on its environmental management system. These two topics have to be presented both in a report to the public and in a report to the government. The reports may be combined, but differences in presentation are allowed. The report for the government must present quantitative data for all relevant pollutants emitted or released by the facility. The public report has to obey the European standards for the EMAS declaration, while the report for the government has to provide all necessary information to monitor the progress of emission reductions as agreed between industry and government. The government report should be an integral source of all reporting obligations from industry to government. The first mandatory reports will be published by facilities in the year 2000 giving emission data for the year 1999.

Central database with national emission data

All emission data of the Pollutant Emission Register are updated annually. The structure of the central database with the national emission data has the following three dimensions, which enables the presentation of the emission data at different levels of aggregation:

1. Pollutants: The database contains the necessary information about the emissions of all relevant species or compounds, for which an environmental policy or emission reduction target has been formulated. Added to this group of pollutants are substances for which international obligations require reporting and a list of pesticides monitored for agricultural policies. In 1998 this includes the emission data for about 170 different substances including waste, listed in the appendix. The information about individual substances can be aggregated to the level of environmental themes distinguished in the National Environmental Policy Plan. With respect to the emissions relevant environmental themes are the following:
- climate change (due to CO_2, CH_4, N_2O, SF_6 and CFCs);
- ozone depletion (due to CFCs);
- acidification (due to SO_2, NO_x, NH_3);
- eutrophication (due to N- and P-compounds);
- dispersion (due to pesticides and other toxic substances).

2. Sources: The database contains plant specific emission data of all large point sources as well as activity rates and emission factors for all small and medium-sized enterprises and diffuse sources. Both industrial and non-industrial sources are included, so that all sources and activities are incorporated. The information about the polluting sources can be aggregated to the level of target sectors or source categories. The most important sectors as determined in the National Environmental Policy Plan are:
- refineries;
- power plants;
- industry, including small and medium-sized enterprises;
- waste disposal sites;
- traffic and transport;

- agriculture;
- consumers;
- miscellaneous, including nature.

3. Locations: The database is linked to a Geographical Information System. This GIS supports the interconnection of emission data to the location of the sources. Both large point sources and small and diffuse sources are localised in a grid of 1*1 km^2. This enables the information system to present the emission densities of spatially resolved emission data. The emissions in the individual grid cells can be aggregated to the level of the twelve different provinces in the country, to the various water catchment areas and of course into national totals.

Collection and dissemination of data

The data collection into the central national database of the PER follows two different pathways:

Large Point Sources
Emission data for most of the pollutants is collected for each individual facility on a site by site basis. Only combustion emissions are collected for each individual plant due to regulations of the European Union. From 1999 onwards these data will be reported mandatory by about 320 facilities to the regulatory bodies, i.e. the provinces. The provinces will validate the reported data and send them to the Inspectorate for Environmental Protection to be inserted into the central database of the PER. The combustion emissions of the large combustion plants are reported annually to the European Union.

Small and diffuse sources
The emission data for these sources is calculated by applying statistical information about the activity rates of the different activities. By multiplying activity rates with emission factors the emissions are estimated and updated in the central database of the PER. The estimation of the waste data occurs by a similar approach.

After processing the data in the national database is fixed for a specific reporting year and published in the annual Emission Report both on paper and on CD-ROM. This publication is a joint result of the efforts of all parties involved in the process of collecting and handling the emission data. Therefore the Emission Report is a co-production of the Ministry of Housing, Spatial Planning and the Environment, the Ministry of Transport, Public Works and Water Management, the Ministry of Agriculture, Nature Management and Fisheries, the Central Bureau for Statistics and the National Institute for Public Health and Environment. Moreover a copy of the database is provided to the institutes preparing environmental reports and also to the provinces to be introduced into their own information systems. In this way the goal has been achieved to use only one consistent dataset for all kind of environmental reports within the country.

In the near future a selection of the national database of the PER will be extracted into a data warehouse to be accessed by all interested parties. By connecting the data warehouse to the Internet the emission data of the PER will be accessible to the public.

International context

As a result of the UNCED conference in Rio de Janeiro in 1992 the OECD took the initiative to promote the introduction of a national Pollutant Release and Transfer Register (PRTR) in all countries. After five workshops the design of a PRTR has been conceived and formulated into a guidance manual for governments. This PRTR guidance document has been accepted by the OECD countries in 1996 together with a council recommendation on implementing PRTR's. The PER/EIS system in The Netherlands has to be considered as the Dutch equivalent of the PRTR.

Basic characteristics of the PRTR in general are the following:
- a PRTR is a national integrated environmental database;
- a PRTR is an effective tool for pollution prevention;
- a PRTR is an instrument to reduce duplicative reporting;
- PRTR data are used by government in the assessment of environmental policy;
- PRTR results are made accessible to the public.

Besides the development of a PRTR cooperation occurs with other international organisations like the European Union and the European Environmental Agency (EEA). Periodically emission data are provided to the EEA as an input for the European information system CORINAIR and the UNECE/EMEP monitoring activities. Furthermore contributions are made to the Atmospheric Emission Inventory Guidebook, aiming at agreement about methods and emission factors. Finally the department for Monitoring and Information Management acts as the National Reference Centre for Emissions for the benefit of the EEA to supply emission data to international emission inventories and information systems.

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APPENDIX: LIST OF SUBSTANCES INCORPORATED IN THE MONITORING PROGRAMME IN 1998

The list of substances mentioned here is being revised for the situation in the year 2000. The main changes will be in the category solid waste and to a lesser extent in the pesticides group. Threshold values have been defined for reporting obligations of individual emissions. The reporting threshold values are given in the tables both for emissions to air and to water in kg/year.

1. ANORGANIC COMPOUNDS

1.1. Metals and metalloids (10)

Threshold values in kg

	Threshold Air	Threshold Water
Antimony	1	1
Arsenic	1	1
Cadmium	1	1
Chromium	10	10
Copper	5	10
Mercury	1	1
Lead	100	10
Nickel	50	10
Selenium	1	1
Zinc	100	50

1.2. Anorganic compounds (14)

Threshold values in kg

	Threshold Air	Threshold Water
Ammonia	5000	-
Nitrogen oxides	100000	-
Dinitrogen oxide	10000	-
Asbestos	1	-
Chlorides	5000	500000
Sulphur hexafluoride	10	1
Fluorides	1000	10000
Hydrogen sulfide	1000	-
Sulphur dioxide	100000	-
Carbon dioxide	100000	-
Carbon monoxide	100000	-
Cyanides	50	10
Fine dust (PM_{10})	10000	-
Coarse dust	10000	-

2. ORGANIC COMPOUNDS

2.1. Specified non-halogenated organic compounds (17) Threshold values in kg

	Threshold Air	Threshold Water
Acrolein	1	-
Acrylonitrile	100	-
Ethene	1000	-
Formaldehyde	100	-
Methane	100000	-
Methyloxirane	100	-
Oxirane	100	-
Benzene	500	10
Toluene	10000	10
Styrene	1000	1
Xylenes	1000	5
Ethylbenzene	10	1
Isopropylbenzene	10	1
Dibutylphthalate	1	1
Dioctylphthalate	100	1
Phthalates-total	100	1
Phenols-total	100	10

2.2. Specified halogenated organic compounds (24) Threshold values in kg

	Threshold Air	Threshold Water
1,2-Dichloroethene	-	-
1,2-Dichloroethane	100	5
Dichloromethane	1000	1
Epichlorohydrin	50	1
Hexachlorocyclohexane	1	1
Tetrachloroethene	1000	1
Tetrachloromethane	100	1
1,1,1-Trichloroethane	1000	1
Trichloroethene	1000	1
Trichloromethane	10	1
Vinylchloride	50	1
Methylbromide	1	-
Hexachlorobutadiene	10	1
Chloroanilines	-	-
Chlorobenzenes non-specified	50	1
Chloronitrobenzenes	-	-
Hexachlorobenzenes	1	1
Trichlorobenzenes	1	1
2-Chlorotoluene	-	-
4-Chlorotoluene	-	-
1,4-Dichlorobenzene	-	-
Dioxins (Teq)	0,001	-
Pentachlorophenols	1	1
Chlorophenols non-specified	-	-

2.3. PAH, CFC, HCFC, HFC, and halones (31) Threshold values in kg

	Threshold Air	Threshold Water
Polycyclic aromatic hydrocarbons (Min. of VROM selection)	500	1
Polycyclic aromatic hydrocarbons (Borneff selection)	500	1
Naphthalene	-	-
Phenanthrene	-	-
Anthracene	-	-
Fluoranthene	100	1
Chrysene	-	-
Benzo(a)anthracene	-	-
Benzo(a)pyrene	-	-
Benzo(k)fluoranthene	-	-
Benzo(g,h,i)perylene	-	-
Chlorofluorocarbons non-specified	1000	-
CFC 11	-	-
CFC 12	-	-
CFC 13	-	-
CFC 113	-	-
CFC 114	-	-
CFC 115	-	-
CFC + Halones (total)	1000	-
Halon 1211	-	-
Halon 1301	-	-
Halon 2402	-	-
HCFC non-specified	-	-
HCFC 22	-	-
HCFC 123	-	-
HCFC 124	-	-
HCFC 141b	-	-
HFC non-specified	-	-
HFC 125	-	-
HFC 134a	-	-
HFC 143a	-	-

2.4. General mixtures (7) Threshold values in kg

	Threshold Air	Threshold Water
Volatile organic compounds	100000	-
Non-methane volatile organic compounds	100000	-
Halogenated organic compounds	10000	5000
Non-halogenated aliphatics	100000	5000
Non-halogenated aromatics	10000	100
Halogenated aliphatics	10000	5000
Halogenated aromatics	100	100

3. Pesticides, herbicides and fungicides (26) No threshold values

DDT	Bentazon
Drins non-specified	Simazine
PCB's non-specified	Trifluralin
Azinphos-ethyl	Organic tin compounds
Azinphos-methyl	DNOC
Dichlorovos	2,4-D
Endosulfan	Diuron
Fenitrothion	Chloridazon
Fenthion	Dimethoate
Malathion	Mevinphos
Parathion-ethyl	Aldicarb
Parathion-methyl	Dithiocarbamates
Atrazine	Pesticides non-specified

4. Other substances (3)

Phosphorus-total
Nitrogen-total
Mineral oil non-specified

5. Miscellaneous (6)

Radiating substances non-specified	Noise
Radon	Black smoke
Smell	Water consumption

6. Solid waste (30)

Waste oil	Office, shop, and service waste
Car tires	Plastic waste
End of life vehicles	Waste paper and cardboard
Dredging sludge	Oxy-lime sludge
Batteries	Shipping waste
Construction and demolition waste	Shredder waste
Animal manure	Slag and fly ash from incinerating household and communal waste
Ferro domestic waste	Waste from painting activities
Phosphoric acid gypsum	Blasting grit
Glass	Street waste, market waste, waste from parks and waterways
Bulky household waste	Polluted soil
Waste containing halogenated substances	Packaging waste
Household waste non-specified	Fly ash from coal fired power plants
Waste from cables	Hospital waste
Jarosite	Sewage sludge

2. VALIDATION AND VERIFICATION

2.1. VERIFICATION, VALIDATION AND UNCERTAINTIES

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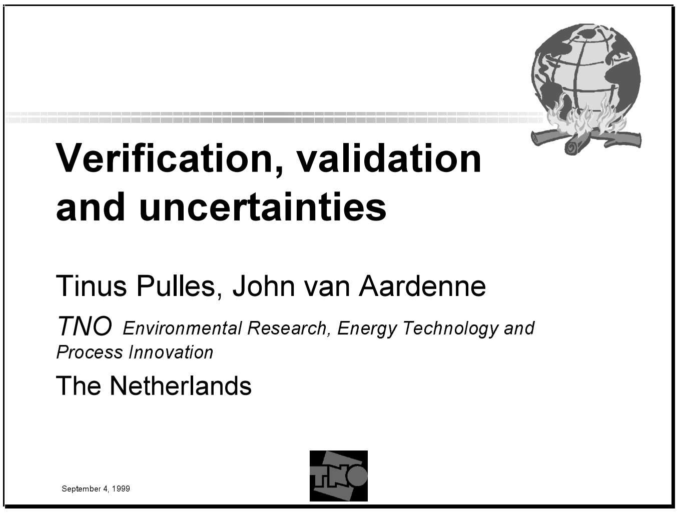
Slide 1



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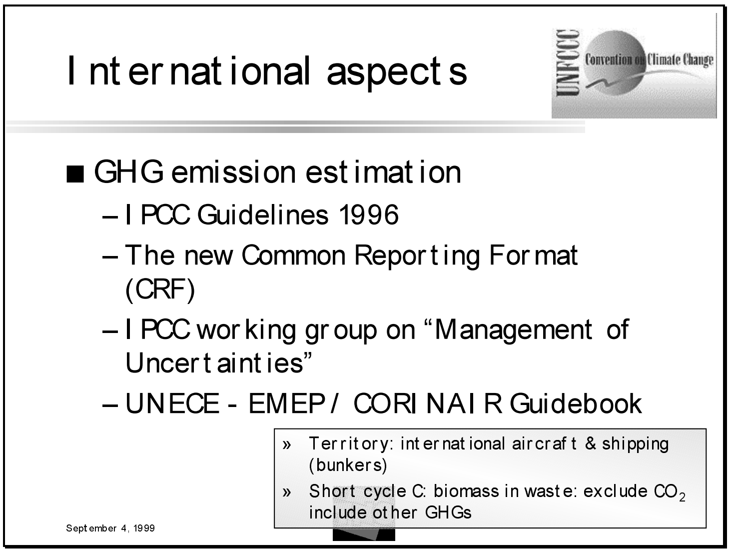


Greenhouse gas (GHG) inventories are produced in response to obligations derived from the Framework Convention on Climate Change (UNFCCC).
Parties to UNFCCC have accepted the IPCC 1996 Revised Guidelines to guide estimating GHG emissions.
Guidelines:

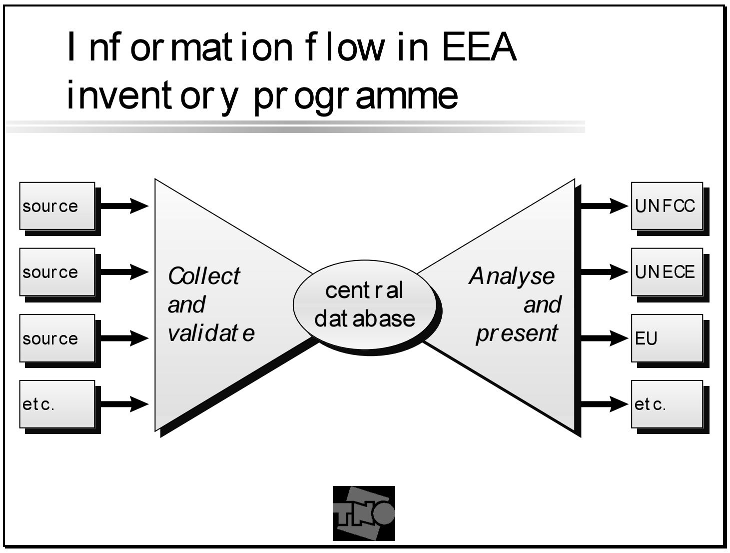
- **list sources and sources sectors**
- **propose default emission factors**
- **propose Summary Tables and Working Tables**

The Guidelines will not be changed soon. The reporting format will. Parties did so far not deliver the inventories in full detail according to the reporting format of the IPCC guidelines, Most parties reported using (derivatives of) the 8 Summary Tables only.
To increase transparency and comparability, SBSTA 10 has decided to adopt a new Common Reporting Format (CRF). Parties are encouraged to use this new CRF for the third national communication. Parties are requested to use the tables unchanged (do not delete or add rows or columns; do not change labels)

SBSTA asked IPCC Working Group on Management of Uncertainties to propose "Good Practice" and to produce guidance for estimating and reporting uncertainties.
Other reporting requirements (UNECE CRLTAP) use different definitions and a different sector split.
The major differences being:

- Territorial: international air traffic & shipping (bunkers); cruising aircraft
- Short cycle C in IPCC: biomass in waste: exclude CO_2 include other greenhouse gases

Slide 3



The inventory collection and reporting process is given in the scheme A clear distinction is made between collecting the data and reporting enabling:

- **consistency between different reports**
- **UNFCCC,**
- **UNECE/CLRTAP,**
- **European Union:**
  - ✓ (Amended) CO_2 Monitoring Mechanism,
  - ✓ Large Combustion Plant (LCP) Directive,
  - ✓ Integrated Pollution Prevention and Control (IPPC) Directive,
  - ✓ Emission Ceilings Directive etc.
- **OSPARCOM/HELCOM**
- **relatively simple adaptation to changing reporting formats of individual protocols and**

This approach is fully compatible with the concept of a Common Reporting Format (CRF), now being proposed by the UNFCCC Secretariat and accepted by SBSTA for a trial phase.
This means that where the CRF contains sectoral back ground data, this should not be interpreted as the activity data and emission factors as used by estimating and collecting emissions, but as information that increases transparency in the sense that it allows cross country comparisons.

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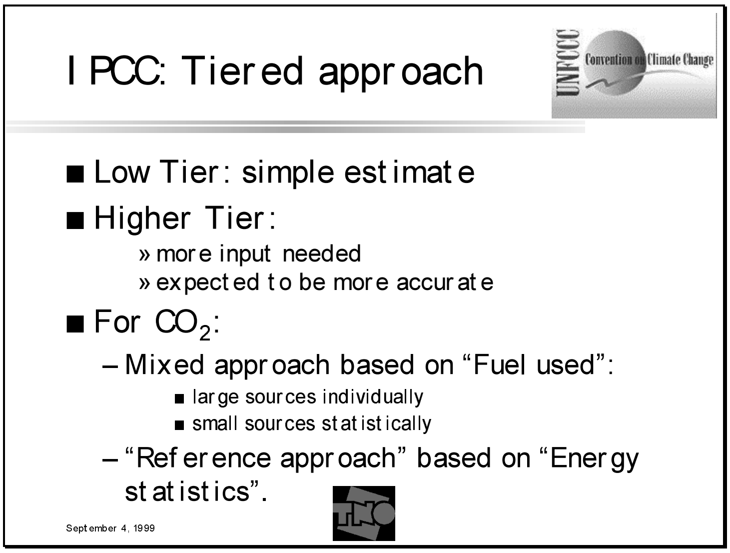
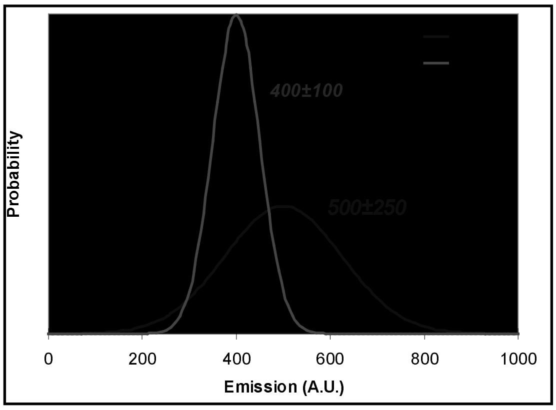


IPCC Guidelines provide different “Tier”s:

- **Lower Tier: “quick and dirty”**
- **Higher Tier: more detail, more input data required,**
  - ✓ expected to have higher scientific quality: smaller 95 % confidence interval

So different tiers produce different estimates with (expectedly) different uncertainties. So by applying higher tier methods, the number might (but need not) change, but the uncertainties should decrease.
For CO_2 most parties (including the Netherlands) apply a mixed approach, using detailed estimates for large fuel using activities and a statistical approach for the smaller sources.
The IPCC Summary tables request in addition reporting the “reference approach”, based on energy statistics (Energy Balance).



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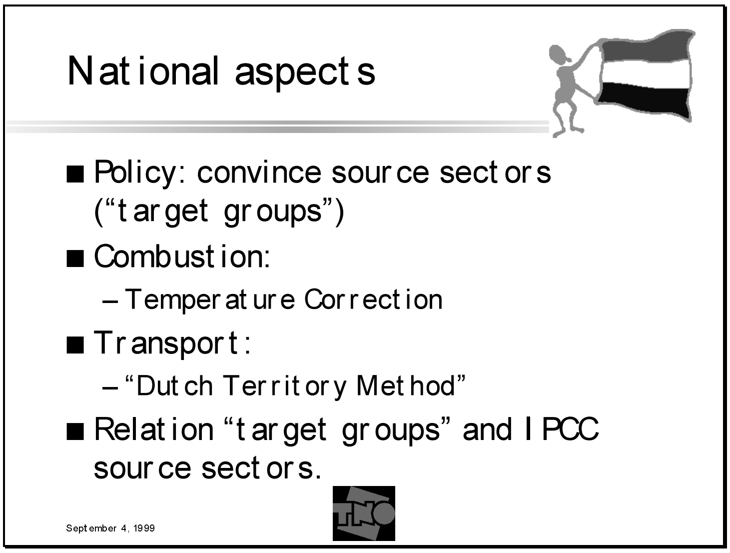


At the national level some additional aspects are relevant:

- **in preparing, performing and monitoring national policy, emission data are needed that**
  - ✓ enables prioritisation of abatement measures
  - ✓ will convince all actors involved of the effectiveness, efficiency and necessity of measures proposed
  - ✓ show continuity in reporting at the national level:
    - ∗ temperature correction
    - ∗ road transport emissions

These aspects are of low importance for the international community.

A second item, recognisable from this workshop's agenda is the relation between the "target groups" defined in national environmental policy and the "IPCC source sectors".
These issues can be more easily solved when indeed a clear distinction is made between data collection and reporting. While preparing a report the database should be left unchanged, but necessary extra analyses, like a temperature correction, should be applied while interpreting and aggregating the data in the inventory towards the different reports.

Slide 6

Perspectives on data quality and intended use of the data

	Perspective	*High quality if ...*
"Scientist"	Scientific debate: search for weaknesses and errors; falsification.	...it produces predictions that are confirmed
"Policy maker"	Political debate: search for consensus and agreement; compromise	...everybody involved agrees
"Lawyer"	Judicial debate: search for proof or doubt; persuasion	...it convinces a judge or jury

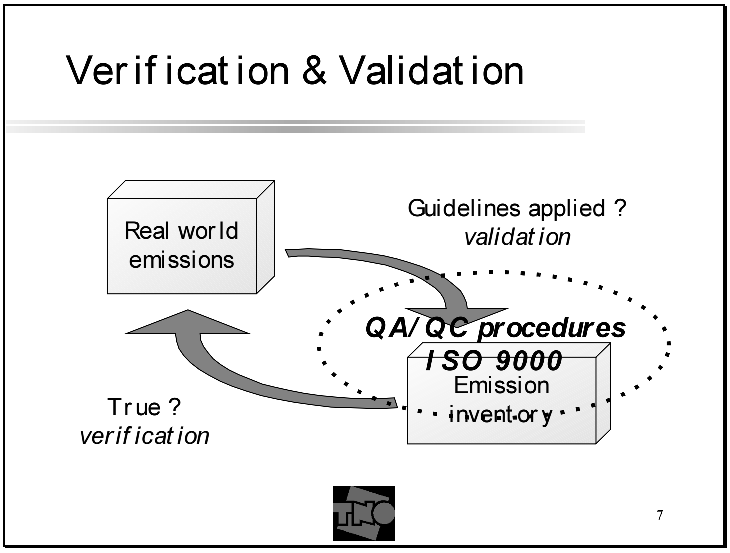
6

Three perspectives on data quality:

- The scientist is looking for the truth by trying to find weak spots in theory and data and by falsification. The data quality will be high if the data or predictions based on them are confirmed by independent estimates. If falsification occurs, the scientist will work on it until he or she understands the reasons and has derived better data or a better theory.
- A policy maker is looking for agreement and will therefore be more inclined towards reaching consensus and compromise. In many cases a policy maker does not have enough time to wait until all scientific problems are solved: a company might have asked for a permit for a new activity and regulations prescribe a decision to be made within a given period of time; or a country has to report its emissions according to a protocol before a certain fixed date. The policy maker will have to decide although a number of uncertainties are still present and a number of phenomena might not be fully understood.
- The lawyer has again a different perspective. He or she might be involved in compliance checking and will regard data to have high quality if the data are convincing.

These perspectives on data quality will also influence the perspective on "truth" and "quality" and hence on verification and validation of emission inventory data and of models.

Slide 7

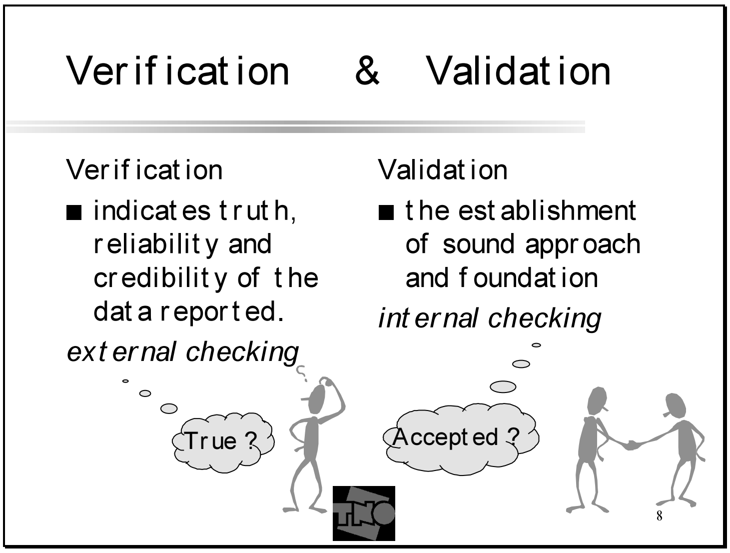


We recognise three levels of inventory quality:

- **procedural quality, to be established by applying "good practice" and "quality assurance / quality control" procedures, assuring adequate documentation and error free arithmetic;**
- **transparency and comparability, to be established in some kind of interaction between the responsible inventory compiler and the receiving body assuring that the inventory is compiled according to the guidelines and that it is comparable to other countries' inventories**
- **accuracy, completeness etc., to be established in primarily scientific assessments of the inventory involving independent estimates or measurements assuring the "truth" in the values stored in the inventory.**
- These three levels of inventory quality will be relevant with respect to national inventories in a cyclic way. Scientific knowledge is brought in while defining the guidelines, including the default emission factors. Once guidelines are accepted, good practice and QA/QC procedures can help in compiling the inventories in such a way that application in national and international environmental policy is possible. The international bodies, receiving national inventories, must validate them with respect to transparency and comparability. Once emission inventories are available, verification studies might be used to check the methods as prescribed in the guidelines and "science" can suggest amendments to the guidelines and the default emission factors therein.

In such a cyclic process, inventory quality can be improved. The development of the tools within the CORINAIR program of the European Environment Agency might very well contribute to this.

Slide 8



Definitions below are derived from the Glossary developed within the IPCC Working Group on Managing Uncertainties:

Verification

The term verification is used to indicate truth or to confirm accuracy and is used to represent the ultimate reliability and credibility of the data reported.
This will call for external checking, using independent estimates by other organisations, models, measurements, etc.

Validation

Validation is the establishment of sound approach and foundation. The legal use of validation is to give an official confirmation or approval of an act or product.
This internal checking of the inventory is meant to ensure that it has been compiled correctly in line with reporting instructions and guidelines and that the calculations are arithmetically correct.

In some earlier reports and papers, both words have been used differently, but at present the definitions as reproduced here are being accepted widely. We propose to also accept in the Netherlands the definitions as above.

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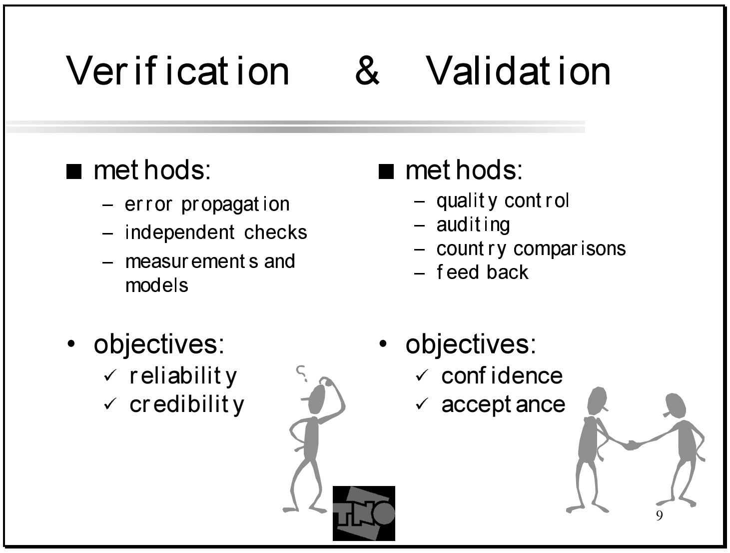

Verification can be performed by applying:

- **estimating errors in variables and parameters and establishing the resulting error distribution in the total number (error propagation)**
- **compare with other independent estimates and calculations**
- **compare with measured values, using models**

Validation uses methods like:

- **QA/QC systems (ISO 9000 certification or equivalent, assuring full documentation and allowing to redo the inventory and to reproduce all numbers**
- **auditing (part of ISO 9000 certification): allowing independent auditors to check the application of the correct procedures and the origin of input data**
- **between country comparisons ("All countries make the same errors").**
- **feed back from the Convention's secretariat**

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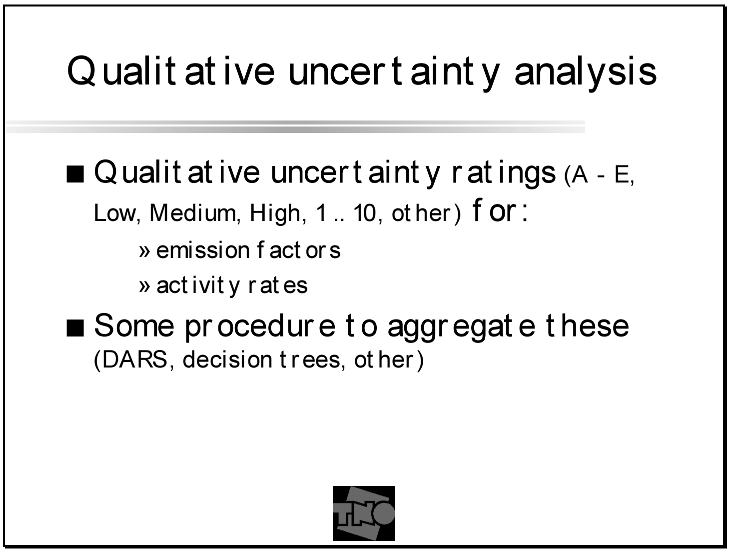

Uncertainty analysis

- **Qualitative**
- **Quantitative**

Qualitative:

- **needs quantitative uncertainty ratings for**
  - ✓ activity data
  - ✓ emission factors
- **needs a procedure to aggregate the individual ratings of emission factors and activity rates towards an overall qualitative rating.**

IPCC Guidelines now request a rating "High", "Medium", "Low" to be given to reported emissions at the level of the summary tables. No detailed guidance is provided on how to do that. The guidelines however also indicate that uncertainties should be expressed as 95 % confidence intervals.

US EPA developed the DARS system:

- **using a decision tree to attribute a rating (1..10) to each emission factor and activity rate**
- **defining a detailed algorithm to combine these towards an overall rating.**

The Dutch Emission Inventory (in Dutch: Emissieregistratie) is experimenting with a 5 point scale (A, B, C, D, E) originally proposed in US EPA's AP42

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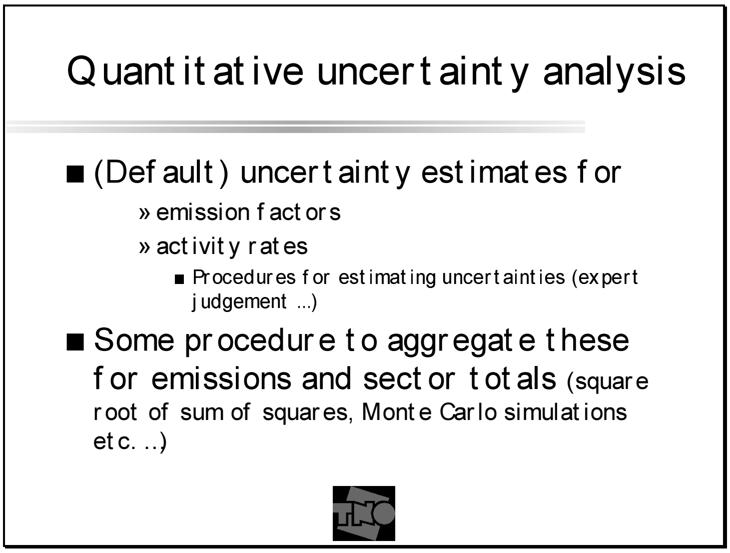

Quantitative

For a quantitative uncertainty analysis quantitative error ranges for activity rates and emission factors are needed. This means that basically also the IPCC Guidelines should contain:

- **guidance to estimate uncertainties quantitatively, i.e.**
- **procedures to estimate uncertainties e.g. expert judgement?**
- **and / or**
- **default values for these error ranges.**

Part of the activities of the IPCC Working Group on Management of Uncertainties is directed towards providing these:

- **guidance on how to combine quantitative uncertainties in variables and parameters towards a quantitative uncertainty estimate for the full inventory:**
- **some algorithm ("square root of sum of squares")**
  - ✓ Monte Carlo simulations
  - ✓ other?
- **guidance on how to report uncertainties.**

The present guidelines mention reporting in 95% confidence intervals. It is expected that this will not be changed.

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Default quality ratings

Rating	Definition	typical error range
A	an estimate based on a large number of measurements made at a large number of facilities that fully represent the sector	10 to 30 %
B	an estimate based on a large number of measurements made at a large number of facilities that represent a large part of the sector	20 to 60 %
C	an estimate based on a number of measurements made at a small number of representative facilities, or an engineering judgement based on a number of relevant facts	50 to 150 %
D	an estimate based on single measurements, or an engineering calculation derived from a number of relevant facts	100 to 300 %
E	an estimate based on an engineering calculation derived from assumptions only	order of magnitude

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Little is known on uncertainties in emission estimates. An attempt has been made to produce default uncertainty ratings at the main sector level in the UNECE EMEP/CORINAIR Guidebook, using the qualitative A, B, C, D, E ratings of US EPA's AP42 manual. The table reproduces the definitions of these ratings.

To help modellers assess the uncertainties in calculated air pollution concentrations, typical error ranges (standard deviations) have been proposed (Guidance Report on Preliminary Assessment under EC Air Quality Directives, Roel van Aalst, Lynne Edwards, Tinus Pulles, Emile De Saeger, Maria Tombrou5, Dag Tønnesen, January 1998, ETC/AQ).

These numbers

- **might provide a feeling of what these qualitative error ranges mean.**
- **pose a challenge to the experts to come up with better default uncertainty ranges**
- **could also provide a link from a qualitative assessment to a quantitative one!**

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Default quality ratings

Source sector	CO_2	CH_4	N_2O
1. public power, cogeneration and district heating	A	C	E
2. commercial, institutional & residential combustion	B	C	E
3. industrial combustion	A	C	E
4. industrial processes	B	D	D
5. extraction & distribution of fossil fuels	D	D	
6. solvent use			
7. road transport	B	C	E
8. other mobile sources and machinery	C	D	D
9. waste treatment	B	C	E
disposal activities	C	D	E
10. agriculture activities	C	D	E
11. nature	D	E	E

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The table, derived from the UNECE-EMEP / CORINAIR Guidebook, shows the default data quality ratings by main source sector.
In greenhouse gas emission inventories:

- **uncertainties are the smallest for the most important gas CO_2**
- **uncertainties are smallest in the most important sectors (combustion related: 1, 2, 3, 7 and 8)**

Nevertheless, the reduction targets for 2008 - 2012 (Kyoto) might be well in the range of or even below the over all uncertainty!
These default uncertainty ranges, combined with the typical error ranges, suggested in the previous table, have been used tentatively in a study made for the IPCC Working Group on Management of Uncertainties, using the simple mathematical treatment that follows.

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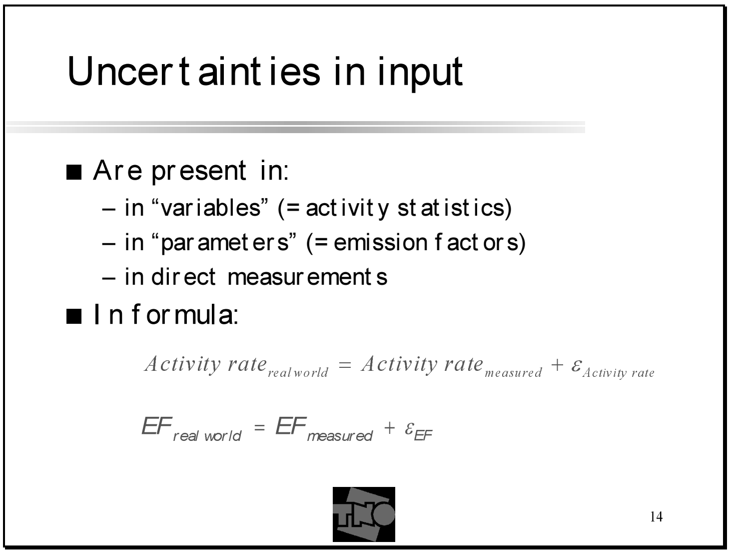

In the following a simple mathematical treatment of error propagation in an emission inventory is presented.

Any emission inventory will be inaccurate by its very nature. The data collected are mostly based upon extrapolation of sample measurements or upon the use of emission factors and activity data. The accuracy of the data will be determined by uncertainties occurring in all stages of the inventorying process. Four sources of uncertainties are discerned:

- **Uncertainties originating from the *real variance* of the emissions in time and between different comparable units: some cars have higher emissions than others and emissions of individual cars will vary depending on the state of maintenance.**
- **Uncertainties originating from *variability in the external conditions* in which the units are working: heating emissions will be higher in a cold winter as compared to a warm winter.**

  These uncertainties are due to "naturally" occurring variances in the emissions. As emissions are mostly being estimated by means of sampling, extrapolation of the sample to the total emission might induce errors. Two other sources of uncertainties stem from the fact that no measurement and no inventory can be perfect:

- **Uncertainties *in the measurements* of emissions, emission factors and activity data, including "unknown sources".**
- **Possible *errors in the databases themselves*, including "forgetting" sources.**

The uncertainties will cause a certain level of inaccuracy of the data collected: any value in the inventory may contain an error. All uncertainties in both energy data and emission factors applied to calculate a national emission inventory will be reflected in uncertainties in the final result.

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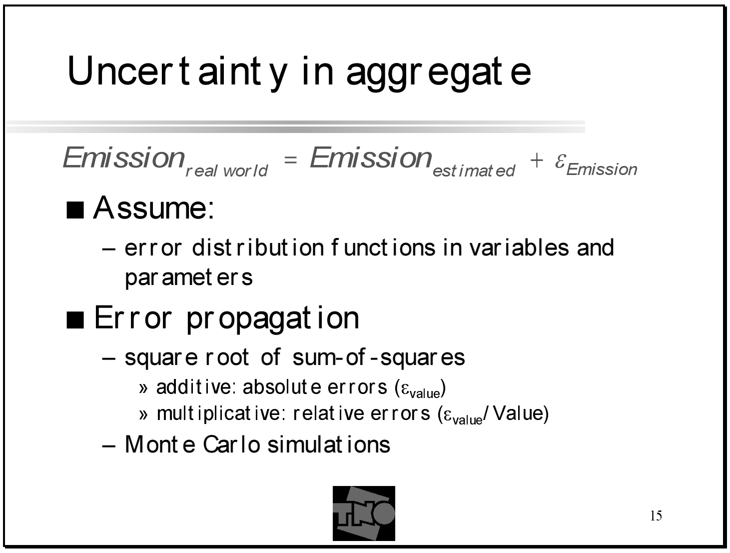

The algorithm as presented above can be applied whenever the standard deviations of the errors in all variables and parameters are available. To find the standard deviation, find an interval, which approximates a 95% confidence interval. In a normal distribution the 95% confidence interval is almost equal to two standard deviations to both sides of the mean value. If such data are not available, as a first estimate the values from the tables could be used. If standard deviations are available the following procedure could be applied:

- **While calculating the emission for each activity and fuel combination, the relative uncertainty in this emission should be calculated as the square root of the sum of squares of the relative uncertainties in both the fuel use and the emission factors (multiplicative operation: use relative errors!).**
- **The absolute uncertainty in the emission of each activity and fuel combination should be derived by multiplying the relative uncertainty with the emission value**
- **The absolute uncertainty in the inventory should be calculated as the square root of the sum of squares of the absolute uncertainties in each separate activity - fuel combination (additive operation: use absolute errors!).**
- **The relative uncertainty in the inventory should be calculated by dividing the absolute error by the total emission.**

This procedure can be applied at the complete inventory, but also by pollutant or for any sector separately. The procedure is not producing mathematically correct standard deviations, but produces a number that is higher when the uncertainty is higher and vice versa and therefore might be used as an indicator of uncertainty.

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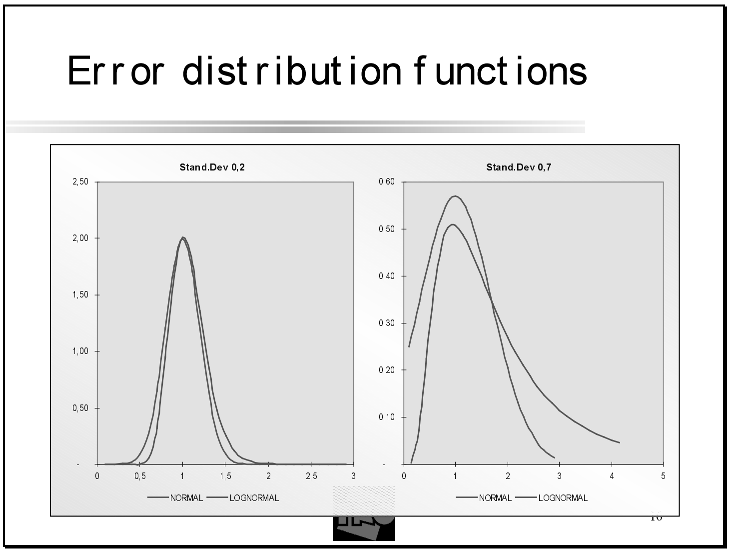

Using more complicated methods, like Monte Carlo simulations, a full description of probability distribution functions for all variables and parameters is needed. This asks for selecting such functions. Two possibilities are normal or lognormal. Both distributions only have two parameters.
Pros and cons between normal and lognormal:

- **With low uncertainty (left)**
  - ✓ not much difference between the two
  - ✓ normal distribution easier to use

- **With high uncertainty (right)**
  - ✓ error distributions look quite differently
  - ✓ normal: zero and negative values could occur; this is unrealistic
  - ✓ lognormal: higher tail: higher probability of high extremes.

Please note that in a normal distribution the mean value and the most probable value ("mode") are equal. In a lognormal distribution they are not!

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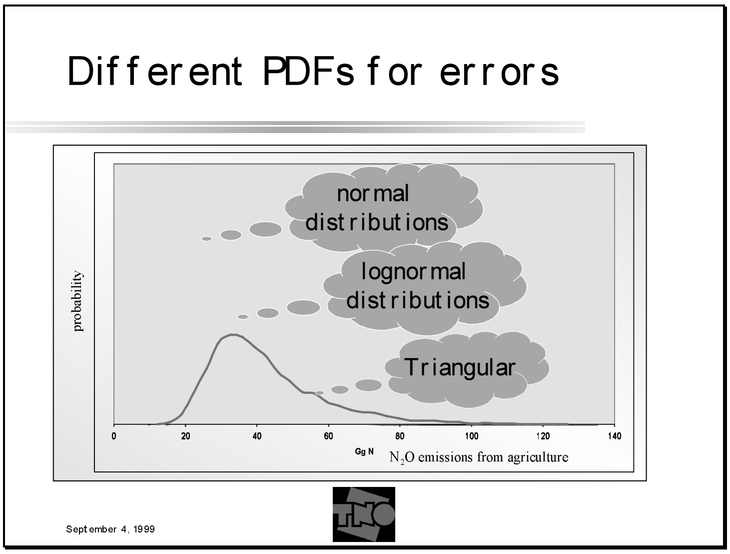

The effect of choosing probability distribution functions for parameters in a complicated emission estimation method (N_2O from agriculture in the Netherlands):

- **The mean value of all these graphs is more or less the same.**
- **This is not true for the most probable value (the mode of the distribution)**
- **The triangular distribution clearly leads to the highest estimate of uncertainty. This is probably too high.**

This analysis also points out that the interpretation of default emission factors and the uncertainty ranges as presented in the literature is not trivial. However the literature does not specify whether these defaults should be understood as mean values or as most probably values.

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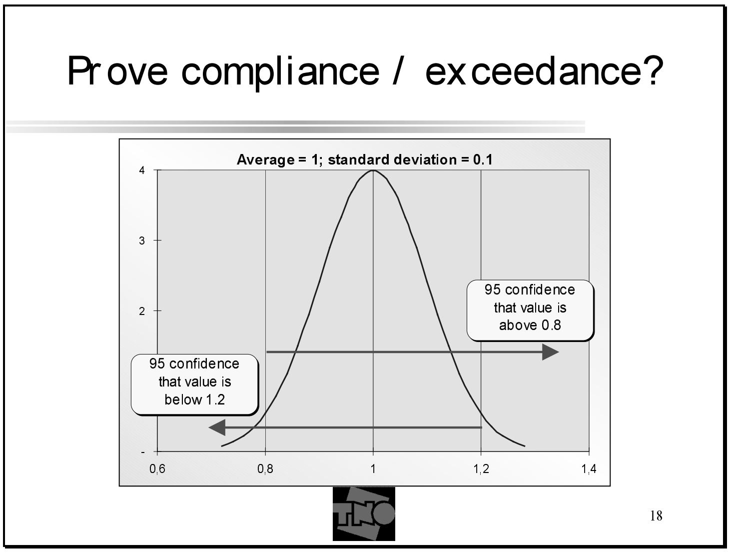

A final item on uncertainties of an emission inventory is presented in the graph above. If the result of an emission inventory shows the above probability distribution function, one should conclude that

- **the probability is 95 % that the total emission is below 1.2**
- **the probability is 95 % that the total emission is above 0.8**

So it depends upon what the user wants to prove (compliance or exceedance) what the value in the conclusion should be!

This observation might be rather relevant for the discussions on the compliance mechanism. When it is decided to report quantitatively on uncertainties, I.e. 95% confidence intervals, this problem of proving compliance versus proving exceedance is important!

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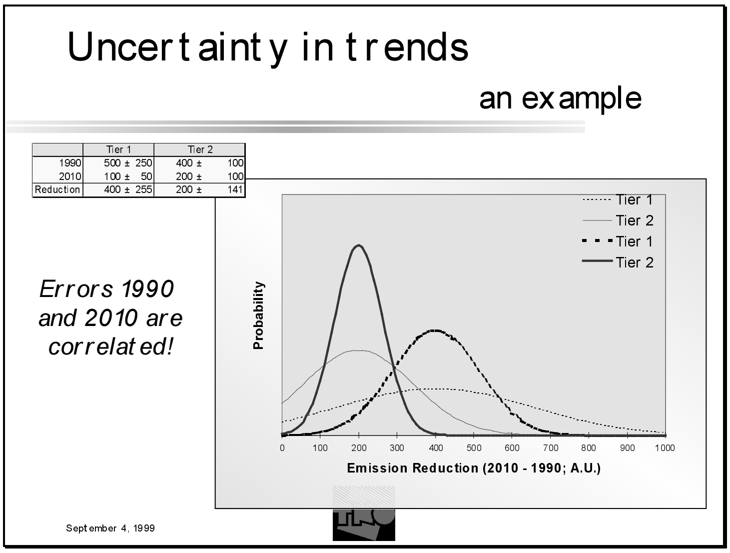

The graph above shows a result of estimating the difference between 1990 and 2010 and the associated uncertainty. The table provides the (assumed) numbers.

If we apply simple error propagation theory, and calculate the uncertainty in the difference between both base years is calculated we find 400 ± 255 and 200 ± 141 for Tier 1 and Tier 2 respectively. These are plotted in the thin lines. In that case both results are compatible. Tier 2 provides a lower reduction with a smaller 95% confidence interval, but both are not significantly different from each other.

However, it is not unlikely that the errors in the estimates for both base years are correlated, meaning that if the 1990 emission is underestimated, probability is high that the 2010 is also underestimated. So assuming that about 80 % of the errors in both base years are correlated, the thick lines result. Now the probability that the Tier 1 and Tier 2 estimates are different increases. In this hypothetical example however, the probability that both Tiers are compatible still is quite high.

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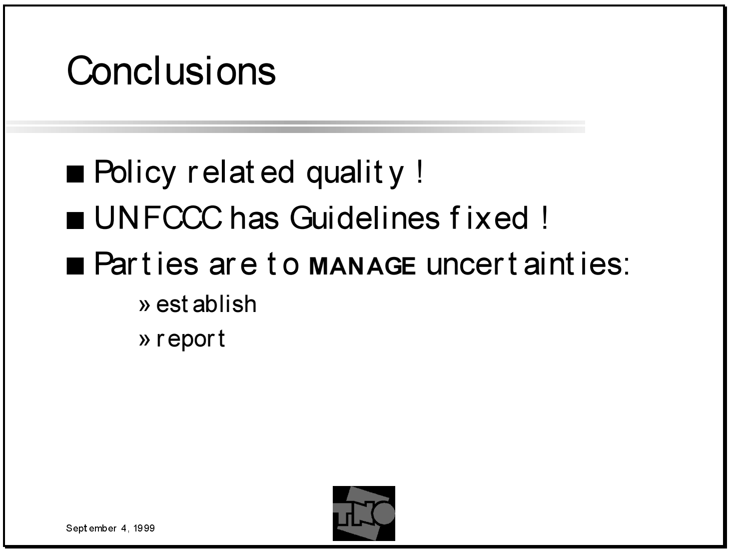

- **While compiling data for reporting to UNFCCC, the policy perspective on data quality is to be used.**
- **It is not expected that UNFCCC will accept any changes in the IPCC Guidelines in the near future. However the reporting format will be changed to a set of much more detailed tables than has been published in national communications until now.**
- **Parties need to manage the uncertainties, not necessarily decreasing them. Uncertainties need to be established and reported.**

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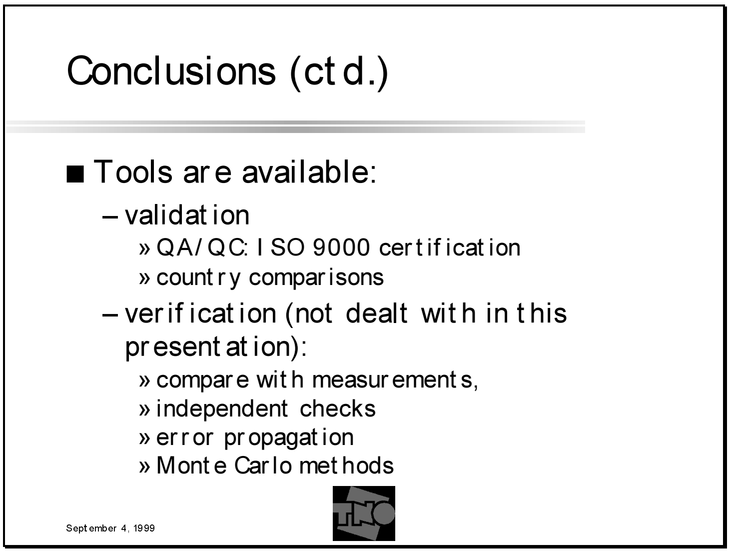

Tools for management of uncertainties are partly available:

- **Validation**
  - ✓ Quality Control / Quality Assurance systems will help parties to properly perform and document their inventory, assuring transparency and compliance with the Guidelines and reporting format; this also will include independent auditing ("in depth reviews"?)
  - ✓ Once data are available at the UNFCCC secretariat country comparisons will be used to validate the inventories against each other ("comparability")

- **Verification**
  - ✓ Inventories can be compared with budget studies, air quality measurements and models (forward and inverse modelling) etc.
  - ✓ Independent checks on the total or part of the inventory can be performed
  - ✓ The propagation of uncertainties in the inventory, given the uncertainties in inputs, can be established by error propagation studies or Monte Carlo simulations. To enable this some issues regarding the probability distribution functions and the interpretation of "default values" need to be solved.

2.2. COMPARISON OF COUNTRY REPORTS WITH EDGAR/GEIA

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Key words: carbon dioxide, methane, nitrous oxide, emission inventories

Abstract
National emission inventories are surrounded with uncertainties, which cannot be eliminated completely but can be managed. In this study methods were developed for the review and assessment of the quality of national inventories for the Kyoto Protocol. Four different approaches can be distinguished: quality control, inventory comparisons, model comparisons and direct emission measurements. In this paper the results of a comparison of national inventories with EDGAR and a comparison of aggregated national emissions with global budgets are presented. It was concluded that EDGAR is a good screening tool for completeness and comparability. With EDGAR large gaps and differences with the national inventories as reported to the Climate Convention could be identified. Differences could be explained in terms of the use of different emission factors or different activity data Aggregated totals compare well with modelled budgets, however uncertainties in both are large. Most National Communications were not transparent and a new common reporting format will be required to improve the detailed reporting needed for a proper review and assessment for compliance to the Kyoto Protocol.

Introduction

Transparent reporting of credible emission estimates is considered crucial for the success of the Kyoto protocol. In addition, uncertainties in greenhouse gas emission estimates need to be managed. Recent emission inventories are produced using the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC/OECD/IEA, 1997). They are generally characterised by relatively large uncertainty ranges. Some evaluation mechanism is therefore needed for the emission estimates of the six (groups of) greenhouse gases reported under the Kyoto Protocol (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride). Different approaches for the assessment of data quality are possible, including a bottom-up comparison of national inventories with (semi-)independent international databases and an independent top-down check through comparison with global budgets derived from atmospheric concentration measurements (Van Amstel et al. eds. 1999). Geographic explicit comparison with global budgets and measured concentration fields is difficult because of the uncertainties in the measurements and models and the lack of sufficient monitoring sites around the world and in particular in polluted continental areas. Comparison of national inventories with independent databases is a good alternative method for inventory validation. Here we made a comparison with the EDGAR 2.0 'Emissions Database for Global Atmospheric Research' developed jointly by the National Institute of Public Health and the Environment (RIVM) and the Netherlands Organisation for Applied Scientific Research (TNO) (Olivier et al., 1996; 1999).

Carbon dioxide

National inventories as reported to the Climate Convention Secretariat and compiled by the Secretariat in tables (UNFCCC, 1996 and 1998) and country results (as cited in Braatz et al., 1996) are compared with EDGAR 2.0 emission estimates (Olivier et al., 1996; 1999). Relatively large differences were investigated further. Eventually, this kind of comparison with independent databases may contribute to the validation of both national inventories and global emission inventories like those of EDGAR and GEIA. In addition, it may contribute to improvement of present IPCC methodologies and recommended default emission factors for estimating emissions. Thus, it may also improve reporting to the Climate Convention.

The difference between the estimated global budget of emissions from fossil fuel use plus industrial processes and the sum of the available inventories is 2000-3000 Tg. This is a relatively small difference (<10%) (Table 1). The global budget published by the IPCC in 1996 was obtained from a similar global database of emission estimates. The total budget is larger because of emissions from forest fires (deforestation) and of large annual natural fluxes from the biosphere and the oceans. This makes the comparison of CO_2 emissions with budgets derived from atmospheric models very difficult, while the anthropogenic flux is but a tiny portion of the total.

Table 1. Global emissions of carbon dioxide in 1990 (modified from Lim et al., 1999)

Source	Number of countries	Total 1 (Tg CO_2/year)	Total 2 (Tg CO_2/year)	Global budget[a] (Tg CO_2/year)
Annex-1 countries[b]	35	13675	14319	-
Country studies[c]	31	5081	5081	-
Global database[d]	124	6666	6666	-
Total	190	25422	26066	28233

[a] IPCC (1996) (7.7 GtC x 44/12), [b] UNFCCC (1997), [c] Braatz et al. (1996), [d] Olivier et al. (1996; 1999). Total 1 is the aggregate from first national reports and Total 2 is the aggregate from second national reports.

Differences that were found between the estimates in the first and second National Communications can be explained by the fact that countries have updated estimates using improved methodology (including emission factors). For EDGAR estimates of carbon dioxide emissions to become comparable – for instance within 5% - to emissions officially reported by the individual countries, the IEA energy data for many countries (including conversion factors) used in EDGAR as data source for activity data 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 cogeneration. Combined Heat and Power (CHP) should be reported within industry. The ambiguity in the IPCC Guidelines about allocation to process emissions or combustion emissions of CO_2 from 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 large. It is about 22% in the Total 1 column, and 16% in the Total 2 column (Table 2). The global budget was derived from atmospheric measurements and is therefore independent of the inventory data. The aggregate of national reports is around the lower end of the IPCC range. This means that on average the emission factors used in some of the larger source categories are rather low.

Differences between national reports and EDGAR estimates were found because of the use of different emission factors, different activity data, different methodology or different definitions of the natural and anthropogenic part of the emission. In most cases EDGAR used default IPCC methodology with activity data from internationally available statistics: from IEA for energy and from FAO for agriculture. National statistics often differed slightly from the international statistics. In some cases the difference in emission factors between EDGAR and a national study were large. A review of all emission factors used is recommended. When comparing national inventories and EDGAR estimates for 1990, the net large differences for methane between national reports and EDGAR are 30 Tg. This may be an indication for the uncertainty of the methane emission inventories. The aggregated world total anthropogenic methane emission of 291-313 Tg compares with the low end of the range of 300-450 Tg methane per year as published by IPCC (1996). This may indicate that for some major source categories such as agriculture, fossil fuel production and distribution and landfills the IPCC default emission factors from the (Revised) IPCC Guidelines and/or emission factors used in national communications, in other national reports and in EDGAR are generally rather low.

Table 2. Global emissions of methane in 1990 (modified from Lim et al., 1999)

Source	Number of countries	Total 1 (Tg CH_4/year)	Total 2 (Tg CH_4/year)	Global budget[a] (Tg CH_4/year)
Annex-1 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 (1996) , [b] UNFCCC (1997), [c] Braatz et al. (1996) and Mitra and Battacharya (1998), [d] Olivier et al. (1996; 1999). Total 1 is the aggregate of first national reports. Total 2 is the aggregate of second national reports.

Nitrous oxide

The sum of inventories for nitrous oxide (N_2O) is close to the lower end of the range of the global budget (Table 3). The global budget was obtained from the observed atmospheric increase, independently of the inventory data. The estimate of the budget for total anthropogenic emissions of 9 Tg N_2O in Table 3 was based on previous IPCC estimates (IPCC, 1994). Using the Revised 1996 IPCC Guidelines (IPCC, 1997), the mid-point estimate for worldwide anthropogenic emissions is thought to be 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 methodology described in the Revised IPCC Guidelines 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 IPCC Guidelines* are consistent with trends in atmospheric concentrations.

Table 3. Global emission of nitrous oxide in 1990 (modified from Lim et al., 1999)

Source	Number of countries	Total 1 (Tg N_2O/year)	Total 2 (Tg N_2O /year)	Global budget[a] (Tg N_2O/year)
Annex-1 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 (1996) (3-8 Tg N/year , midpoint 5.7, x 44/28), [b] UNFCCC (1997), [c] Braatz et al. (1996), [d] Olivier et al. (1996; 1999). Total 1 is the aggregate of first national reports. Total 2 is the aggregate of second national reports.

National estimates of N_2O emission were analysed. We compared estimates as presented in the first and second National Communications (NC1 and NC2, respectively) with estimates from EDGAR. Agriculture is the most important anthropogenic source of N_2O on a global scale as well as in most country estimates. Fuel combustion, industrial processes and biomass burning are less important sources of N_2O.

For about two-thirds of the countries the EDGAR 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 IPCC Guidelines*. About one-third of all countries report agricultural emissions that do not exceed EDGAR estimates, 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* completely.

For N_2O from fuel use the analysis indicates that the EDGAR 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 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 estimates are lower than the National Communication, indicating that the EDGAR estimates for industrial sources may also be on the low side.

Conclusions

EDGAR proofed to be a useful screening tool for checking completeness and comparability by identifying large gaps and many differences with the national reports. 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 coal, oil and gas, manure, rice and waste. Measurements may be needed to improve country-specific emission factors. This information may be needed for the development of new IPCC default emission factors.

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.

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, these gaps are very distinct. Country studies in developing countries were made for capacity building and to learn about IPCC methodology. We expect a more complete reporting when more official national communications come due.

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.

Comparison with global budgets
The comparison of aggregates of available inventories with IPCC budgets was meaningful only for methane and nitrous oxide, while the uncertainties of inventories and budgets were comparable. For carbon dioxide the anthropogenic emissions could only be compared with other (semi-) independent inventories developed on a per country basis. For methane we concluded that the aggregate is at the low end of the IPCC budget, possibly because of generally low emission factors in some major sources. For nitrous oxide we concluded that countries that did not report complete inventories caused the difference.

To make inventories more transparent, the UNFCCC is recommended to publish new standard data tables in their Guidelines for reporting, and countries are advised to improve the detailed reporting on emission factors and activity data in the national inventory reports.

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2.3. EVALUATING EMISSIONS: FACTSHEETS FOR GREENHOUSE GASES

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[Paper based on the RIVM report '*Measuring, Modelling and Uncertainty'* (in Dutch). RIVM techn. report 408 129 005.]

Emission Registration system

Emissions of polluting substances to air, water and the soil are compiled collaboratively in the 'Emission Registration' project under the auspices of the Chief Inspectorate for the Environment of the Ministry of VROM by Statistics Netherlands (CBS), the Netherlands Organisation for Applied Scientific Research (TNO), the National Institute for Inland Water Management and Wastewater Treatment (RIZA), National Reference Centre, Agricultural Research Department (DLO) and the National Institute of Public Health and the Environment (RIVM). Methodology reports describe the procedures of how this is done. Within this collaboration, methodology and figures are constantly under discussion, just as in every scientific process. Working from their own contexts, positions and diverse backgrounds, institutes strive to obtain collective estimates. Cooperation often takes place with such international bodies as the United Nations and the European Union to establish scientifically sound protocols. The RIVM has undertaken to archive and manage the base data files once they have been compiled by the institutes, certified under ISOO9001. This will guarantee the storage and retrieval of the correct emission data in the ER database.

Data are published in the *Annual Report on Emission and Waste* (EAJR) (VROM, 1998), of which an excerpt is included the *Environmental Balance* annually released by RIVM (RIVM, 1998a,b). Only in exceptional cases, for example, in the presentation of the most recent data to the Dutch Lower House other data than the EAJR figures are used.

Determining emissions

Emissions cannot generally be measured directly but are usually compiled from measurements and statistics. For the most important substances RIVM has compiled factsheets containing summary information on the methodology for compiling emission estimates, as well as their reliability and validation (e.g. see attached factsheet on CO_2).

In the Netherlands emission figures originate in two ways: *individual* registration and *collective* registration. Point sources used to be the most important sources of emissions. Targeted environmental policy has increased the importance of diffuse sources for most of the environmental themes. This in turn has placed higher demands on the data behind the policies.

- For large *industrial plants*, the emission figures are reported by the individual plants themselves (the CO_2, SO_2 and NO_x contributions of large industrial plants to the total emission of the industrial target group are 80-90%). These figures are partly the result of measurements and partly of calculations. Their quality is verified by the official authorities and on the main items pertaining to quality by TNO under the responsibility of the Chief Inspectorate for the Environment. This procedure investigates the methods used by a company in determining the emissions (for traceability and systematic approach). Where emissions are calculated, the calculation method is compared with methods found in the national and international literature. The plausibility of the emission compared with the trend in preceding years is also investigated per company or installation. All the figures are approved by the official authorities before integration into the Emission Registration system. The official authority does not provide any judgement on the uncertainty of these figures.

- *Collective emissions* from traffic, households, small companies and agriculture are determined according to statistical data often taken from Statistics Netherlands (SBS). Included here are the number of vehicles, inhabitants, number of livestock, the number of jobs, the use of fossil fuels, etc. These data are translated into emission data by the working groups of the ER project using emission factors which, for example, are again dependent on the average speed of cars, the number of cars with a catalytic converter and the relation between speed and emissions. Experimental measurements are taken to determine the emission factors. Emissions from cars are measured under different test conditions in experimental installations by such organisations as TNO. As another example, the emission of ammonia after spreading manure is also experimentally determined.

Sources of uncertainty in the collective registration are spot-check fluctuations, measuring errors, working with derived quantities as indicators for production volumes in certain industrial sectors and assumptions related to homogeneity of processes within sectors. Another important variable is the extent to which technical measures have been implemented by the target group. An extensive network of experts estimates these degrees of implementation. Not monitoring these data makes the figures less reliable.

Assessing emissions in a broader context
In the *Environmental Balance*, subsequently developments in environmental conditions are described for themes as Climate Change and Acidification. Depending on the objective these developments will centre on either emissions or environmental quality (concentrations and depositions of the contaminated substances). Apart from the emission inventories, the *Environmental Balance* is largely based on monitoring results or a combination of monitoring and models. In only a few cases is the development of environmental quality mainly based on model calculations, as in the transfer of measured concentrations to ecosystems, the dispersion of ammonia, the description of noise pollution and the external safety.

Uncertainties
In policy-oriented overviews compiled by the RIVM, like the Environmental Balance, uncertainties are only indicated where these are relevant to the conclusions drawn. Uncertainty ranges are, however, not explicitly indicated, but qualitatively pointed out in the text. Sometimes a confidence interval can be statistically supported, but often we have to rely on expert judgements. Background information on the reliability of the data presented by the RIVM is available at the institute (e.g. in the form of factsheets in which this information is summarised - see attached example for the Netherlands total CO_2 emissions) (RIVM, 1999a). Information on the reliability of data is usually exchanged within scientific circles and described in various underlying research reports and publications. In some cases uncertainties are reported in memoranda presented to parliament and to UN bodies, as in the *Second Netherlands National Communication on Climate Change Policy* (May 1998 update; pp. 33-38) (VROM, 1998).

Box 1: Examples of environmental measures and related data for estimating emissions

Examples of environmental measures are the introduction of the 3-way catalytic converter for passenger cars, carbon filters in industry and incorporation of manure into the soil on farms.. The method to establish the degree of implementation will be illustrated by the two examples below.

1. *Traffic: implementation of the regulated 3-way catalytic converter*
   In calculations for implementing the regulated 3-way catalytic converter it is assumed that all new cars (petrol and LPG-fuelled, dating from 1993), have been fitted with a 3-way catalytic converter. For models older than 1993 the number of cars with catalytic converters has been established on the basis of car-sale figures supplied by RAI/BOVAG.
2. *Agriculture: manure application*
   The most recent data is found in the 1995 Agricultural census, in which virtually all farms were obliged to participate. Questions on the type of equipment most commonly used for manure application were voluntary. The response was 95% for total grassland and 86% for total arable land. Answers were processed by the Agricultural Economics Research Institute (LEI-DLO), with the help of data collected via spot-checks from the Company-Information Network and translated into the spreading of manure (in %) among manure application techniques per agricultural area. It is also assumed that only the techniques allowed by law will be applied. At the advice of experts (and due to a lack of more recent figures), the manure application taken for 1995 is used for calculations for 1996 and 1997. Only for the cultivated land in the Drenthe Turf Colonies the calculations have been corrected for the application of manure spreading methods with higher ammonia emissions, an area which is exempted from the stricter regulations in force since 1996.

Comparison of emissions with other measurements in the physical environment

Even though emissions are estimated using all available expertise and measurements, they will always have an uncertainty range. The quality of emission estimations is investigated by applying alternative calculation methods, by comparing estimates with those made abroad and by means of scientific fact sheets (see example on CO_2 attached). Direct measurements in the environment also often allow an independent validation. RIVM is highly focused on this issue: i.e. emission estimates (levels and trends) are compared as much as possible with measured concentrations in the environment, making use of insights into the dispersion of substances in the environment. Comparing emissions with concentrations received extra attention in the Environmental Balance of 1998.

Uncertainties also occur when testing environmental quality measurements . The scale on which measurements are possible may deviate from the most policy-relevant scale – and for the environment – necessitating translation of these measurements to fit the policy context. For example, it is impossible to take comprehensive and continuous measurements of air, soil and water. Whenever the RIVM found that the translation of national emission totals into concentrations was not (yet) feasible, this was explicitly stated in the *Environmental Balance*.

Uncertainty in estimating levels and trends

In describing uncertainties, levels and trends in emission estimates, a distinction must be made between the uncertainty in the level and the uncertainty in the trend of a particular emission estimate. Policy objectives for emissions are usually formulated in terms of reduction percentages, in other words, trends. The *Second Netherlands National Communication on Climate Change Policy* (May 1998 update) gives an indication of the uncertainty in the total yearly emission in the Netherlands, including: CO_2 at ±2%; NO_x at ±25% and SO_2 at ±25% (VROM, 1998). RIVM has extensively investigated the relationship between emissions and measured concentrations. On this basis, the trends in concentrations could be accurately followed. In the 1970s and 80s, RIVM carried out air traffic measurements for NO_x and SO_2 above the Netherlands, after which an input–output balance was compiled. Concentrations for NH_3 show a sensitivity analysis with a ±30% range. However, confrontation with measurement in air implies that the NH_3 emission is more likely to be higher than lower than the current reported value. An initial estimate for the uncertainty in N and P emissions to the soil is ±10%. At the moment research on different substances is being carried out to improve insight into the uncertainty (RIVM, 1999a). For many policy themes, the distance of emissions to many policy targets is still great compared to the uncertainty ranges.

Conclusions on emission trends are often more reliable than those on emission levels. The more years studied, the better the trend can be estimated. Although growth percentages are reported for separate years in the *Environmental Balance*, reports on emission trends are rather expressed in terms of a 'range of years'. In several cases, like climate change, acidification, eutrophication and waste disposal, short-term (4-year) prognoses have also been carried out to see if an observed trend continues into future years.

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ANNEX: Factsheet CO_2 for Netherlands Total

Source: (RIVM, 1999a)

1	Substance/target group	CO_2/Total Netherlands
2	Investigator/date	Ir. J. Spakman - LAE, 27 January 1999
3	Policy objective	* Reduction of 3% in 2000 compared to 1990 (incl. temperature correction); this will mean 162.6 billion kg for 2000 (compared to 167.6 billion kg for 1990) [ref. 11] * There is no specific CO_2 goal for the period after 2000. However, barring unforeseen circumstances, the Netherlands has agreed to reduce its total greenhouse gas emissions (CO_2, CH_4, N_2O, HFCs, PFCs and SF_6) in the Kyoto budget period by 6%, compared to 1990.
4	Emission level 1995	**179.7 billion kg** (Mtonne) after temperature correction for energy consumption for space heating. Without this correction the emissions mounted to 177.2 billion kg. These values are updates, deviating only slightly from more recent reports [refs. 1,12, 13].
5	Calculation scheme	The total CO_2 emission figure in the Netherlands is the sum of CO_2 emissions of all target groups plus the emissions due to energy consumption not allocated to specific users, the so-called 'statistical differences' in the Netherlands Energy Statistics (NEH) of Statistics Netherlands (CBS). The inventory and report conform to the IPCC guidelines [ref. 2] and will be included in detail in [ref. 3]. The method for temperature correction is similarly described in [ref. 3]. The total CO_2 figure for the Netherlands contains all the emissions from human activities with carbon from fossil/mineral origin. Emissions from incineration of biomass, sludge, wood and fermentation are not included. Other factsheets on CO_2 per target group show the relevant given calculation schemes.
6	Input	* Energy consumption figures for sectors and total energy supply: CBS: energy statistics, annual report figures [ref. 4]. The uncertainty margin for total energy consumption: <2% [ref. 5]. * Emission factors for incineration emissions: ENINA working group [ref. 3]. Uncertainty margin is fuel-dependent, but on the average comes to 2% on the basis of limited dispersion in the ratio of C level: energy content of the fossil fuels [ref. 6]. * Indicators for temperature correction: heating degree-days (HDD); uncertainty: <0.2% (KNMI). Uncertainty range in the contribution of natural gas consumption to the space heating sectors: 5% [ref. 3]. *Note added May 2000*: total uncertainty in the T-correction, which is at maximum 4% of the Netherlands total, due to the choice of reference temperature and reference levels of HDDs is estimated at about 30%.
7	Uncertainty in emission	Indication of the uncertainty range for the total CO_2 figure for the Netherlands total: 2% [ref. 13]. Better insight into the underlying uncertainties of energy figures and emission factors [refs. 1,3,7,10], in particular on feedstock use of energy carriers, leads to a somewhat higher uncertainty range of **about 3%.** Emissions 1995 = 179.7 ±5 billion kg, incl. temperature correction. Comment 1: an *essential* difference with the target group figures is that the total figure for CO_2 for the Netherlands uses the total supply of fossil fuels in the Netherlands, while CO_2 target group figures are

based on the energy demand within the target groups. In general, the total energy supply is better known than the division into the demand sectors. For this reason the uncertainties in energy consumption and CO_2 emissions of target groups are either usually coupled or statistically dependent and cannot be summed according to simple standard error propagation/summation formula.

Comment 2: in 1995 the CO_2 emission corresponding to 'statistical differences' was 2.5 billion kg, which is 1.4% of the Netherlands total. In 1996 and 1997 there is a strong growth in the statistical differences[1]. It is expected that this category can and will be adjusted downward, with retroactive effect. The current emissions are probably at the top of the reported uncertainty range.

8 Validation input

* The ('official') issuing body, usually the province, has the task of validating emissions registered for companies that have a permit; this amounts to ca. 80 billion kg CO_2, more than 40% of the total.
* There is no validation done through stack gas measurements.
* The fact sheets on CO_2/Target Groups indicate which validation procedures take place.
* Emission factors in incineration: review on chemical composition of fuel.
* FCCC/IPCC carry out structural reviews on reported national emissions [refs. 8,9];

9 Current actions

* RIVM initiated and organised a workshop on indicators and methodology-T correction;
* CBS is working on reducing uncertainties in energy statistics (registration of energy consumers);
* CBS will apply corrections in energy statistics retroactively to total domestic consumption, thereby decreasing the statistical differences.

10 References

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[1] Registration of export of small quantities of oil and coal products has not been so good since European internal borders have disappeared. This lack of export flows leads – in the statistics – to a higher figure in domestic use. This extra consumption lands up in the 'statistical difference', an indication of the research margin in the consumption figures. This margin is temporarily greater, however, Statistics Netherlands is working on a solution to the problem..

2.4. DETERMINATION OF EMISSIONS OF GREENHOUSE GASES USING ATMOSPHERIC MEASUREMENTS AND TRANSPORT MODELS

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Introduction

Various methods exist to complete an emission estimate. Bottom-up emission inventories are produced by using process information and applying some emission estimation algorithm (most frequently "activity rate x emission factor" but more complicated algorithms are also used for some source categories).
The most important characteristic of bottom-up emission inventories is that the figures are based on the upscaling of process information to a higher level of aggregation i.e. to figures which are generally representative for that emission process at a larger (global, regional or national) scale. In upscaling, the "best available" average emission factor appropriate for the available statistics, is used to aggregate at a global, regional or national scale. Statistical data, notably values of the activity index "A_p", are used for upscaling.

$$\text{Emission}(p,r,t) = Ef_p \times A_p \qquad (1)$$

where:

Emission (p,r,t) = emission of process p at location r and at time t
(e.g. N kg CO2/year by cars in the Netherlands)
Ef_p = emission factor representative for Activity of process p
(e.g. CO2 emission/km)
A_p = activity index of process p
(e.g. number of car-km in the Netherlands)

Top-down emission estimates are produced by using appropriate proxies to derive higher resolution (in space, time or source category) inventories from aggregated estimates. An example of a top-down emission estimate is the result of downscaling of a limited number of atmospheric measuring points in a large (continental) area to an emission estimate on a much smaller spatial (national) scale. Atmospheric transport models are used for downscaling.

$$\text{Emission}(s,r,t) = dM(r,t)/dt - \sum T(r',t') \qquad (2)$$

where:

Emission (s, r_i,t) = emission of source s at gridpoint r_i and at time t
(e.g. kg CO_2/year in grid r_i).
$dM(r_i,t)/dt$ = change of mass in grid r_i at time t (e.g. kg CO_2/year)
$\sum T(r_i',t')$ = transport of mass from all other grids from t = t' to t

The term $dM(r_i,t)/dt$ can be derived from measurements or from a combination of measurements and model calculations e.g. spatial interpolation algorithms. The term $\sum T(r_i',t')$ is derived from model calculations.

All methods have their own uncertainties. Errors are made in up- and downscaling and the availability and accuracy of the data may differ. In the next we concentrate on an analysis of emission estimates derived from atmospheric modelling.

Use of atmospheric measurements and model calculations

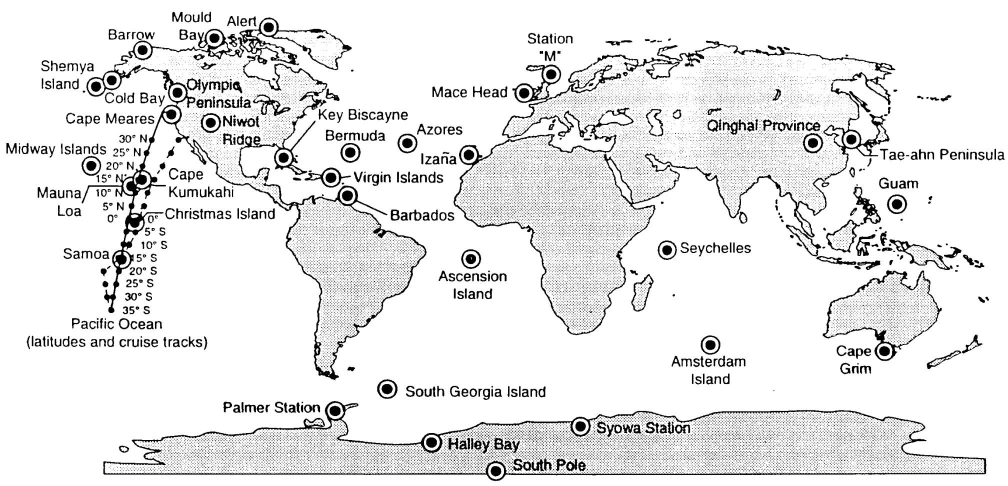
The questions that can be addressed by using information of atmospheric measurements and atmospheric transport models are:

1. Agrees the global atmospheric budget, which has been derived from atmospheric measurements, with the total of the various separate emission estimates.
   Are sources or sinks missing?
2. What is the efficiency of emission reduction measures in terms of the resulting atmospheric concentrations
3. Top-down methods can be used to estimate the emission of diffuse sources of large spatial scale or which have very inhomogeneous emission factors (e.g. N_2O emission from soils or CH_4 emission from rice).
4. Verification of bottom-up emission estimates.

These options will be addressed more in detail and an example of option 4 (verification) is elaborated in the next chapter.

The atmospheric budget

Figure 1 below shows sampling sites of the NOAA/CMDL network. These sites are considered as background stations. Information of concentrations in source areas on a global scale is lacking in many occasions.



Sites in the NOAA/CMDL air sampling network.

Figure 1. Sampling sites of the NOAA/CMDL network

Carbon dioxide

The table below shows the fractions of the global budget of CO_2

Table 1. The global budget of CO_2

Emission/reservoir	GtC/yr Period 1980-1990
Fossil Fuel/cement	5.5.-6
Deforestation	0.5-2
Atmosphere	1.5-3.5
Ocean	2
Biosphere	1-3

Whereas the values of fossil fuel use and cement production can be established with reasonably accuracy with bottom-up methods and the change in mass of CO_2 in the atmosphere and the oceans can be established by accurate measurements, the largest uncertainties in the budget are the net effect of changes in the biosphere. Closure of the global budget of CO_2 will only be possible by use and analysis of atmospheric measurements and models.

Methane

The table below shows the fractions of the global budget of CH_4

Table 2. The global budget of CH_4 [2]

CH_4 budget	Tg/yr Period 1985-1990
Natural sources	160
Anthropogenic sources	375
Total identified sources	535
OH	490
Stratosphere	40
Soils	30
Total sinks	560
Atmospheric increase	30-40
Implied sources (sinks + atmospheric increase	597
Misfit sources-sinks	60

Table 2 shows that there exist a misfit of about 60 Tg/yr between sources and sinks of the atmospheric budget of CH_4. Closure of the global budget of CH_4 will only be possible by a combination of bottom-up estimates and use of atmospheric measurements and models.

[2] See for a discussion of the uncertainties of these figures " Comparison of CH_4 inventory data and emission estimates from atmospheric transport models and concentration measurements" (Janssen, Olivier and van Amstel, 1999)

Nitrous oxide

The table below shows the fractions of the global budget of N_2O.

Table 3. The global budget of N_2O (based on Kroeze et al. 1999)

N_2O budget	TgN/yr (period 1985-1990)
Energy	0.9
Industry	0.3
Biomass burning	0.6
Agricultural	6.2
Total anthropogenic	8
Natural	9.6
Global total	17.7
Atmospheric increase	4

Global budget studies showed how difficult it is to explain the observed increase in atmospheric nitrous oxide. Notably the quantification of the biogenic N_2O emissions and their changes over time is not well constrained. A careful analysis of N_2O sources constrained by atmospheric measurements of the N_2O increase lead to a revision and a preliminary closure of the global N_2O budget.

The efficiency of emission reduction measures

To evaluate the efficiency of emission reduction measures in terms of changes in atmospheric concentrations, which is the object of the Framework Convention on Climate Change, we analyse the change in emissions of the main greenhouse gases and the change of mass of the greenhouse gas in the atmosphere, using atmospheric measurements and the global budget as shown in the Tables 1-3.

Carbon dioxide

Figure 2 shows the increase of the average CO_2 concentration in the atmosphere.

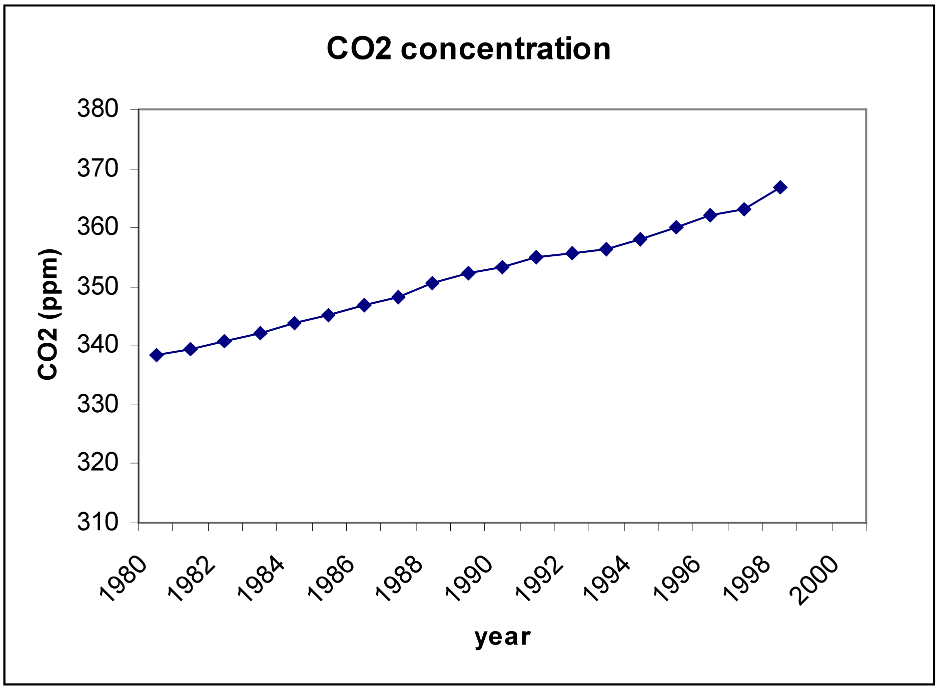


Figure 2. The increase of the CO_2 concentration in the atmosphere.

If we analyse this atmospheric increase as a function of changes in CO_2 emissions, see Table 4, we may notice:

- about 50% of fossil CO_2 emission is absorbed in the climate system (biosphere and the oceans)
- this percentage may vary from year to year depending on various processes in the climate system

Table 4. Ratio of atmospheric increase and fossil fuel emission (from van Amstel et al. 1999)

Author	Period	emission (GtC)	Atm increase (GtC)	Ratio Atm incr/emission
IPCC 1994	1980-1989	5.5	3.2	0.58
IPCC1995	1980-1989	5.5	3.3	0.60
Houghton	1980-1989	5.5	3.2	0.58
Tans et al.	1981-1987	5.3	3	0.57
Enting et al.	1980-1987	6.13	3.8	0.62
Enting et al.	1989-1990	6.5	3	0.46
S. Fan et al.	1988-1992	5.9	2.8	0.47
Ciais et al.	1992	6.1	1.5	0.25
Heimann	1991-1994	6.1	2.3	0.38

We may conclude from Table 4 that the emission of 1 kg CO_2 leads to between 0.25 and about 0.60 kg CO_2 in the atmosphere. As this ratio, due to natural variability varies from year to year, it may be possible to derive a best estimate of the effect of CO_2 emission on the atmospheric reservoir by averaging over a certain representative or typical period and the notion of representative or typical to be defined.

N.B The 1991 Mount Pinatubo eruption led to cooler, wetter conditions and a much higher global carbon uptake. We may conclude that in the period 1980-1987 the atm increase/CO_2 emission ratio was substantially higher than in the period 1989-1992. The cause of this difference is largely unknown.

Methane

Figure 3 shows the increase of the average CH_4 concentration in the atmosphere.

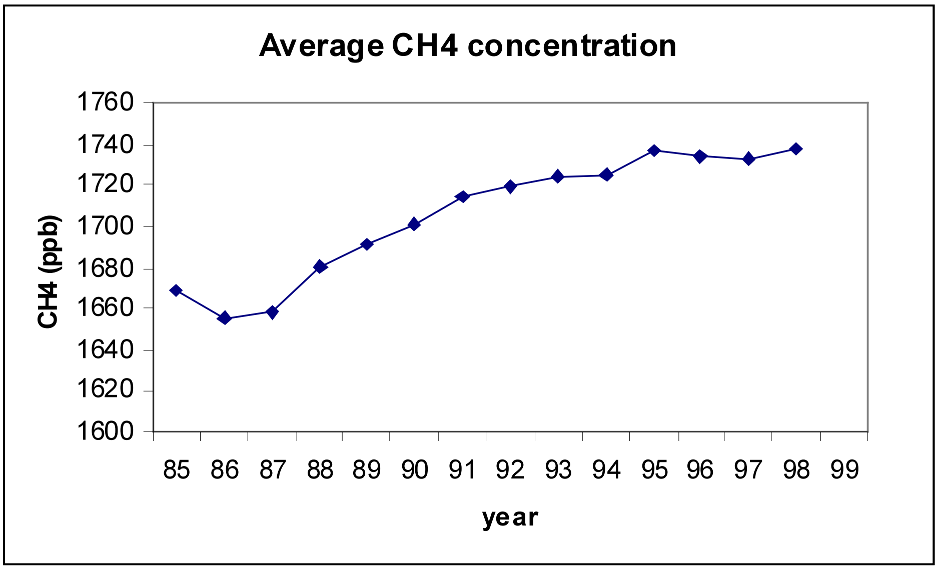


Figure 3. The increase of the average CH_4 concentration in the atmosphere.

If we analyse this atmospheric increase as a function of changes in CH_4 emissions, see also Table 3, we may notice:

- about 90% of anthropogenic CH_4 emission is absorbed in the climate system (notably converted by OH radicals)
- this percentage may vary from year to year depending on various (mostly unknown) processes in the climate system.

Nitrous oxide

Figure 4 shows the increase of the average N_2O concentration in the atmosphere.

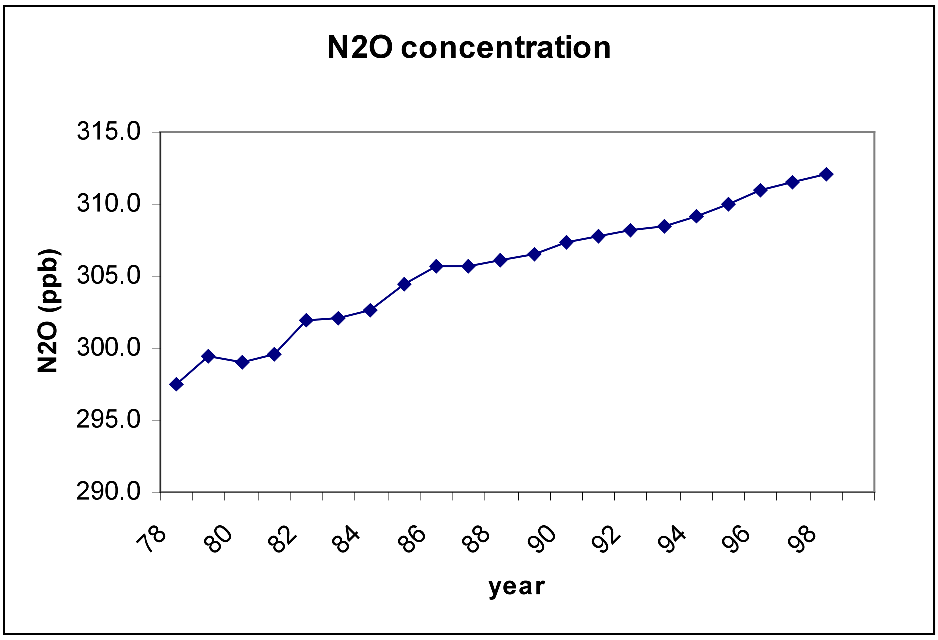


Figure 4. The increase of the average N_2O concentration in the atmosphere.

If we analyse this atmospheric increase as a function of changes in N_2O emissions, see also Table 4, we may notice:

- about 50% of anthropogenic N_2O emission is absorbed in the climate system (notably destroyed in the stratosphere)
- this percentage may vary from year to year depending on various (mostly unknown) processes in the climate system.

Conclusions

We conclude that a very substantial part of anthropogenic greenhouse gas emissions is absorbed and converted in the climate system.

- These percentages are at the moment 50%, 90% and 50% for CO_2, CH_4 and N_2O respectively.
- This percentages can only be determined by analysing the atmospheric budget using measurements and climate models.
- These percentages determine the emission reduction effort that should be undertaken by climate policy to agree with the Article 2 of the FCCC.
- These percentages vary from year to year due to largely unknown processes in the climate system.

It is therefore not clear whether these percentages will remain about the same in the future, notably if human influence on the climate systems continues or even grows.

Estimation of the emission of diffuse sources of large spatial scale and/or very inhomogeneous emission factors

Equation (1) is a general equation to calculate the emission a bottom-up method:

$$\text{Emission (p,r,t)} = Ef_p \text{ x } A_p \quad (1)$$

If the processes which determine the emission (included in the emission factor Ef_p) are well known and do not vary too much for the separate sources of a particular type, and their number (included in the activity index A_p) is accurately known the emission can be calculated which reasonable accuracy. But if not
the parameter A_p could be estimated more easily or accurately by top down methods or a combination of bottom-up and top down methods if:

- sources or sinks are extended over a large area, such as forests or oceans, or
- are scattered,
- not easily be identifiable or
- simply have too large a number to be measured individually

than top down methods using atmospheric measurements and models can be used to estimate the emission much accurately than by using top down methods.
Also if emission factors Ef_p vary very much in space and time, such as CO_2 absorption by the biosphere, N_2O emission from soils or CH_4 emission from rice, top down methods can be used to estimate the emission more accurately or at a more aggregated level

Verification of bottom-up emission estimates

As discussed before, using (statistical) bottom-up data alone will never prove that all sources and their emission strengths are covered and calculated correctly. We therefore need a top-down analysis using atmospheric measurements and analysis of these measurements by models to verify bottom-up emission estimates. The use of atmospheric measurements and models to verify bottom-up CH_4 emission estimates is discussed in detail by Janssen et al. (1999) and an example of an application is presented by Berdowski et al. (1999) in the next chapter of this report. We refer to these publications and limit ourselves here to some remarks.

If solely results of atmospheric modelling are used in principle only total emissions (added natural and anthropogenic emissions summed over a number of source categories) can be calculated. Additional information of isotopes, temporal and spatial variations in emission strengths, correlation with other species (fingerprints) and "a priori" emission estimates etc is needed to derive information about the locations and strengths of specific sources or source categories. An accurate estimation of emission inputs from atmospheric measurements and transport models is most of the time severely hampered because of lack of sufficient measurements. This makes that the system has degrees of freedom (the number of variables is larger then the number of equations) and several solutions, which all satisfy the boundary conditions, are possible. Therefore the estimation is considered as an "ill-conditioned" or "under-determinated" problem. Next comparing bottom-up and top-down emission estimates is not trivial because the way by which emissions are averaged in time and space differs as well as the subdivision of emissions into sectors (bottom-up) and source categories (top-down). The differences between the methods decrease the accuracy of the comparison. Next some expert judgements is often involved in choosing the "best estimate". An inventory expert uses various sources of information to select the best emission factor; the atmospheric modeller can use different approaches to adjust the emissions assumed to the available observations. Because of all these degrees of freedom, the question arises whether a comparison of emission inventories compiled by different methods can be used to independently verify emission data. We are obviously dealing with a comparison process and at this stage of scientific knowledge we should not consider the results of this cross-examining as a method to arrive at a “true result” but as a way to reduce uncertainties and reinforce the scientific credibility of the various emission estimates.

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2.5. INDEPENDENT CHECKS FOR VALIDATION AND VERIFICATION OF METHANE ESTIMATES

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Introduction

The agreed emission reductions in the Kyoto protocol require methods to establish the quality and accuracy of the inventory data and to monitor compliance with the protocol. The IPCC Expert Meeting in November 1997 in the Netherlands concluded that an assessment of inventory data quality was strongly supported by independent checks and additional analysis of uncertainties in the emissions inventories. In the framework of the Dutch National Research Programme on Global Air Pollution and Climate Change (NRP) a study has been carried out in which three connected validation procedures have been applied for a methane emission inventory: the comparison of emission inventories, the comparison of modelled with observed methane concentrations, and the comparison of bottom-up emission estimates with inversely modelled emission estimates (Berdowski et al., 1998a, b). In other words, the NRP project has been initiated to establish, validate and verify a detailed CH_4 emission database for the Netherlands and Northwestern Europe (METDAT). This presentation will present results of this project, focusing on the first two procedures. As such it is an example of the possibility of applying measurement strategies and modelling tools to verify emission inventory data for methane.

Methods

Virtually it is impossible to measure each individual emission source when preparing an emission inventory. In general, these inventories are based on extrapolations and generalisations of a limited number of measurement data, which are transformed into more or less general applied emission factors in combination with all kind of activity statistics and source characteristics. The CH_4 emission database prepared for this validation and verification study has been built up this way as well. The database has been developed for the base year 1994 for the Netherlands and Northwestern Europe with a spatial resolution of 5x5km^2 and 10x10′ (about 10x20km^2), respectively (Berdowski et al., 1999). The area covered include the countries Norway, Sweden, Ireland, United Kingdom, the Netherlands, Denmark, Germany, Belgium Luxembourg and France.

The following source categories have been included in the database: enteric fermentation, animal waste, oceans, coastal waters, lakes, rivers, wetlands, biomass burning, rice paddies, landfills, gas and oil exploration, gas transport, gas distribution, waste water treatment, coal mining, combustion processes. Emissions were estimated from information on emission factors and activity statistics and data necessary for spatial apportioning, such as population density and agricultural land use.

On five locations in the Netherlands ambient air concentrations of CH_4 have been measured on hourly basis during a number of years: at Arnhem (1990 – 1997), Cabauw (200 m height, 1994 - 1997), Delft (1994 - 1997), Kollumerwaard (1991 - 1997), Petten (1995 – 1997) (Hollander & Vosbeek, 1996; Vermeulen et al., 1997; Vermeulen, Hollander & Vosbeek, 1997; Janssen et al., 1997). As a reference station, concentrations at Mace Head (Ireland) have been used (1990 – 1995). These measurement data have been used in trend analysis.

The following data have been collected as well:
- hourly CO_2 and CO concentrations at Arnhem (1990-1997) and CO_2, CO, NMVOC, ethane and acetylene concentrations at Kollumerwaard (1991 - 1997).
- hourly wind speed, wind direction, temperature, radiation at each station.
- hourly mixing heights and Accumulating Potential of the Atmosphere (APA) indices at Eindhoven and Amsterdam airport (Schiphol) in 1994.

APA is calculated from wind speed, mixing height and strength of the inversion layer. The 1994 mixing heights and APA indices have been calculated and validated according to Erbrink (1995).

The measurement data have been analysed in four steps:
- Analysis of the temporal variability (for diurnal, weekly and seasonal cycles) and wind direction dependency of methane concentrations.
- Analysis of the temporal variation of main emission sources in The Netherlands.
- Determination of the relation between the temporal variation in concentrations and atmospherical conditions.
- The daily averaged CH_4 concentrations are modelled by a structural time series model with the APA index (APA_t) as a single explanatory variable.
- Test for the possibility of source apportionment from concentration patterns.

To estimate trends, cycles and the influence of explanatory variables we have used the approach of structural time series models in combination with the Kalman filter. For the theory we refer to Harvey (1994) and Visser and Molenaar (1995).

The LOTOS model has been applied to calculate methane concentrations with the METDAT data as input. The LOTOS (LOng Term Ozone Simulation) model is a Eulerian three-dimensional model describing the behaviour of various ozone related species in the lowest 2-3 km of the atmosphere over Europe (Builtjes, 1992; Roemer et al., 1996). The model is driven by analysed meteorological fields. For this study, data for the year 1994 were available and used. The model produces hourly averaged concentrations in grid cells with a horizontal size of about 60x60 km^2. The height of the lowest grid cell is equal to the boundary layer height. The thickness of the two layers above are determined by the difference between boundary layer height and the ceiling height of the model domain. The emissions used as input for the model are the METDAT emissions for the NW part of Europe. For the rest of the model domain the emissions of the EDGAR database (Olivier et al., 1996) have been used. In this model version the chemical processes in atmosphere and deposition are ignored. The background concentrations were provided by the TM-3 model (Houweling, personal comm.).

Results

The bottom-up methane emission database METDAT for 1994 shows a clear dominance of a number of source groups (Table 1). Agriculture, especially enteric fermentation, fossil fuel production and landfill emissions are the predominant sources for methane in NW Europe.

Table 1. The METDAT methane emission estimates for 1994 in NW Europe

IPCC source category	Gg/year	% of total
1 Energy	**4980**	**28.2**
A Combustion	546	3.1
1 Transformation	15	0.1
2 Industry	65	0.4
3 Traffic	143	0.8
4 Other combustion	315	1.8
5 Biomass combustion	9	<0.1
B Fossil fuels	4434	25.1
1 Solid fuel	3364	19.1
2 Oil & gas	1070	6.1
2 Industrial processes	**n.i.**	**<0.1**
3 Solvent use	**n.i.**	**<0.1**
4 Agriculture	**6784**	**38.4**
A Enteric fermentation	5154	29.2
B Animal waste	1145	6.5
C Rice	14	0.1
D Agricultural soils		<0.1
E Agricultural waste burning	468	2.7
F Forest fires	3	<0.1
6 Waste	**5316**	**30.1**
A Landfills	5254	29.8
B Waste water	61	0.3
C Waste incineration	n.i.	<0.1
D Other waste	n.i.	<0.1
7 Other sources	**n.i.**	**<0.1**
8 Natural sources	**571**	**3.2**
A Fresh waters	58	0.3
B Oceans and coastal waters	38	0.2
C Wetlands	475	2.7
Total	**17651**	**100**

n.i. = not included

In Table 2 the METDAT data are compared to the national total emissions of methane as reported in the National Communications. There is only 0.5% difference in the total emissions between the METDAT data and the National Communication data for the region as a whole. However, for the individual countries, distinct differences can be seen. The METDAT CH_4 emissions are much lower for Germany, Norway and Denmark and much higher for Belgium, France, the United Kingdom, Ireland and Sweden.

Table 2 Comparison of the METDAT inventory data with the data presented in National Communications of the different countries in Northwest Europe

	METDAT Gg/year	Nat. Com. Gg/year	Difference %
Belgium	627	379	66
Denmark	351	428	-18
France	3326	2860	16
Germany	5734	7555	-24
Ireland	873	754	16
Luxembourg	24	n.i.	-
Netherlands	977	1068	-9
Norway	289	464	-38
Sweden	482	296	62
United Kingdom	4900	3843	28
TOTAL	17561	17649	-0.5

n.i. = not included

The time series of ground-level methane concentrations can be characterised by a seasonally varying background of about 1800 ppb (Mace Head concentrations) with superimposed on that occasionally elevated contributions of 400-1000 ppb lasting a few days and/or elevated short term contributions of 1000-2200 ppb. On an annual average the above background elevation ranges from 100-400 ppb. The latter have a typical time scale of a few hours. The same pattern is seen at Cabauw (200 m. above the ground) but with the important difference that the short-term elevations are much smaller, usually 10-30 per cent of those seen at ground-level. At Mace Head, Ireland the short-term elevations are virtually absent. The methane concentrations show a significant wind direction dependence. The maximum lies around 150 degrees (i.e. SSE), the minimum around 300 degrees (NWW).

Elevated concentrations during a few days or more are connected to stable easterly flows. The short-term peak concentrations are a manifestation of local sources. Calculations with a simple Gaussian plume model show that differences between the peak values at Cabauw and the ground-level stations can easily be explained as a vertical gradient in a plume of ground level sources within 60 km of the receptor.

Modelling temporal variations with the Accumulating Potential of the Atmosphere (APA) index as explanatory variable, indicates that the variability in methane concentrations can be attributed to a large extent to atmospheric conditions. Of course, this variation indicates the presence of emitting sources as well. Especially, concentrations above 2500 ppb are observed when the accumulating potential of the atmosphere is high. An example is given in Figure 3.1, where daily averaged CH_4 concentrations are modelled by a structural time series model with the APA index (APA_t) as a single explanatory variable. The Figure shows estimates for station Delft, based on all daily data in the year 1994 (N= 365). The squared correlation between measurements and model predictions is R^2= 0.69. Especially, the high concentration peaks from day number 270 onwards are modelled very well.

The fact that concentrations are very "sensitive" to atmospheric conditions (Figure 1), shows that local emissions significantly contribute to concentration levels as background concentrations are not influenced by hourly variations in mixing heights.

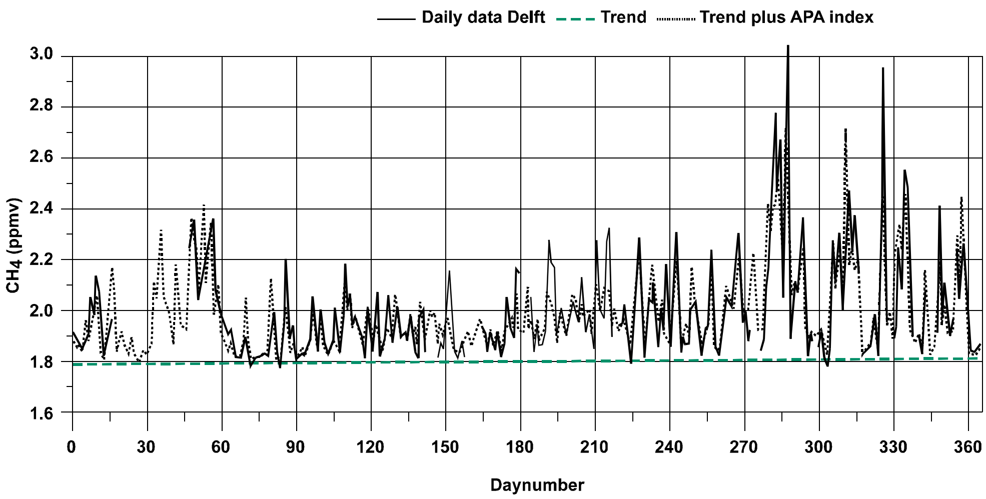

Figure 1. Daily averaged CH_4 concentrations with model predictions for station Delft. Data are for the year 1994 (N= 365).

Another indication of the large influence of meteorology on methane concentrations as measured at the ground stations is the high correlation between CH_4 and other components concentrations at the same station (e.g. CO_2, CO, NO_x, ethane and acetylene). If the structural time series model above is estimated with CO_2 as explanatory variable, instead of APA_t, a squared correlation is found amounting to 0.91 for Arnhem.

The inferences above show that variations in methane concentrations in the Netherlands are largely determined by sources at distances less than 2-3 days from the receptor point, that is sources in the Netherlands and nearby countries.

Temporal variation in CH_4 concentrations due to temporal variation in emissions sources (e.g. the diurnal cycle in enteric fermentation) could not be detected due to atmospheric variation. Therefore, we conclude that temporal concentration patterns of methane are not suited to detected specific emission sources. As a consequence, this approach is not very well suited to validate emission estimates.

It should be noted that this conclusion does not imply that local emissions do not contribute to concentration levels of CH_4. Figure 1 shows that local emissions significantly contribute to concentration levels.

There is a good agreement between the LOTOS modelling results and the methane concentration measurements in Mace Head. The correlation coefficient of monthly means is 0.78, the bias and mean standard error are 5 and 10 ppb respectively. It shows that the background of methane concentrations, which in the Netherlands is predominantly determined by western winds, is realistically incorporated in the model.

The LOTOS calculations show that emissions in the Netherlands, Belgium, France, Germany and the United Kingdom account for 90-95 per cent of the elevation of methane concentration above the background. This is in line with the results of the time series analysis. Occasionally, emissions from the Northsea or Eastern Europe are of significance.

The methane concentrations calculated by the model nicely represent many of the characteristics found in the observations. It reflects the moderate elevations of methane concentrations on a synoptic time scale. However, the short-term elevations are generally well represented in time, but not in amplitude. The peak values are grossly underestimated by the model. The observations suggest a considerable gradient over the lowest 200 m with regard to the peak values and therefore it is expected that a model that assumes homogeneity in vertical direction is not capable to simulate the amplitude of the short-term peaks. Model results and observations compared on the basis of daily minima indicate that the local influences are effective during a few hours only leaving the rest of the day relatively free from local disturbances.

A summary of the model results is presented in Table 3. The correlation between model output and measurements on an hourly basis vary are high and even better on a monthly basis. from The BIAS varies from less than 10 ppb in Cabauw and Arnhem to 44 ppb in Delft, which is a good agreement. Including dry deposition in the model did not noticeably affect the correlation parameters. The BIAS dropped by about 10 ppb at the stations in the Netherlands, and by 5 ppb at Mace Head equivalent to a reduction of the average methane concentration with 0.3-0.5 per cent.

Table 3 Correlation coefficients of LOTOS model output and methane concentration measurement data, BIAS and MSE for four sites in the Netherlands and Mace Head in Ireland.

Station	**Correlation Coefficient (hourly)**	**Correlation Coefficient (monthly)**	**BIAS [1] (ppb)**	**MSE (ppb)**
Arnhem	0.46	0.61	4.7	99.1
Delft	0.59	0.88	-44.0	99.5
Kollumerwaard	0.58	0.73	26.8	75.1
Cabauw	0.61	0.80	8.2	57.5
Mace Head	0.67	0.78	18.9	31.1

[1] A negative bias means that the model underestimates the methane concentrations

It is concluded that this technique of emission validation is useful. The methane emissions of the METDAT database produced modelled methane concentrations that were in acceptable agreement with the measurements. This indicates that the overall emissions estimates in the METDAT database are realistic. The technique applied so far is however not able to indicate whether the individual sources are estimated realistic as well. Due to the absence of an adequate local dispersion module, due to differences in calibration standards (2%), and due to model uncertainties (10%), this method of emission validation will have an overall inaccuracy of at least 15%.

Conclusions

There is a good overall correspondence between the consistent bottom-up METDAT emission inventory and the National Communication data. However, on a country level large discrepancies could been found.

The analysis of concentration measurements gives a clear indication of the contribution from the different areas. Time series analysis as such appeared not to be suitable for verification purposes in this study.

The technique of emission validation by modelling methane concentrations with the bottom-up estimated emission data as input for the model and comparing the results with measured concentrations has been proven quite successful. The technique applied so far is however not able to indicate whether the individual sources are estimated realistically as well. The overall inaccuracy of this method of emission validation will be 15% at least.

A combination of independent bottom-up emission estimates, based on consistent methodology, atmospheric measurements and atmospheric dispersion models are the necessary tools to ascertain that:

- the emission data incorporated in the Protocol indeed reflect the scientific established atmospheric budget of emissions of greenhouse gases on a global, regional and even national scale, and
- the emission inventories as National Communications deserve the scientific credibility needed to ascertain compliance with the Protocol.

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2.6. VERIFICATION OF NON-CO_2 GREENHOUSE GASES

The possibilities - and costs - to reduce the uncertainties in emission estimates using modelling and field observations

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Introduction

Recently, a study has started to investigate the possibilities to reduce the current -often substantial- uncertainties in emission estimates of non-CO_2 emissions in the Netherlands by means of state-of-the-art modelling combined with inverse modelling / data assimilation and appropriate field observations. Reducing the uncertainties in emission estimates is important to increase the level of acceptance of abatement measures for the different source categories, and to base emission trading and joint implementation on a reliable and general accepted methodology. Using independent field observations -and possibly also satellite observations- to reduce this uncertainty is a possibility that deserves further investigation

Elements of the research

The focus of the research is on the emission estimates in the Netherlands, in principle per source category, of the non-CO_2 greenhouse gases under the Kyoto protocol, CH_4, N_2O, HFCs, PFCs and SF_6.
A very accurate emission estimate would be created in case every emission source in the Netherlands would be measured separately and continuously. Because this is not possible from a financial and logistic viewpoint, the question is with how many field observations, and where located, a reliable estimate of the emissions is possible. The set-up of such a measuring strategy will depend on a number of aspects.

These aspects are whether the emission source is an isolated point source or a diffusive area source, and the relative contribution of the Dutch sources to the concentration level in the Netherlands. This last aspect is directly related to the atmospheric residence time of the trace gas under consideration. The possibility to perform field observations with a specific accuracy is also of importance. It should also be noted that monitoring of the development of the emissions in time, trend analysis, is a very important issue that might require less absolute accuracy than the determination of the current emission estimates themselves.

A measuring strategy to determine the emission of a specific source will strongly depend on the characteristics of the source. For a diffusive or a point source, for a source that is constant in time, or has a variable emission or has an spatial inhomogeneous character, a different measuring strategy will be required. Next to concentration measurements, it can be expected that specific meteorological parameters have to be measured to be able to determine the - local - dispersion characteristics.

Inverse modelling and data assimilation is a powerful tool to use in an objective way the information contained in both measurements and modelling. As an example, the COMET, a two-layer Lagrangian atmospheric transport model, is applied for CH_4. In the inverse mode of COMET a SVD matrix inversion is used to calculate the emissions of a number of source areas using a five-year of 6-hourly concentration data of methane at the Dutch station Cabauw. The calculated emissions compare well with the current emission inventory data for the Netherlands and its surroundings. Similar experiences have been found by applying data assimilation (extended Kalman-filtering) around the Eulerian grid model LOTOS.

Outlook

Inverse modelling and data assimilation using both COMET and LOTOS will be used to make an estimate of the number of measuring stations/masts required to determine with a specific accuracy the emissions of non-CO_2 gases over the Netherlands. Indications will be given concerning a measuring strategy to determine the emissions of local diffusive and point sources.
Attention will be given to the formal structure in which these measuring strategies and results based on observations can be handled within the framework of IPCC.

3. A STRATEGIC PLAN FOR THE REDUCTION OF UNCERTAINTIES

André van Amstel

Wageningen University, Environmental Systems Analysis

The following instructions were given just before the group split up in parallel sessions.

SESSIONS PER TARGET GROUP

The sessions in the afternoon are grouped according to target group:

- Energy: combustion emissions of CO_2, CH_4, N_2O en CH_4 from exploitation of oil and gas
- Industry: process emissions CO_2, CH_4, N_2O; HFCs, PFCs [, FICs]and SF_6
- Transport: combustion emissions, incl. bunkers [and possibly evaporation] CO_2, CH_4, N_2O
- Agriculture: CO_2[?], CH_4, N_2O
- Waste, Consumers and Trade-Services-Public Service: CO_2, CH_4, N_2O

CHAIRPERSONS AND RAPPORTEURS

Energy: Chair: Jos Olivier RIVM.
RAPPORTEURS: Jan Spakman RIVM/ Dolf Gielen ECN

Industry: Chair: Tinus Pulles TNO.
RAPPORTEURS: Hans van der Steen NOVEM/Dick Heslinga TNO

Transport: Chair: Jan Anne Annema RIVM.
RAPPORTEURS: Jan Hulskotte TNO/Robert van den Brink RIVM

Agriculture: Chair: Oene Oenema.
RAPPORTEURS: Peter Kuikman AB-DLO/Klaas van der Hoek RIVM

Waste/Consumers /Other: Chair: Trudy Rood.
RAPPORTEURS: Hans Oonk TNO/ Andre van Amstel WU/MSA

Reporting was asked on the following:

1. Quality of the documentation for each estimate
    - Methodology, statistics, emission factors, uncertainty estimates
    - Using the Revised *IPCC Guidelines,* completeness of sources
    - Quantitative estimate of the uncertainty in emissions per sector and gas

2. Magnitude of uncertainties

- Refer to discussion paper for the table on uncertainties in the Netherlands
- Essential supplemental remarks

3. Identification of important sources of uncertainty
   - Magnitude
   - Relationship to reduction policy

4. Technical possibilities to reduce these uncertainties
   - What is fast and relatively cheap?
   - What is more difficult but important?

5. Mapping information flows and points for improvement with respect to the current approach and system

6. Setting up a 'Plan of action' for reducing uncertainties
   - Who?
   - What?
   - When?
   - At what cost?
   - Order of priority for actions

Suggestion for content of discussion paper (drawn up by the chairpersons)

- Overview of emission sources. Short description of the current method/approach per sector and per gas in the emission inventory (see Dutch-language) report on Methods for Emission Registration, nos. 37 and 44).
- Short description of the current method for estimating the uncertainties per sector and per gas. If not explicitly estimated, a reference to the literature is included.
- Description of the most important sources of uncertainty per sector per gas e.g. monitoring laughing gas in industrial plants for the production of saltpetre.
- Short overview of the current actions (national and international) for reducing uncertainties.
- Identification of possibilities for reducing uncertainties at national level in the short, middle and long terms (within 1, 1-5 and >5 years, respectively)

SUGGESTIONS FOR DISCUSSION IN SESSIONS:

- Is the overview of sources per gas per sector complete?
- If not, where are the possible gaps? How can they be filled in?
- Is the uncertainty per gas per sector well estimated?
- Are there possibilities for reducing uncertainties? (<1, 1-5, >5 years)
- What methods need to be improved in the short term? What emission factors could be better?
- How can we approach this substantially (modelling, monitoring, using another system for Emission Registration)?
- Is it possible to estimate what reduction in uncertainties can be realised using such a method?
- Who should take action here? What are the priorities?

4. SESSION REPORTS AND DISCUSSION PAPERS

4.1. SESSION 1: ENERGY

Discussion paper

Jos Olivier and Jan Spakman
RIVM

This session focuses on *combustion emissions* of CO_2 (including feedstocks), CH_4 and N_2O, and on *process emissions* of CH_4 from oil and gas production from the Target Groups:

- Energy sector (oil and gas production and transmission, power generation)
- Refineries
- Industry

The combustion emissions of these groups are combined in one session because they are characterised by individual annual emission reporting by the largest companies, the so-called *Emission Registration-Individual (ER-I).* This is in contrast with the other emission sources, of which emissions are calculated from statistical information on activity levels and emission factors. Combustion emissions from Waste (except waste incineration), Transport and the Target Groups Residentials, Services and Agriculture are dealt with in other sessions.

The session aims at:

1. Quantitative estimate of the uncertainty in emissions per sector and per fuel
2. Compilation of a list of the largest sources of uncertainty
3. Compilation of options for reducing these uncertainties
4. Describing the procedures of the annual emission update process (final for t-2, preliminary for t-1, possibly revisions for other years) and identifying areas for improvement in procedures and methodologies used
5. Drafting of a Plan of Action for reducing uncertainties

As a basis for discussion in the breakout group on Energy, this paper summarises per gas the key elements of the emission calculation for the three Target Groups as well as the variables influencing the estimation of the associated uncertainties. Since time for discussion (and for follow-up improvement too) is limited, focus should be on completeness and the largest sources in terms of emissions or uncertainty.

CO_2

1. We will first consider national total CO_2 emissions, since total combustion emissions of CO_2 are closely linked to total top-down domestic energy supply as reported annually by the Netherlands Central Bureau of Statistics (CBS) in the Netherlands Energy Review (formerly 'NEH'). Also, total apparent fuel consumption is also considered by UNFCCC/IPCC as an official and mandatory *reference calculation* to check the bottom-up sectoral emission calculation. Table 1 presents a summary of uncertainty estimates per source/fuel type based on statistical data and expert judgement.

Table 1. Summary of uncertainty estimates for CO_2 per source/fuel type based on statistical data and expert judgement.

Target group/subsector	Activity	Uncertainty*	Emission factor	Uncertainty*	Emission	Uncertainty*	Absolute	Priority
Combustion**	PJ ('90)	(±)		(±)	Tg CO_2	(±)	(±)	
Coal	370	3%	94***	3%	34.8	4.2%	1.5	#2
Oil products	696	3%	73***	2%	50.8	3.6%	1.8	#1
Gas	1195	1%	56***	1%	66.9	1.4%	0.9	#3
Feedstock								
Coal (excl. coke consumption)	5	3%	0%	10%	0.0	10%	0.0	
Oil	246	5%	18%	25%	3.2	25%	0.8	#4
Revised preliminary values: [1]		***20%***	***5-10%***	***50%***	***1.8***	***50%***	***1.0***	***#3***
Gas	95	1%	90%	10%	4.8	10%	0.5	#5
Other sources								
Flaring	..	10%	var.	10%	0.4	14%	0.1	
Waste incineration	..	10%	aggr.	10%	1.2	14%	0.2	
Cement etc.	..	5%	var.	5%	1.9	7%	0.1	
TOTAL Kyoto					**164.0**	**1.6%**	**2.6**	
Temperature-correction:								
• Share of Industry: 20% (in 1990)								
• Shares of Residentials: 40-45%, services: 20%, agriculture: 20%								
Change from moving to fixed 30-year normal: +30% for years > 1990.					**-4.3 to +4.3 Tg**	0 to +30%	0-1.5	(#3)
Biofuel combustion								
wood, wood waste	Not Applicable					Not Applicable		

* Estimated as 2-sigma or 95% confidence limits. ** Including coke consumption. *** Example calculation only.
1) See session report.

2. If we now follow the *bottom-up sectoral approach* of determining emissions (per Target Group), each group can be split into (a) a fraction consisting of the largest companies individually reporting their annual emissions (ER-I) and (b) a fraction with the remaining part of the Target Group (see Fig. 1). Emissions of the latter part are calculated by so-called Task Groups (on the basis of calculated remaining fuel consumption and standard emission factors):

- Industry: 44 Tg CO_2 (± 5%), of which 60% ER-I
- Energy sector (oil and gas production en transmission, power generation): 41 Tg CO_2 (± 2%), of which 80% ER-I
- Refineries: 10 Tg CO_2 (± 5%), of which 98% ER-I
- Other (= statistical differences): between 1 Tg in 1990 and 6 Tg in 1997

The submissions by individual company reports, which make up 75% of the total of the three target Groups, are compared with the standard Netherlands' emission factors for CO_2. If they differ more than 5%, then these large deviations are corrected via modification of the remaining energy consumption used for additional estimate of CO_2 emissions for non-ER-I-reporting firms within the Target Group. This procedure is followed because it is implicitly assumed that the submitted fuel consumption data are incorrect and because the ER Task Group 'ENINA' is not allowed to revise individually reported emissions figures. This ensures that total CO_2 emissions for these three Target Groups cannot be off the reference calculation by more than 5% (in practice, the group total may show much less deviation). Statistical differences are usually less than 2% of the total fossil fuel consumption (except for 1997).

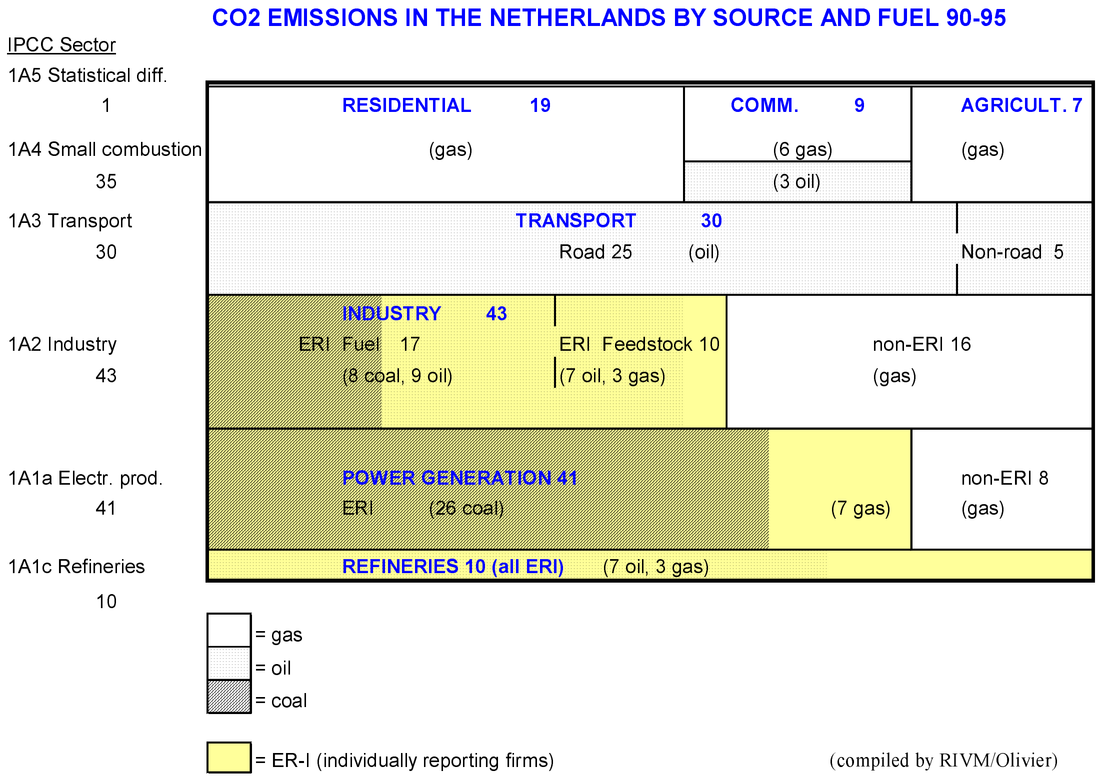

Figure 1. Schematic overview of CO_2 emissions from fuel combustion (IPCC Category 1A) showing the relative shares of sub-sectors as well as main fuel types and the total contribution of individually reporting firms (ER-I). Data are representative for the period 1990 to 1995.

Possible points of attention (values; documentation):

- *Uncertainty estimates for emission factors and activity data (in particular coal)*
  Priorities: a 50% decrease of uncertainty:
  - in oil emissions would reduce the uncertainty in total CO_2 by 0.3% points
  - in coal emissions would reduce the uncertainty in total CO_2 by 0.2% points
  - in gas emissions would each reduce the uncertainty in total CO_2 by 0.1% points
  - in oil feedstocks emissions would reduce the uncertainty in total CO_2 by 0.06% points

- Research into possible trends in emission factor for coal

- Documentation of standard emission factors
- Documentation of fractions unoxidised
- *Ensuring consistency in times series in ER-I submissions:*
  - *Emission factor coal/oil/gas* ER-I Power generation
  - *Emission factor coal/oil/gas* ER-I Refineries
  - *Emission factor coal/oil/gas* ER-I Industry

- Flaring/venting
  - Documentation of the amount flared/vented and selection of the data source

- *Feedstock*
  - natural gas: fraction not oxidised
  - oil products: amounts consumed and fractions not oxidised

- Fraction of fossil carbon in waste incineration:
    - Research into possible trends in fossil carbon factors and non-ERI amounts.
    - Definition and amount of industrial waste combustion by industry firms.

- P.M.: Temperature correction
    - methodology (moving or fixed 30-year average; present vs. WMO recommendation); threshold temperatures
    - application factors

CH_4

Although agricultural sources and landfills are in the Netherlands the largest sources of methane, the energy sector – in particular fugitive emissions for oil and gas production and transmission – contributed with 180 Gg about 15% to CH_4 emissions in 1990 (or 3.8 Tg CO_2-eq.). In Table 2 we have summarised the emissions of three target groups.

Table 2. Summary of uncertainty estimates for CH_2 from energy sources per source/fuel type based on statistical data and expert judgement.

Target group/subsector	Activity	Uncertainty	Emission factor	Uncertainty	Emission	Uncertainty	Absolute	Priority
Fugitive sources		(±)		(±)	Gg	(±)	(±)	
Oil production	0.19 mld m^3	1%	var.	25%	13	25%	3	
- offshore								
- onshore								
Gas production	72 mld m^3	1%	var.	25%	85	25%	21	#2
- offshore							(=0.4 Tg CO_2eq)	
- onshore								
Gas transmission		1%	% of total transmitted:					
- transport	72 mld m^3		0.02%->0.0125%	50%?	7	50%	3	
- distribution	21 mld m^3; 655 PJ		0.6%->0.5%	40%	72	40%	29	#1
							(=0.6 Tg CO_2eq)	
Refineries			% of total VOC:					
- total VOC emissions			4%		IE*			
Coke production								
- coke produced	62 PJ(?)				IE*			
Combustion sources			% of total VOC:					
Natural gas		5%	60%	25%	\ 3	25%	0.7	
LPG / other gases			35%		|			
Oil			20%		|			
Coal and coal products			50%		/			
Wood	NE**		25%		NE**			
TOTAL of 3 Target Groups					**180 Gg**	**20%**		
* Included Elsewhere. ** Not Estimated					**(= 4 Tg CO_2-eq.)**			

Possible points of attention (values, methodology, documentation):

- *Uncertainty estimate for activity data (e.g. length of networks) and emission factors. Priorities: a 50% decrease of uncertainty:*
  - in gas distribution emissions would reduce the uncertainty in group CH_4 by 6% points
  - in gas production emissions would reduce the uncertainty in group CH_4 by 3% points

- *Gas transmission methodology:*
  the methodology (emission factor per Tg of gas transported) is in fact **not** suited for **monitoring trends in emissions**; an alternative may be to convert emission factors as follows:
  - gas transport: emission factor in 1990 * trend in number of compressor stations and their operational practices
  - gas distribution: emission factors in 1990 * trends in length of network, in particular split into old cast iron vs. rest (monitored??)

  correction of distribution factors for partial oxidation by soil bacteria (~ 0-20%)?

- *Oil/gas production (gas venting and flaring):*
  - Documentation of the amount vented and selection of the data source (see CO_2)
  - Determination and documentation of trends in emission factors of vents and flaring

- Combustion (minor source):
  - Document emission factors used for gas, for oil and for coal
  (Now defined as % of total VOC; document the explicit value for CH_4.)

- P.M. Coke production
  Two facilities, one included as individual source and one part of total steel source in ER-I.

- *Biofuel combustion in power generation and industry (activity data and emission factors)*

N_2O

Fossil fuel combustion sources are only a very small, be it very uncertainty, source of N_2O (0.5 Gg or 0.15 Tg (Mton) CO_2-eq.). By far the largest default emission factor for combustion is reported for coal. Emissions from biofuel combustion are currently *not estimated (?).*

Possible points of attention:
- *Uncertainty estimate for emission factor for coal*
- *Emission factor for coal:*
  1. not to be applied to coke consumption as that is predominantly a non-combustion process? (refinement of application of Revised IPCC Guidelines)
  2. separate for FBC? (one facility in the Netherlands estimated at 0.1 Gg)
  3. country-specific value of ~0 for power generation? (there are measured values ~0; see NRP-MLK report)

- *Biofuel combustion in power generation and industry (activity data and emission factors)*

Issues to be discussed in the breakout group on Energy and conclusions to be drawn

1. Review of uncertainty estimates used, in particular for large sources and apparent large uncertainties
2. Identification of weak spots in estimating uncertainties
3. Conclusions on the largest uncertainties; in term of CO_2-eq., per gas, per target group
4. Identification of the major factors underlying the estimated uncertainty in emissions
5. Options for reducing these uncertainties, by gas and sector
6. Review of procedures of the annual emission update process (in particular for ER-I and Company Environmental Plans and their verification); conclusion on areas for improvement in procedures, methodologies used, or parties to be involved
7. Drafting a "Plan of Action" for improvement of the emission monitoring process, i.e. reducing uncertainties: in ER-I sources; in activity data, emission factors and methodology; in uncertainty estimate and uncertainty calculation.

In addition to this evaluation of the present 'National System' for updating greenhouse gas emissions in the Netherlands, one could also check the draft UNFCCC Common Reporting Format (CRF), which is under development. This would be to see whether the Netherlands for these target groups can: (a) meet the data requirements and (b) justify the activity data, emission factors and trends in emission factors used for calculating the Netherlands' greenhouse gas emissions. This, however, is considered to be out of the scope of the discussion of the breakout group as it requires a much more detailed approach.

Session 1: Energy - Conclusions

Rapporteurs: Jan Spakman, RIVM; Dolf Gielen, ECN

Members of discussion group present: John van Aardenne (Wageningen University), M. Beeldman (ECN), E. de Jeu (Ministry of Economic Affairs), Geert Draaijers (TNO), E. van Gelder (CBS), Dolf Gielen (ECN), Heleen Groenenberg (Utrecht University), BertJan Heij (RIVM-NRP), Frans Hoefnagels (Ministry of Environment), Evert Kamperman (TNO), Marianne Kuijpers (RIVM), Joop OudeLoohuis (RIVM), Jan van der Plas (Ministry of Environment), E. Schols (RIVM), A.J.M. SchootUiterkamp (Groningen University), J. van der Sluijs (Utrecht University), E.J. Sneek (KEMA), Jan Spakman (RIVM), Jasper Vis (Ministry of Environment), E.J.M. van der Werf (Province of Gelderland), Bart Wesselink (RIVM), Ruud van den Wijngaart (RIVM), Ed Zonneveld (CBS).

1. Introduction

Starting point is *Table 1* in the discussion paper (Olivier and Spakman). Eventually, policy makers define the *required accuracy* of CO_2 emission estimates. For domestic reasons they would like to monitor and explain year-by-year changes in CO_2 emissions. Of course their main objective is to have enough accuracy to check whether the Netherlands complies with the obligations of the Kyoto-protocol (-6% greenhouse gas emissions over a period of 20 years). In the first case, the required uncertainty in the mutation would be <<1%, which is practically impossible. In the second case the required accuracy in the emission-change would be typically about <0,5% over the 20-year period. However, part of the uncertainty has a structural character while the contribution of true 'noise' is hard to quantify. *Therefore it appears to be very difficult how these requirements should be translated in requirements on the uncertainty of the annual CO_2 emission estimate.*

2. Uncertainty in emission factors for CO_2

About the history of the *emission factors* applied in the Netherlands:

- For coal (products) we use 94 – 103 (kg/GJ). These values result from an analysis by KEMA of about 10 years ago. The exceptions to these values are blast furnace gas (we use 200 kg/GJ) and coke oven gas (44 kg/GJ). Despite the huge differences in coal quality, the uncertainty as reported in Table 1 (3%) does not seem unlogical because an almost linear relation between carbon content and net caloric value can be assumed. *It is recommended to ask GKE about historic data on caloric value and carbon content of coal used in the Netherlands.*

- For oil (products) we use 73-77 (kg/GJ). Exceptions are LPG (66 kg/GJ) and refinery gas / residual chemical gas (46 kg/GJ). Presently some actions are underway to check and improve on the emission factor of refinery gas, because of the highly variable composition of these gases. Discussion issue: is it useful to make a distinction between winter and summer diesel? No, for this distinction is averaged out when making an inventory on the basis of a one year period.
- For natural gas we use 56 kg/GJ, on the basis of analyses by Gasunie and Gastec. This value is believed to be highly accurate for the Groningen reservoir (which produces about 60% of the total Netherlands gas production). However, this 'Groningen' factor is also used for all other reservoirs, though their gas-composition may be quite different. How about British and Norwegian gas that is already used within the Netherlands*? It is recommended to check the bandwidth of emission factors that should be used for natural gas delivered by Gasunie.* Furthermore there is a possibility to check emission factors on the basis of information that companies should supply according the so-called BEES regulation. So far it appears that the values can deviate more than 5% from the standard value (56 kg/GJ). A complication might be that gas-types as registered in the ER-I database, are different from the gas types as identified within the energy-statistics (CBS-NEH). This might lead to increased uncertainty per gas type of consumption and emission factor. On the other hand, the documentation about the used emission factors can be quite good.
- Although the underlying emission factors expressed as g CO2 per physical unit (kg or m3) are specified with 3 *significant digits*, the final emission factors used in the emission calculation are expressed per GJ and these are rounded and specified with 2 significant digits (see Table E.1 in the ER methodology report no. 37). Apart from a possible error identified in the calculated value for gasoline, this practice means a unnecessary loss of some accuracy in the emission calculation.

3. Uncertainty in carbon storage in petrochemical products

It is uncertain how many oil products are actually used as a feedstock in the petrochemical industry. The energy statistics show feedstock figures that differ significantly from data that can be collected from other sources. Triggered by critical researchers of UU, CBS has recently published a re-estimation of the feedstock volumes. For the years 1990-1996 it turned out that the volumes should be tens of PJ (~10%) *less* than was previously estimated. However, Gielen (ECN) notices that he expected the re-estimation to result in about 40 PJ *more* feedstock use. Therefore Gielen states that the uncertainty in the volume of feedstock for petrochemical products is about 20% (instead of 5% as in table 1). As a consequence, the storage percentage of carbon in these products could be 90-95% (instead of 82% as is presently used), and its complement, the emission percentage could be as low as 5-10%. Obviously the uncertainty in emissions from petrochemical products is typically 50%! *Dolf Gielen (ECN) will initiate additional research, coordinated with similar activities at EU level (NEU-CO2 project).*

A secondary problem is that the IPCC Guidelines do not make clear how these 'chemical feedstock' emissions, partly from (intermediate) product manufacture and product use, should be allocated to importing or exporting countries. However, the *CO_2 Reference Approach* of IPCC, where the apparent energy consumption at the level of energy carriers accounted for in energy statistics is the basis of allocation of emissions, offers some explicit guidance. This however, shifts the problem of the fate of intermediate products to determine the average carbon storage factor per energy carrier, since these products can be exported without sufficient knowledge of the final end use applications abroad.

4. Uncertainty in activity data (energy figures)

- The energy statistics (NEH) from CBS are - on an ad hoc basis - reviewed with respect to uncertainty. The problem is that some sectors and energy carriers are only partly covered by the CBS questionnaires and therefore require a suitable technique for estimating the complementary part of the energy consumption.
- *Natural Gas:* The supplied volumes are (very) well known. Traditionally the surplus of demanded (distributed) volume is caused by from differences in measurement-temperatures. This is a structural error. *Coal:* The reported uncertainty of 3% for coal (table 1) refers to the supply-side and mainly results from uncertainties in (import and) export volumes. Furthermore, in theory some minor losses of energy can occur due to fugitive emissions of especially methane from stored coal. *Oil:* on the supply side the uncertainty of import and export of oil products lead to relatively large statistical differences. However, there is also a contribution from uncertainties on the demand side data (quality and coverage of the questionnaires).
- How should we interpret the *statistical differences?* Is it part of the inland consumption that can not be allocated to one of the sectors? Or is it just an indication of the uncertainty of the energy figures? The latter explanation looks sound. Including the statistical difference within the national consumption figures for calculating national CO_2 emissions (like in the Reference approach of the IPCC Guidelines) is a choice. This should be made more explicit and might be reconsidered.

  Presently CBS is working on *eliminating the statistical differences*. Remark/warning: if this elimination is not done by improving the actual demand and supply estimates, but is simply performed by distributing the statistical difference over supply and demand, then such a solution does neither improve the quality nor reduce the uncertainty of the statistical data.
- *ER-I data:* about 50% of the Netherlands CO_2 emissions is emitted by large plants. These emissions must be reported to the authorities (provinces). After validation by the provinces the data are input for the ER-I database. But companies tend to aggregate data in their reports and thus hide details more and more. Also, some majors only supply emission data but refuse to report their energy consumption. Furthermore the quality of the validation is believed to be rather poor and thus functions as an additional source of

uncertainty. As a result of this misery, experts fear that the quality of the reports - and input for ER-I - will get worse in the near future. Because of the multiplier effect in estimating total (national) emissions, this may have severe consequences for the uncertainty in total national emissions.

Another problem may arise from the *assumption that certain sectors are fully covered* within ER-I. Indeed, due to the obligations under the BEES regulation one might expect that all large combustion plants are recorded within ER-I. However, in some cases this may not be the case. It appeared that some large power plants are not recorded in ER-I.

5. Gas flaring/venting; gas distribution

- There are two data sources for estimating process emissions of CO_2 and CH_4 in the Netherlands oil and gas industry. There is the top-down estimate of TNO/RIVM/CBS on the basis of aggregated emission factors and production figures versus the bottom-up inventory of the oil companies as collected and presented by NOGEPA. *Further study on these two datasets is recommended and will reveal (a) what dataset has the best quality and should thus be selected for emission calculations; (b) will provide insight in apparent uncertainty in the figures reported in both datasets.*
- Although the recommendation in the discussion paper to change the methodology of estimating CH_4 emissions from gas transport and distribution was supported by participants, it was also observed that data to estimate the annual leak percentage over time is not available.

6. Conclusions

On CO_2:

- Requirements for uncertainty

  The minimum uncertainty is defined by policy goals: monitoring on a year-to-year basis and checking on long-term (20 years) reduction targets. However, it is very difficult to translate the necessary accuracy needed for monitoring emission reduction into specifications for the uncertainty in the annual emission estimate. This is because the structural and the random contributions to the uncertainty are not quantified.
- Emission factors

  The uncertainties of the emission factors can be and should be reduced. *Actions are addressed with respect to the emission factors of natural gas, coal and refinery gas as well as in the number of significant digits used in the final emission factors.*
- Carbon storage in petrochemical products

  The uncertainty in the volume of feedstock in this industry is presently preliminary estimated at 20% (instead of 5% as was previously assumed). This results in an uncertainty of 50% in the CO_2 emission from production and use of petrochemical products. *Additional research for the Netherlands' case is initiated (coordinated with a similar EU project).*

- **Activity data (energy statistics)**
  Natural gas consumption is well known; only a small structural difference between supply and demand exists. Uncertainty in total coal consumption mainly concerns the supply side and stems from uncertainties in export volumes. Oil consumption figures are difficult to generate because of the multitude of small export volumes and because sectors are only partly covered by the CBS questionnaires.
- Statistical differences
  These can be interpreted as a first order indication of the uncertainty. Including statistical differences for national CO_2 calculations (as could be inferred from the IPCC Reference Approach) is a choice that should be made more explicit and might be reconsidered in time. The present system of companies supplying emission and energy data to the authorities introduces additional uncertainties in estimating total national CO_2 emissions. *CBS is currently taking action to reduce these differences in the statistics.*
- Present uncertainty estimates
  The *order of magnitude of the uncertainties* presented in *Table 1* of the discussion paper were endorsed by the participants, except for feedstock emissions which are assumed to be much larger (see note). The ranking of sources of uncertainty as presented in the discussion paper were also endorsed, with the additional remark that the *industry sector is a special case* due to the variable quality of their ER-I emissions.

On CH_4:

- Oil and gas production / distribution
  Uncertainties can be reduced by comparing and studying two independent emissions data sets. The current methodology for estimating emissions from leaks in the gas distribution network should be reconsidered. *However, this requires data on leak percentages that will be hard to get.*

4.2. SESSION 2: INDUSTRY

Discussion paper

Tinus Pulles
TNO-MEP

1. Reporting format

The breakout group on Industry will discuss the status quo and required improvements in reporting GHG emissions from industrial sources.

Within the UNFCCC a new reporting format for Annex 1 parties is being developed ("CRF" or "Common Reporting Format"). The objectives of this new reporting format are given in Box 1 (copied from the relevant UNFCCC/SBI document). One of the explicit objectives of such a new reporting format is to enhance possibilities of verification and validation.

> **Box 1** FCCC/SB/1999/1
> Page 9
>
> **DRAFT GUIDELINES FOR THE PREPARATION OF NATIONAL COMMUNICATIONS BY PARTIES INCLUDED IN ANNEX I TO THE CONVENTION**
> **PART I: INVENTORIES**
>
> **A. Objectives**
>
> 1. The objectives of these guidelines for the preparation and reporting of national inventories of greenhouse gas emissions by sources and removals by sinks for the purposes of the United Nations Framework Convention on Climate Change (UNFCCC) by Parties included in Annex I to the Convention (Annex I Parties), referred to below as the UNFCCC reporting guidelines on inventories, are:
>
> (a) To assist Annex I Parties in meeting their commitments under Articles 4 and 12 of the Convention and in preparing to meet possible future commitments under Articles 3, 5 and 7 of the Kyoto Protocol;
>
> (b) To facilitate the process of considering annual national inventories and national inventories included in national communications, including the preparation of technical analysis and synthesis documentation; and
>
> (c) To facilitate the process of verification and technical assessment and expert review of the inventory information.

From this it is proposed to structure the discussion along the lines of the draft reporting format for the sector "Industry" as reproduced in annex 1 to this discussion paper.

Annex 2 reproduces the tables for the sector "Industry" from the second National Communication from the Netherlands as drawn from the UNFCCC web site. These tables represent the present reporting on emissions to UNFCCC. The report of course contains lots of additional data, information and knowledge.

The "National System" for GHG reporting in the Netherlands should result in the full CRF tables. In its simplest version therefore, the problem for this discussion could be formulated as:

1. What information is needed to develop reporting emissions (from the sector "Industry") as in the Second National Communication towards the CRF and how could this information be obtained?

> **Box 2** FCCC/SB/1999/1/Add.1
> Page 10
>
> 1. All Parties should report their inventory information using the tables of the common reporting format. This information should include activity data and emission factors, in the specified units, as well as other numerical and textual information.
> 2. Parties should not change the order or notation of the table cells, as this will work against the purposes of the common reporting format by complicating the handling of the data by the secretariat. If additions to the existing category split of sources and sinks are necessary, these should be made using the empty rows (or columns) provided for this purpose. If it is absolutely necessary to make changes to the order or notation of the tables, this should be indicated by changing the colour of the font to red for the changed cells.

Box 2 reproduces some directives for completing the CRF tables. These are the easy to apply. It simply means that, where in the tables in the National Communication lines and columns have been deleted or rearranged, this should no longer be done. Instead either

- **a zero if the emissions are negligible,**
- **NO (if not occurring),**
- **NE (if not estimated)**
- **NA (if not applicable)**
- **IE (if included elsewhere) or**
- **C (if confidential)**

should be entered.
UNFCCC foresees parties to deliver the data in electronic formats (MS Excel ?), rather than as hard copies.

2. Data on "Industry"

The data on emissions from the sector "Industry" to be included into the national inventory and the national communications are collected in the framework of the Dutch emission Inventory (in Dutch: "Emissieregistratie"). Part of the data on individual companies in this inventory originates from environmental reports produced by these companies themselves in response to obligations formulated in the Law on Environmental Reporting (in Dutch: "Wet Milieuverslag").
The resulting inventory contains data on emissions only, without direct information on activity rates and fuel used. In preparing the first and second national communications this information is added where available, resulting in the detailed tables as published in the second national communication (see annex).
Comparison between the tables as reported by the Netherlands and those required in the CRF, shows that the main additions to the type of information needed concerns the production, use and emissions of the high GWP (or "new") gases: HFCs (7 specific compounds plus one rest group), PFCs (4 specific compounds plus one rest group) and SF_6. Some space in the tables is available to specify "other". In addition for the "old gases" (CO_2, CH_4, N_2O) the activity data and the aggregate emission factors for industrial sectors are requested in somewhat higher detail.
The issue to be discussed here then is:

Is all information on industrial GHG emissions, needed for reporting to UNFCCC, obtained within the national emission inventory procedure of the "Emissieregistratie"?

If not: Should it?

If so: what need to be changed in inventory procedures and monitoring protocols

If not: How to organise the data flow?

3. Data quality and uncertainties

In the above, we concentrated on requirements, obligations and procedures. Within the UNFCCC however, the data quality and uncertainties are more and more important. In other words, parties are asked to be more and more explicit on the quality of the data delivered to the UNFCCC secretariat.

SBSTA has asked IPCC to produce a report on "good practice" and on managing uncertainties in GHG inventories in relation to the reduction targets set in the Kyoto protocol. It is expected that this activity will lead to the establishment of a reporting format on uncertainties and data quality.

Obviously data quality first has to be known, before it can be improved. At present data quality is already asked for in the IPCC reporting guidelines (summary table 8, as reproduced for NL 1990 below in Table 1). In this table countries have to report data quality in a three level qualitative way ("high", "medium", "low"). It is expected that on the basis of the ongoing work in the IPCC working group on management of uncertainties, the reporting requirements will be further elaborated.
As shown in Table 1, the Dutch 2nd National communication reported data quality for

Table 1 Overview table of greenhouse gases in the Netherlands in 1990 (Gg/year full molecular weight,
including temperature correction for CO2)
(quality and documentation for 1994 and 1995 is the same as for 1990) [IPCC Table 8A];
(H: high; M: medium; L: low) from: 2nd National Communication

Greenhouse gas emissions (Gg a-1)	CO2		CH4		N2O		NOx		CO		NMVOC		SO2		Docur
Source categories	Estimate	Q.	Estimate	Q.	Estimate	Q.	Estimate	Q.	Estimate	Q.	Estimate	Q.	Estimate	Q.	
Total nett national emissions	173950	H	1103.8	M	51.2	L	573.9	M	1071.8	M	444.3	M	202.5	H	
1. All energy (combustion and fugitive)	171200	H	211.7	M	5.5	L	556.6	M	951.6	M	242.6	M	174.5	H	
1A. Fuel combustion total	171200	H	33.2	M	5.5	L	556.6	M	951.6	M	207.5	M	174.5	H	
1A1. Energy & Transform. Industries **	51600	H	0.3	M	0.5	L	99.9	M	17.1	M	IE		118	H	
1'A2. Industry (only energy) **	34100	H	2.7	M	0.1	L	63.2	M	131.4	M	IE		25	H	
1A2f. Actual from feedstocks	14800	M	NE	M	NE		NE		NE		NE		NE		
1A3. Transport	26800	H	7.2	M	4.9	M	350.9	M	706.4	M	196.9	M	26.5	H	
1A4. Small combustion	42800	H	19.3	M	0	L	40.5	M	11.9	M	1.2	M	4.8	H	
1A5. Other ***	1100	H	0	M	NA		NA		NA		3.5	M	NA		
1A6. Biomass burned for energy	(1600)*	L	3.7	L	0	L	2.1	L	84.7	L	5.9	L	0.2	L	
1B. Fugitive fuel emissions	NA		178.5	M	NA		NA		NA		35.1	M	NE		
1B1. Solid fuels	NA		NA		NA		NA		NA		NA		NA		
1B2. Oil and natural gas	NE		178.5	M	NA		NA		NA		35.1	M	NE		
2. Industrial processes	1850	H	5.8		18.6	L	12.7	M	116.1		101.5	M	25	H	
3. Solvents and other product use	NE		NE		0.5		IE		2		100.1	M	NA		
4. Agriculture	0		504.9	M	22.2	L	NA		NA		NA		NA		
4A. Enteric fermentation	0		401.9	M	NA		NA		NA		NA		NA		
4B. Animal wastes	0		103	L	IE	NA		NA		NA		NA		H	
4C. Rice cultivation	NA		NA		NA		NO	NO	NO	NO	H				
4D. Agricultural soils	0		0	L	22.2	L	NA		NA		NA		NA		
4E. Savanna burning	NA		NA		NA		NA		NA		NA		NA		
4F. Agricultural waste burning	0		NE		NE		NE		NE		NE		NE		
5. Land-use change and forestry	(-1500)*	M	NE	M	NE	L	NE	M	NE	M	NE		NE		
6. Waste	900	M	379.4	M	0.6	L	4.6	M	2.2	M	0.1	M	3	M	
6A. Landfills (solid waste disposal)	NE		376.4	M	NE		NA		NA		0.1	M	NA		
6B. Wastewater (sewage) treatment	NE		3	M	0.5	L	IE	M	IE	M	IE	IE	M	H	
6C. Waste incineration	900	M	0	M	0.1	L	4.6	M	2.2	M	0	M	3	M	
7. Other sources (specified)	IE		2	M	3.8	L	NA		NA		NA		NA		
A. Drinking-water treatment	IE		2	M	NE		NA		NA		NA		NA		
B. Polluted surface waters	NA		NE		3.8	L	NA		NA		NA		NA		
International bunkers	40400	H													
Nature *	..		125	L	1.5	L	16.3	L	26.7	L	3.7	L	..		

the 1990 inventory in the three level qualitative system as required by the reporting format for the "original" greenhouse gases and the ozone precursors. In addition some uncertainty estimates for the "high GWP" gases is given. No similar table for later inventories has been included. The uncertainties for 1994 and 1995 are stated to be the same.
From Table 1 it can be seen that for the sector "Industry" only very little information on the uncertainties and data quality has been reported. It might be expected that more information in this respect will be requested, once the IPCC working group has finalised its work and SBSTA and COP agreed on reporting requirements for uncertainties.

Issues to be discussed in the breakout group Industry might be the following:

1. How could data quality for industrial GHG emissions be better characterised and reported?

(level of detail; activity rates, emission factors; qualitative or quantitative approach)

2. What quality is needed for industrial GHG emissions data?
3. How could the data quality for industrial GHG emissions be improved?

4. Other usage

Apart from the reporting requirements to UNFCCC, GHG emission data are also needed for national policy use. These data need to be of sufficient quality to enable prioritisation within the national environmental policy and decision making and to convince relevant target sectors of abatement measures to be taken.

The following issues should be discussed in this respect:

1. Does national use of emission data ask for a different quality compared to UNFCCC use?
2. If so, how to get this information?

Session 2: Industry - Conclusions

Hans van der Steen (NOVEM) and Dick Heslinga (TNO-MEP)

Process emissions, excl. feedstock CO_2 emissions from energy carriers

Participants of this discussion group present:
- Julia Williams (VROM/DGM/LE)
- Hans Holtring (VROM/DGM/LE)
- Bart Wesselink (RIVM/LAE)
- Joop van Haasteren (VROM/DGM/ICB)
- Kees Peek (RIVM/LAE)
- Emile Schols (RIVM/LAE)
- Bas Guis (CBS)
- Reinoud van der Auweraert (Tebodin)
- Jan Jonker (TNO-MEP)
- Elly de Jeu (EZ/I&D)
- Margreet van Brummelen (Ecofys)
- Rene Wismeijer (Novem)
- Meindert Timmer (VROM/DGM/ICB)
- Dick Heslinga (TNO-MEP) (reporter, oral)
- Hans van der Steen (Novem) (reporter, written)
- Tinus Pulles (TNO-MEP) (Chair)

The discussion followed the guidelines below:

1. Quality of the documentation
- Methodology, activities, emission factors/ uncertainty estimates
- Use of the Revised *IPCC Guidelines,* completeness of sources

2. Magnitude of uncertainty factors
- Quantitative estimates
- Essential supplemental remarks

3. Identification of important sources of uncertainty
- Order of priority and technical causes (per target group)
- Relationship to reduction policy

4. Technical possibilities to reduce uncertainties
- What is fast and relatively cheap?
- What is more difficult but important?

5. Setting up a ‘Plan of action’
- Who?
- What?
- When?
- Effectiveness?
- Order of priority for actions

The discussion was carried out partly with the help of several pages from *Common Reporting Format for providing inventory data to the UNFCC by Annex 1 Parties*, particularly the tables showing industrial processes.

Two preliminary remarks:

- It was a pity that the authorities (Inter Provincial Coordination (IPO), the Vereniging Nederlandse Gemeenten (VNG), Organisation of municipalities in the Netherlands were not represented.
- How were we to tackle emissions from products (cooling systems, spray containers, etc.), since these do not represent process emissions. The inconsistencies appearing in the *Common Reporting Format* on pages 10 and 11 were cited; although page 10 does indeed deal with industrial production processes, page 11 deals with emission estimates from the production, use and scrap phases.

1. Quality of the documentation

- **Methodology, activities, emission factors/ uncertainty estimates**
- **Using the Revised *IPCC Guidelines,* completeness of sources**

In the discussion, limited in this context to process emissions, considering that combustion emissions are dealt with by the 'target group' on energy, the following remarks were made under the above headings:

- ➢ The PFC emissions in the aluminium industry are well known and can be given with a margin of error of 5%; this is also true for HFC emissions in HCFC production by the only Dutch manufacturer, Du Pont (Dordrecht);
- ➢ The reliability of emission data is generally unknown;
- ➢ One of the problems is that data obtained through Statistics Netherlands (CBS) is public; because the Netherlands is a small country, production or, for that matter, emission data are easily traced to individual companies;
- ➢ If the Netherlands, in conformance with international agreements takes on the obligation to report according to the *Common Reporting Format*, the question is whether individual companies are willing to cooperate in the case of sensitive emissions from a competitive angle, How can such a situation be solved? Is legislation necessary here? Despite some companies being more open on this matter, production figures are usually not given in environmental reports. Similar problems now occur because certain energy data are lacking in environmental reports or because there are gaps in the monitoring estimates;
- ➢ The quality of environmental reporting is decreasing.

Conclusion: some of the tables in the *Common Reporting Format* cannot be filled in because of the problems of reliability and definition. There is no provision in the Netherlands to deliver background data for emission estimates with a required limited uncertainty. The Environmental Report legislation only asks for emission estimates, not how the estimate is arrived at.

2. Magnitude of uncertainty factors

- **Quantitative estimates**
- **Essential supplemental remarks**

The following remarks were made here:

- There is a difference between combustion and process emissions: the last group is generally characterised by a larger uncertainty margin.
- There is a large difference between point and diffuse emissions.
- It is uncertain if there are already enough sources about which little or nothing is known (unknown sources);
- A start will have to be made with quantifying emissions according to magnitude; working from this situation will allow a more accurate estimate. Magnitude estimates are available (RIVM fact sheets, expert judgements).

3. Identification of important sources of uncertainty

- **Order of priority and technical causes (per target group)**
- **Relationship to reduction policy**

The following remarks were made here:

- Source of uncertainty forms two reference years (1990 and 1995) for the various greenhouse gases. The *Kyoto Protocol* accommodates HFCs, PFCs and SF_6 for both base years.
- N_2O emissions formed during catalytic reduction forms an uncertainty;
- Ibidem for CO_2/CH_4 emissions from torches; it is not clear if these emissions are allocated to the target group of industrial emissions or not;
- One uncertainty is formed by the huge amount of (greenhouse) gases that are stored or used in all sorts of products; these are potential emissions. How should they be considered? Referring in part to the remark above about pages 10 and 11 of the *Common Reporting Format)* the question arises here if these are industrial emissions.

4. Technical possibilities to reduce uncertainties

- **What is fast and relatively cheap?**
- **What is more difficult but important?**

The following remarks were made here:

- Set 1990 and 1995 as reference years and then verify the emission data;
- The uncertainties in the CO_2/CH_4 emissions from (industrial) flares are at the moment being dealt with in an investigation by NOGEPA;

- Ibidem for the N_2O emission from SCR, which, for example, is monitored at the AVI incineration plant;
- It is important to gain insight into the relationship between NO_x and N_2O (this can have influence on the policy);
- The N_2O determination has been incorporated into the KEMA protocol by monitoring NO_x emissions in subsidised programme Reduction Emissions to Air from Companies, under the section: end of pipe techniques (Reductie Luchtemissies Bedrijven in Dutch);
- It may be important to gain more insight into international developments. Technical problems are the same everywhere.

5. Proposed plan of action

- **Who/what/when/effectiveness**

The following remarks were made in this context:

- *It was proposed to involve the provinces in the network of data collection and monitoring (the shorter routes) as well as the short routes to the FO industry [this is, in principle, already the case for emission registration and the new Annual Report Environment that companies have to deliver]*
- *Monitoring data used to be set down by a regular group of experts after consultation with the company and the authorities. Nowadays the company supplies the data, which are checked by the authorities (mostly the provinces); the loss of quality using this procedure compared to the earlier situation is remarked on; a substantial central facilitating role in data collection for the authorities is desirable. Only emissions are given not activity data or emission factors.*
- *The problem of confidentiality should be solved;*
- *A lot of research; a lot of monitoring ;*
- *Who decides which monitoring method is the right one? (CoP!)*

4.3. SESSION 3: TRANSPORT

Discussion paper

Transport and the monitoring of greenhouse gas emissions

Jan Anne Annema and Robert van den Brink
RIVM

Introduction

The goal of this paper is to stimulate discussion on the quality of current monitoring of greenhouse gas emissions from transport in the Netherlands and about ways to improve this quality. This paper will be discussed at the Workshop, 'Monitoring greenhouse gas emissions', to be held in Bilthoven on 1 September 1999. The aim of this workshop is to implement the Kyoto Protocol, which is part of the United Nations Framework Convention on Climate Change (UNFCCC). The authors of this paper will present an explicit outline expressing their own views on the matter to get the discussion going.

Here the authors suggest five ways to improve the quality of the monitoring (from high to low priority). Important questions during the workshop will be the following: 'Are the estimated uncertainty ranges correct?' 'Are the research recommendations complete?', 'Is more or other research required?', 'Is the prioritisation proposed for the research correct?', 'How long will it take before the research proposed will result in improvements?' and 'how will these improvements affect the current uncertainty ranges?'

Complete overview

Yearly overviews for greenhouse gas emissions from transport in the Netherlands can be made for the 1980 to 1998 period (CBS, emmob-files). The 1997 emissions are listed in Table 1. Total emissions in 1997 amount to approximately 36600 x 10^6 kg CO_2 equivalents (method: IPCC guidelines). Road transport is by far the most important contributor, with a share of 90% in the total emissions; CO_2 is the dominating greenhouse gas, with a share of 93% in the total emissions, while N_2O has a share of 6%. The CH_4 and HFC emissions are of minor importance. The international emissions are included (Table 2) because of bunkered fuels on Dutch territory. These (bunker) emissions are excluded from the national totals (Table 1) in accordance with the IPCC format.

View 1: *The current monitoring of greenhouse gas emissions from transport results in a detailed and complete emission overview. Focus on road transport and the CO_2 and N_2O emissions is advisable for improving monitoring methods.*

Table 1: Greenhouse gas emissions from transport in 1997 (in 10^6 kg CO_2 equivalents[a])

(10^6 kg CO_2-eq.)	**CO_2 According to IPCC Guidelines**	**CO_2 According to Dutch territory method**	**N_2O According to IPCC Guidelines**	**N_2O According to Dutch territory method**	**CH_4 According to IPCC Guidelines**	**CH_4 According to Dutch territory method**	**HFCs**
Cars		17637		1150		73	93
Vans		3254		89		5	
Lorries		5786		430		7	
Buses		542		51		1	
Special vehicles		286		20		0	
Motor-bikes		227		1		8	
Mopeds		63		0		7	
Road transport	*30814*	*27794*	*1920*	*1741*	*103*	*100*	*93*
Rail transport	100	100	7	7	0	0	
Inland shipping	847	1959	58	134	1	2	
Aquatic sports	0	108	0	10	0	2	
Sea shipping	0	1102	0	75	0	1	
Air transport	359	715	6	15	1	1	
Mobile off-road vehicles	2270	2270	155	155	6	6	
Other transport		*6257*	*227*	*395*			
National total	**34348**	**34049**	**2150**	**2136**	**111**	**112**	**93**

[a] GWPs used N_2O: 310; CH_4: 21; HFC-134a: 1300 kg CO_2-eq./kg
Source: CBS, RIVM, TNO

Table 2: International emissions due to bunkered fuels on Dutch territory in 1997 (in 10^6 kg CO_2 equivalents[a])

(10^6 kg CO_2-eq.)	**CO_2 According to IPCC Guidelines**	**CO_2 According to Dutch territory method**	**N_2O According to IPCC Guidelines**	**N_2O According to Dutch territory method**	**CH_4 According to IPCC Guidelines**	**CH_4 According to Dutch territory method**	**HFCs**
Marine bunkers	39400						
Air bunkers	9000						
Total	**48400**						

Source: CBS, RIVM, TNO

Methods

Two methods are used to estimate CO_2 emissions from transport in the Netherlands:

a) one based on fuels sold according to IPCC guidelines, and

b) b) one based on fuel used on Dutch territory.

The method for estimating HFC emissions will be treated separately below.

a) According to IPCC guidelines
The method is based on CBS[3] data: fuels sold for road and rail transport, inland and sea-going ships, air transport and mobile off-road vehicles. In the statistics fuels are distinguished into petrol, diesel oil, Liquefied Petroleum Gas (LPG), light and heavy oil fuels, and jet fuels. Based on IPCC default emission factors (in kg/GJ), the different fuel sales are converted to CO_2 emissions. All international shipping and aircraft emissions according to bunker fuel sales in the Netherlands are excluded from the 'national total' (Table 1), but are presented separately in Table 2. Following IPCC guidelines, the presented CO_2 emissions for inland shipping and aircraft in Table 1 are only related to trips within the Netherlands (inland shipping) and to domestic flights (aircraft). Since 1988 inland skippers no longer have to pay an excise duty on (diesel) oil bought for inland trips. Since then it has become more difficult to make a distinction between domestic and international inland shipping, so that the CO_2 emission figure for domestic inland shipping is unreliable. The figure for rail transport includes only diesel sale emissions; emissions due to electricity use are not reported as transport emissions but are classified under electricity production emissions.

The calculation of the N_2O and CH_4 emissions differs from the CO_2 calculation. The fuel sales are converted to N_2O and CH_4 emissions using emission factors derived from the 'Dutch territory method' (see below). The reason is that the emission factors for these substances (in kg/GJ) are related to vehicle technology and fuel type, in contrast to CO_2, which is only related to fuel type. Therefore the total fuel sale to road transport is divided over vehicle categories (based on their share in energy use determined in the 'Dutch territory method'). Consequently, the resulting fuel sales per vehicle category (in GJ) are multiplied by emission factors per vehicle category (in kg/GJ). These emission factors are based on limited measurements and literature studies. Their quality is relatively poor.

View 2: *The transport fuel sales statistics in the Netherlands is of a sufficient quality as to provide a reliable overview of the CO_2 emission trend. The quality of the sales data for off-road mobile vehicles, rail transport and inland shipping is relatively poor. It is recommended to start research aimed at improving the sales data for these categories. Based on view 1, the priority for this type of research is low. Emission factors of N_2O and CH_4 are of poor quality. See view 3 for a description of research to improve these factors.*

b) According to 'Dutch territory' method
The 'national total' of CO_2 emissions calculated according to IPCC guidelines is reliable but has one main disadvantage: a breakdown in CO_2 emission per road vehicle category is not possible. This breakdown is required for policy evaluation because most policy measures and instruments focus on one specific vehicle category. Furthermore, as mentioned above, to calculate the emissions of substances related to vehicle technology (N_2O, CH_4 but also NO_x, NMVOC, CO etc.), insight into transport volumes per road vehicle category is required. The emission calculation method 'according to Dutch territory' is based on calculating emissions per specific vehicle category. In general, the method combines volume data (vehicle kilometres on Dutch territory) with specific emission factors (in g/km) and energy use factors (in MJ/km). The 'real' causes of emission from road transport are identified in this method :

- For cars and commercial vehicles, the emission factors, N_2O, CH_4 and other substances that are technology related, are desaggregated into road classes (built-up areas, country roads and motorways), year of construction of vehicle, the extent of penetration of 'clean' technology according to construction year of vehicle (e.g. three-way-catalysts) and kind of fuel used. Desaggregation to road classes is required because trip characteristics on these roads like cold start, speed and driving behaviour affect the emission factors. The 'detailed' emission factors for CH_4 and N_2O are roughly estimated on the basis of limited

[3] Statistics Netherlands

measurements[4] (CH_4), the literature (N_2O) and on model calculations[5]. The emission factors for CO_2 are derived from inquiries: every year a random sample of car owners (CBS, PersonenAutoPanel) and every four years a random sample of commercial vehicle owners (CBS, BedrijfsVoertuigen Enquête) are asked what their specific energy use is (in l/km). These specific energy use data can be easily converted to CO_2 emission factors (see above), which are also desaggregated to road classes[6] using model calculations.
- CBS collects volume data using a combination of inquiries, traffic-counting data and extrapolation techniques. The macro figures - total vehicle kilometres on Dutch territory - are desaggregated by CBS to the three different road classes (vehicle kilometres in built-up areas, on country roads and on motorways), to vehicle age, fuel type, etc. in order to combine these detailed volume data with the detailed emission factors.

It would take too long to explain the emission calculation method for road transport in detail. The most important aspect is that the required desaggregation steps will result in loss of quality (see 'uncertainty' below).

For non-road transport, the 'Dutch territory method' also differs from the method 'according to IPCC'. However, the main differences have to do with the assignment of transport activities to Dutch territory, which is of minor importance here for the discussion.

View 3: *The method 'according to Dutch territory' is required to evaluate policy and estimate N_2O and CH_4 emissions. Several major improvements in this method can be identified.*
- *In June a discussion was launched on improving the inquiries (PAP), resulting in specific energy use (in l/km) for cars and commercial vehicles. It is important to continue this discussion (what is possible?, at what price?, who are the actors?) . Furthermore, research is recommended in which the figures from the inquiries are compared with model results, CO_2 measurements in test cycles and CO_2 measurements during 'real' trips on roads (current TNO-WT research). The aim of this discussion and research is to improve the CO_2 emission factors for road transport. In view of the importance of the CO_2 emission from road transport in the national total, the priority for carrying out this type of research will be high.*
- *The N_2O and CH_4 emission factors could be improved by carrying out measurements. CH_4 is of minor importance to totals, so research in improving the emission factors for these substances has less priority. N_2O is of more interest. The Ministry of Housing, Spatial Planning and the Environment will start a measurement programme for N_2O emissions from road transport to be carried out in 1999/2000. It is recommended to wait and see if it results in useful and relatively reliable data for national emission statistics and whether a follow-up study is required.*

c) HFCs

The HFC emissions in transport are related to the use of air conditioners in cars. These emissions are estimated using the method described in Matthijsen and Kroeze (1996): the emissions in year (t) are $0.33 * stock_t + 1.0 *$ use for new $aircos_{t-15}$.

$stock_t$:	total HFC stock in cars in year t
use for new $aircos_{t-15}$:	the total amount of HFCs used to fill car airconditioners in year t-15

4 TNO-WT: Steekproefcontroleprogramma's personenauto's en vrachtauto's. Delft: TNO-WT.

5 TNO-WT: VERSIT

6 This disaggregation is not required to evaluate Dutch policy goals, which state that the level of CO_2 emissions from road transport in 2010 must be 90% compared to the level in 1986. However, disaggregation helps policy evaluation, for example, in estimating specific effects of mobility measures in built-up areas.

View 4: *HFC emissions in transport are of minor importance with reference to the total greenhouse gas emissions from transport. However, the use of car air conditioners is growing. Therefore it is recommended to start research to evaluate the current estimation method, where it will be important (probably even more important than for HFC emissions) to include the consequences of the current and future airco use on car energy use and, subsequently, on CO_2 emissions.*

Uncertainty
RIVM has made a rough estimate of the uncertainty of the greenhouse gas emissions (Table 3).

Table 3: Rough estimate of uncertainty in CO_2, N_2O, CH_4 and HFC emission data

	'IPCC'	'Dutch territory'
CO_2		
total transport	±5% (±1700 x 10^6 kg CO_2-eq.)	±10% (±3400 x 10^6 kg CO_2-eq.)
N_2O		
total transport	± 50% (±1000 x 10^6 kg CO_2-eq.)	± 50% (±1000 x 10^6 kg CO_2-eq.)
CH_4		
total transport	± 50% (±50 x 10^6 kg CO_2-eq.)	± 50% (±50 x 10^6 kg CO_2-eq.)
HFCs		
total transport	± 75% (±70 x 10^6 kg CO_2-eq.)	± 75% (±70 x 10^6 kg CO_2-eq.)

Source: RIVM

These uncertainty estimates have to be considered as 'expert judgements'; there is no statistical analysis to underscore the results. The results show indicatively that to lower the uncertainty in total transport greenhouse gas emission data, one should focus on improving CO_2 (especially in the 'Dutch territory' method) and N_2O emission monitoring. The difference in the uncertainty ranges between 'IPCC' and 'Dutch territory' for CO_2 results from the 'IPCC method' using total fuel sales as input and 'Dutch territory' detailed emission factors and transport volumes (see above). Total sales figures from the fuel trade in the Netherlands are relatively reliable. 'The Dutch territory method' requires fairly detailed information (see above). In determining these detailed figures, a requirement is adaptation of inquiry and measurement results, which will result in some loss of quality.

View 5: *It is probably not very cost-effective to improve fuel sales data determining the CO_2 emissions according to IPCC. The uncertainty range in results using the IPCC method is considered to be relatively low (±5%). However, this point of view is open to debate! Other research possibilities, arranged below (from high to low priority) , are probably more cost-effective:*

1. *research to improve energy use figures in the CBS inquiries and to compare these data with model results, CO_2 measurements in test cycles and CO_2 measurements during 'real' trips on roads (current TNO-WT research);*
2. *carrying out measurements to improve N_2O emission factors;*
3. *research on the use, emissions and consequences of car air-conditioning;*
4. *research to improve the fuel sales data for off-road mobile vehicles, rail transport and inland shipping;*
5. *research to evaluate the possibilities of improving CH_4 emission factors.*

Difference between the 'IPCC method' and the 'Dutch territory method'

To comply with the Convention on Climate Change only the emission monitoring method according to IPCC is acceptable. One could argue therefore that to avoid confusion it would be better not to use a second monitoring method in the Netherlands either. However, the 'Dutch territory method' is useful and required for three reasons: a) only the 'Dutch territory method' will result in CO_2 emissions per road transport category, which is indispensable for Dutch policy evaluation; b) the CO_2 per cent emission share per road transport category determined by the 'Dutch territory method' is required to divide the total CO_2 emission of road transport calculated with the 'IPCC method' among the different road categories and c) the two independent CO_2 emission estimation methods for road transport in the Netherlands, which can be used to evaluate the plausibility of the CO_2 emission estimate.

The difference between the CO_2 emissions calculated with 'IPCC' and 'Dutch territory' method for road transport is 10% for 1997 (see Table 1). This percentage varies per year. In the period 1980-1997 the difference ranged from 1% to 10% (Van den Brink and Annema, 1999). Since the difference is relatively small, both monitoring methods seem fairly reliable. Although the proposed research items in view 5 will probably diminish the difference between the methods, some differences will be unavoidable (CBS, 1996). i.e.:

- stocking of supplies is only included in fuel sales;
- military vehicles and cars from diplomats are not included in the 'Dutch territory' method;
- differences are introduced because some motorists tank petrol and diesel on the other side of the border.

View 6: *The use of two monitoring methods in the Netherlands is sometimes confusing but unavoidable. It is recommended to continue monitoring using two methods.*

References (in Dutch)

CBS (1996), *Maandstatistiek verkeer en vervoer, september 1996*, Heerlen/Voorburg: Central Bureau for Statistics.

Matthijsen, A.C.J.M and C. Kroeze (1996), *Emissies van HFK's, PFK's, FIK's and SF_6 in Nederland in 1990, 1994, 2000, 2010 and 2020*. Bilthoven: RIVM. Report 773001008.

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Session 3: Transport - Conclusions

Jan Anne Annema (RIVM)

Present: Hans Nieuwenhuis (VROM), Floortje Hanneman (AVV), Alex Vermeulen (ECN), Ed van Gelder (CBS), Peter Janssen (RIVM), John Klein (CBS), Jan Hulskotte (TNO), Jan Anne Annema (RIVM)

1. Quality of documentation

1a. Methodology and uncertainty analysis

Two methods are used to estimate CO_2 emissions from transport in the Netherlands: a) one based on fuels sold according to IPCC guidelines and b) one based on fuel used on Dutch territory. The methods are roughly described in several papers, see for example the discussion paper of Annema en Van den Brink (1999), and, in more detail, in a draft methodology report (in Dutch). The meeting recommends in giving high priority to finishing this draft report, so that the methodologies can be reviewed scientifically. It is also noted that the description of the methodology should be as detailed as possible: not only the way of determining emission factors should be discussed but it is also important to be very clear about the way of estimating activity levels.

By doing so, the methodology report could form a sound basis for statistical analysis of uncertainties. Right now the uncertainty estimates of greenhouse gas emissions (Annema and Van den Brink, 1999) have to be considered as 'expert judgements': there is no statistical analysis to underscore the results. It is recommended to carry out such a statistical analysis. This analysis should not only lead to an uncertainty estimate of the aggregated CO_2-equivalent emission of total transport in The Netherlands, but also to uncertainty estimates of the emissions of the different vehicle categories and greenhouse gases. As a result of which this analysis can be used to prioritise research to improve the monitoring methodology.

The meeting stresses that in estimating uncertainty ranges bunker emissions should be included. In the current method the division between national and international inland shipping emissions is especially highly uncertain. It is also recommended to study the current definitions of national and international sea shipping and aircraft emissions in the Dutch monitoring system. It is possible that the current used definitions differ somewhat from the IPCC format.

1b Application of *Revised IPCC guidelines* and completeness of emission sources

The emissions are estimated according to IPCC guidelines. N_2O and CH_4 emissions of bunkers are not estimated. However it appeared in the central meeting that IPCC has developed default emission factors for these substances.

The meeting concludes that, except for N_2O and CH_4 emissions of bunkers, the emission overview seems complete.

2. Uncertainty estimates

In the discussion paper (Annema and Van den Brink, 1999) the authors suggest some uncertainty ranges. The meeting judges:

- that it is required to underscore the estimates for CO_2 with statistical analysis. There is considerable doubt that the presented figures, based on expert judgement, are correct. On the other hand there is also some doubt if a sound statistical analysis can be carried out at all. However, it is concluded that it is worth the effort to try.
- that the presented N_2O uncertainty estimates (±50%) are probably too low. Measurements of N_2O emissions of vehicles are currently carried out.
- that HFC emissions as a result of air conditioners in cars are highly uncertain.

3. Identification of important causes of uncertainty

Partly based on the discussion paper, the meeting identifies six important causes of uncertainty (from important to less important):

1 ‘Dutch territory’: the quality of passenger car kilometre data and car energy use data (MJ/km) is decreasing because of poor insight in the lease and business car market. The share of lease cars in the fleet is increasing.

2 ‘Dutch territory’: the quality of van and lorry kilometre data and energy use data is decreasing because responses to surveys are poor.

3 ‘IPCC’: fuel sales data for off-road vehicles, rail and inland shipping are rather poor

4 N_2O: emission factors are highly uncertain

5 HFCs: use and emissions are highly uncertain

6 CH_4: emission factors are highly uncertain

Points 1 and 2 are worrying because emission reduction policy is aimed at different vehicle categories. Only ‘Dutch territory’ method results in CO_2 emission monitoring data per road transport category. So, when the quality of these monitoring data decreases, policy evaluation will become more difficult. Point 3 is for policy evaluation of less importance because no policy right now is aimed at reducing CO_2 emissions of these transport categories. However, the share of these transport categories in the total CO_2 emission is 10%, so they are not negligibly. Therefore, the meeting recommends some research in these transport categories.
N_2O is probably the most important non-CO_2 greenhouse gas in transport. So it is concluded that it is worth the effort to carrying out research to improve the N_2O emission factors. The other two gases, HFCs and CH_4, are of less importance.

4. Technical possibilities to improve quality

Two questions have to be answered in this section: a) what are the possibilities to improve the quality easily and quickly, b) what is more difficult but, nevertheless, important to solve?
The uncertainties in the transport activity data, energy use data and fuel sales data (point 1, 2 and 3) in the previous section are difficult to improve. However, the National Bureau of Statistics is aware of the decreasing quality of the data and the Bureau has already started research and discussion with other institutes to improve the quality of the data.
The Ministry of Housing, Spatial Planning and the Environment will start a measurement programme for N_2O emissions from road transport to be carried out in 1999/2000. So, perhaps, based on these measurements it will become easily to improve the N_2O emission factors in the future.
The meeting mentions some sources of information which could lead possibly easily to improvement of the HFC emission estimates.

5. Proposal to improve the quality of greenhouse gas monitoring in the sector of transport

The meeting proposes the following plan to improve the quality of greenhouse gas emission monitoring:

What	Who	when
1. finishing a detailed methodology report. Comparing used definitions of national and international emissions with IPCC format (inland shipping, sea shipping, aircraft)	Taakgroep[a)] Verkeer	1999/beginning 2000
2. estimating uncertainty based on statistical methods	RIVM, in co-operation with Taakgroep and AVV	end of 2000
3.research and discussion to improve CBS data: activity data, energy use data, fuel sales (PAP/OVG/ NEH, etc.): passenger cars, vans, lorries, bunkers (especially inland shipping), off-road transport	CBS, in co-operation with Taakgroep and VROM	1999 ongoing
4. improving energy use data per kilometre for road transport using measurements of TNO-WT	Taakgroep	1999- mid 2000
5. estimating N_2O and CH_4 emissions of bunkers	Taakgroep	1999 – mid 2000
6. carrying out N_2O measurements	VROM	end of 2000
7. HFC emission desk research	Taakgroep	1999 – mid 2000

[a)] CBS, TNO-MEP, TNO-WT, RIVM and RIZA

4.4. SESSION 4: AGRICULTURE

Discussion paper

Monitoring Greenhouse Gas Emissions From Agriculture; Identification Of Uncertainties

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1. INTRODUCTION

Annex 1 countries of the Kyoto Protocol have agreed to report their total annual emission of greenhouse gases into the atmosphere to the United Nations Framework Convention on Climate Change (UNFCCC) on an annual basis. As a consequence, countries have to set up a monitoring programme. Monitoring will allow evaluation of the progress in emission reduction as agreed in the reduction targets of the Kyoto protocol. Evidently, the monitoring system needs to be complete and consistent, accurate and precise, transparent and verifiable.

Current estimates of greenhouse gas emissions indicate that the uncertainties in the estimates on a country basis are as high or higher than the emission reduction targets set in the Kyoto Protocol. Uncertainties are especially large for greenhouse gas emissions from agricultural sources. This is due to the fact that these sources are diffusely spread over the countryside and, furthermore, controlled by many interacting factors.

The Ministry of Environment (VROM), in co-operation with National Institute of Public Health and the Environment (RIVM) en Wageningen Institute for Environment and Climate Research (WIMEK), has organised the workshop “Monitoring of greenhouse gases” on September 1, 1999. The aim of the workshop is:

(i) to assess the uncertainty of major sources of greenhouses gases
(ii) to identify ways to minimise these uncertainties and
(iii) to indicate how, when and by whom the monitoring system will be improved.

This discussion paper has been prepared to stimulate discussion at the aforementioned workshop on “monitoring of greenhouse gas emissions from agricultural sources”. Suggestions are provided for decreasing the uncertainties in estimates of emissions of CO_2, CH_4 and N_2O from agriculture. Useful additional information can be found in “Background notes for the Workshop”, which have been prepared by André van Amstel et al.

2. OVERVIEW OF MAJOR AGRICULTURAL SOURCES IN THE NETHERLANDS

Fuel combustion for the heating of greenhouse gases was the single largest source of greenhouse gas emissions from agriculture in 1995, when expressed in Mton CO_2-equivalents (Tg CO_2). Second was the emission of N_2O from agricultural sources and third the emission of CH_4 from ruminants (Table 1).

Table 1. Overview of emissions from agricultural sources in 1995 (in Gg; in bold = Mton CO_2-eq.)

Source/Sink	CO_2	CH_4	in CO_2-eq.	N_2O	in CO_2-eq.
Sources					
Heating of greenhouses	**8.9**	3	**0**	0	
Ruminants	-	377	**7.9**	-	
Animal waste	-	99	**2.1**	1	**0.3**
Agricultural soils	-	NE	-	27	**8.4**
Agricultural waste burning	-	0		0	
Polluted surface water*	-	-		4	**1.2**
Sinks					
Woody biomass	**1.7**	-		-	

* Also including some indirect emissions from N deposition from non-agricultural sources.
Source: Jos Olivier, RIVM

2.1. Carbon dioxide

The carbon cycle in agriculture is dominated by the annual cycling of CO_2 between agricultural land and atmosphere. However, the net storage of CO_2 in agricultural products is a temporary sink, because nearly all of the fixed organic carbon is digested. In emission accounting, only the net emission is taken into consideration.

The net-emission of CO_2 from the agriculture is the result of a number of sources and sinks. The following sources of CO_2 in agriculture may be distinguished:
- heating of greenhouses
- energy combustion for transport and tractor power
- energy combustion for use of electricity
- net mineralisation of soils (peat after drainage, ploughing and management, drainage polder soils) in land-use
- biomass burning (crop residues)

So far, the source “energy combustion for transport and tractor power” has been attributed to “Target Group Transport”, but would have to be attributed to the item ‘Combustion, Agriculture’ according to the Revised 1996 Revised Guidelines. The item “energy combustion for use of electricity” is attributed to the sector Energy. The item biomass burning is negligible in the Netherlands. Indirect sources like the energy consumption during the production of fertilisers and machinery are not included here.

Major sinks of CO_2 in agriculture are:
- net increase in aboveground woody tissue in biomass production
- net increase in belowground (soil) organic matter.

The net increase in aboveground woody tissue in forests in NL has been estimated at 1500 Gg CO_2 per year.

It should be noted that no attention will be paid to sinks of CO_2 on the Workshop “Monitoring of greenhouse gases” on September 1, 1999

2.2. Methane

The estimated total 1995 emission of CH_4 from agriculture was 476 Gg CH_4. Major sources of CH4 in agriculture are (with a rough indication of the relative contribution):
- enteric fermentation in ruminants (about 80%)
- storage units of animal manure (about 20%)
- wetlands (about 2%)

Well-drained soils are a sink of CH_4, but this consumption is less than 1% of the total emission. Emissions are considered net-emissions.

2.3. Nitrous oxide

The estimated total 1995-emission of N_2O from agriculture was 17.6 Gg N_2O-N. The major source is the soil (>80%). Following the Revised 1996 IPCC Guidelines, agricultural sources are partitioned into (with a rough indication of the relative contribution):

- direct emissions from crop production systems, as the result of the input of nitrogen (N) into the system via fertiliser, animal manure, crop residues, compost, leguminous crops and the net mineralisation of farmed peat soils (about 40%),
- direct emissions from animal production systems, i.e. directly from manure storage basins and from soil following deposition of urine and dung from grazing animals (about 25%), and
- indirect sources, as the result of the leakage of N from agriculture via ammonia volatilisation and nitrate leaching to surrounding non-agricultural environments (about 35%).

Soil can potentially be a sink of N_2O as well, but this influx is small and included in the emission estimates. Hence, emissions are considered to be net-emissions.

3. OVERVIEW OF METHODS FOR ESTIMATING CO_2, CH_4 AND N_2O FROM AGRICULTURE

The Revised 1996 IPCC Guidelines provides methods for the calculation of CO_2, CH_4 and N_2O emissions from agriculture. These methods are rather simple and transparent, as follows from the brief overview presented below. So far, emission estimates for The Netherlands are based on (various approved modifications of) this methodology.

Basically, ***CO_2 emissions*** related to fossil fuel burning are estimated in a similar way as the emissions from the Industry and Transport sectors (see e.g. Annema & van den Brink, 1999) . CO_2 emissions due to changes in biomass and/or soil organic carbon are estimated from [(number of ha) x (net change in biomass, in kg per ha) x (C content of biomass, in kg per kg)]. Emissions due to burning of biomass in agriculture are calculated in a similar way, but this source is considered negligible in The Netherlands (it is 'not done').

Emissions of ***CH_4 from ruminants and stored dung*** are calculated from [total input of digestible carbon x emission factor]. The emission factor expresses the fraction of carbon that is released as CH4.The input of digestible carbon is estimated from number, type, size and production level of the animals and corrected for its digestibility using empirical conversion factors. CH4 from wetland is estimated from [area of wetland (in ha) x emission factor]. The emission factor expresses the amount (kg) of CH4 released per ha.

Emissions of ***N_2O from agricultural sources***, both direct and indirect, are calculated from [input of N from different sources into a system (soil, manure storage basin, surrounding environments, etc.) x emission factor]. The emission factor reflects the fraction of N that is lost in the form of N2O into the atmosphere.

The Revised 1996 IPCC Guidelines for Emission Inventory provide countries with flexibility in the application of the methodology. For example, countries may choose to apply a simple method, using Tier I, or a more advance method, using Tier 2, for the estimation of CH_4 emissions from ruminants and dung (depending on the available information). Default values for activity data and emission factors or, as is recommended by IPCC, own estimates may be used for some of the activity data and emission factors. However, countries do have to justify the methodology selected.

The methods for estimation of CH_4 and N_2O from agriculture have been discussed at a workshop in Wageningen, February 23-26, 1999. Useful guidelines for good practice in inventory preparation have been presented and useful suggestions have been proposed for improving the methods presented in the Revised 1996 IPCC Guidelines. Many of these suggestions are to be incorporated into the existing methods.

With time, the available information and insight will increase, and this may lead to a continuous refinement of methods and change the total estimate. Ideally, there has to be a standard methodology applied over the years and proper documentation dealing with the origin and accuracy of the data for verification and quality control purposes.

Thus far, the Netherlands has used IPCC-like methods. A range of estimates for the emissions of greenhouse gases from agricultural sources can now be found in research papers. These estimates may differ by a factor 2 due to slight differences in sources, activity data and emission factors. Clearly, the uncertainty in estimates of greenhouse gas emissions from agricultural sources is large. By now, the uncertainty range (see also Table 2) in estimates of emissions is much larger than the range of emission reduction targets as set in the Kyoto Protocol.

4. ORIGIN OF UNCERTAINTIES IN EMISSION ESTIMATES

Assessments of uncertainty require that all possible sources of uncertainty are evaluated in the complete chain from the very beginning of the measurement of primary data (activity data), the derivation of emission factors up to the compilation of emission estimates for the whole agricultural sector. Basically, uncertainties may arise from biases and errors. *Bias* is defined here as misrepresentation, leading to a systematic deviation of the estimated mean from the true (scientific) mean. We use '*Accuracy*' as a measure for bias; a high accuracy means that the deviation of the estimated mean from the true mean is small.
Error is random variation around the true mean, leading to a confidence interval around the estimated mean. We use '*precision*' as a measure for error; a high precision means that the variance of repeated determinations is small.

There are five possible sources of biases, which may lead to inaccuracies in emission estimates, i.e.

(i) personal biases, due to different and incomplete views presented in work on emission estimates
(ii) sampling biases, due to sampling of non-representative populations, sites, etc.
(iii) measurement biases, due to artefacts in analytical equipment or sampling procedures for the measurements,
(iv) data manipulation biases, due to artefacts in the averaging, generalisation, guestimation, upscaling, rounding off, etc. and
(v) fraud, which is consciously introducing biases.

Errors occur as a result of random variations, and show up as variance in repeated determinations. Two types of errors can be distinguished,

(i) sampling errors, originating from 'within-area' heterogeneity, and
(ii) measurement errors, originating from variations introduced during determinations.

Generally, biases are a more serious problem than errors. Biases defer from best emission estimates. Preventing biases requires in-depth analyses of sources and sinks of all the greenhouse gas emissions and of its controlling factors. It also requires testing of assumptions and proper data acquisition and handling. Errors show up as a confidence interval around the mean. Minimising error requires improved sampling and measurement strategies. The consequence of low precision estimates is that small changes in the annual emissions over time will be not statistically significant, unless the period considered involves a large number of years

5. HOW TO MINIMIZE UNCERTAINTIES

Table 2 provides provisional uncertainty ranges for the estimates of the major sources of CO_2, CH_4 and N_2O from agriculture. These estimates are more or less in line with the estimates given in the Revised 1996 IPCC Guidelines. The ranges form a basis for discussion, and may reflect both biases and errors. As noted before, the uncertainty range of most estimates is large, due to the facts that

(i) heterogeneity in the numerous sources in the countryside that contribute to the total emission,

(ii) a complex set of interacting factors controls the emission strength of these sources.

Table 2. Provisional ranges of uncertainty in estimates of emissions of CO_2, CH_4 and N_2O from agricultural sources. Uncertainty is expressed in percent of the mean estimate and can be considered as an approximation of the 95% confidence interval (± 2 times the standard deviation). Tentative data, based on a qualitative assessment (guestimates), using three classes: 0-10; 10-50 en 50-100%.

Sources of greenhouse gases	Mean estimate in Gg per y	Uncertainty range in %
Carbon dioxide		
• heating of greenhouses	8900	0-10
• transport, tractor power, electricity	?	0-10
• net mineralisation of peat soils	4200	50-100
• biomass burning	negligible	50-100
• aboveground woody tissue	1500	10-50
• belowground organic matter.	?	50-100
Methane		
• enteric fermentation in ruminants	380	10-50
• storage units of animal manure	95	10-50
• wetland	7	10-50
• upland	-0.5	50-100
Nitrous oxide		
• direct emissions from crop production		50-100
- fertiliser,		
- animal manure,		
- crop residues,		
- compost,		
- leguminous crops		
- net mineralisation of peat soils		
• direct emissions from animal production		50-100
- manure storage basins		
- grazing animals		
• indirect sources due to N losses via,		(>) 50-100
- ammonia volatilisation		
- nitrate leaching		

Prerequisite to minimise uncertainties is formal systems analyses, in which the following questions have to be addressed:

- are all possible sources included, including sources that have yet to appear and so may become important only with time?
- what are the driving and controlling factors and how do these factors interact, i.e. what are linear and non-linear relations with time?
- how are emission factors affected by the aforementioned interactions and controlling factors?
- what are the assumptions in the emissions estimates and are they tested?
- how accurate are the activity data and what are future trends?

Such an analysis should be carried out for all gases, and should be repeated once in a while to find out whether new sources have appeared and other have faded away. Identification and quantification of driving forces (including policies and measures) at various scales is notably important, as these driving forces trigger changes in the emission rate.

Current research activities may contribute to a further quantification of uncertainties, and to a decrease of the uncertainty range of the emission estimates. In The Netherlands, these research activities are carried out by universities and research institutes, and are funded by various agencies (e.g. EU, Ministries, NRP-MLK, IPCC, IGBP, etc. The research plan "Reductieplan Overige Broeikasgassen" (ROB) is meant especially for the introduction of easy-to-implement measures and technologies to decrease the emissions of CH_4 and N_2O from major sources in the Netherlands (industrial and agricultural sources). Further, IPCC/OECD are organizing workshops that specifically address "good practice in inventory preparation" and "diminishing uncertainties in emission estimates". These workshops have delivered a number of suggestions for decreasing uncertainty (more will come in future) and should be considered at this workshop.

6. STATEMENTS FOR DISCUSSION

1. Basically, the current IPCC inventory guidelines include all major sources of CO_2, CH_4 and N_2O from agriculture. Some minor sources should be included as well (e.g. clover grassland, transformation of grassland into arable land for the N2O budget), other sources may require more detailed specification (distinguish more sub classes and sub groups).
2. The uncertainty in most of the emissions estimates for agricultural sources is large. This large level of uncertainty is intrinsically related to the diverse nature and dynamics of the sources, partly also to lack of data.
3. Biases in the emission estimates are a more serious problem than errors and are thought to arise from i) personal bias, ii) sampling bias and iii) data manipulation. This may lead to overlooking sources or drivers of emissions. Proper system analyses combined with measurements are required to identify these biases.
4. Measurements of net emission of carbon dioxide from agriculture requires long term monitoring of changes in pools whereas measurements of nitrous oxide and methane emissions require continuous flux measurements.
5. Net emissions of carbon dioxide from soil and terrestrial biosphere are hard to quantify on a per year basis. The accuracy may improve by using measurements of changes in pools over longer time frames, due to the cumulative effect of carbon sequestration or losses, both above- and belowground.
6. For methane, the uncertainty in activity data and emissions factors is equally large. For nitrous oxide, the uncertainty in activity data is smaller than the uncertainty in emissions factors

7. A major source of uncertainty in the activity data and in quantification of emission factors lies in the lack of insight in farmers' activities, i.e. "what do farmers actually do". Acquisition of actual numbers of animals (where up to 15% can be missing), their real nutrition, timing and management of manure storage and application and in fertiliser application will improve the accuracy of activity data.
8. There are reasons to deviate the emission factors for agricultural sources of CH_4 and N_2O from the default values proposed by IPCC. These relate to the intensive nature of agricultural practices in the Netherlands, to the effectiveness of environmental policies and measures and the nature of soil and hydrological conditions and all effect the level of control over the nitrogen cycling and nitrogen losses from agricultural practices.
9. System analyses will reveal major, minor and unknown sources for greenhouse gases. It will direct the design of factorial experiments and long-term (≥2 years) flux and pool measurements that form the basis for emission factors. Simulation modelling exercises will improve the accuracy of estimates for various emission factors. This will enable the acceptation and use of more accurate emission factors that are a function of environmental conditions and actual management.
10. A coordinated research effort at spatially sufficient detail, similar to that of for example "Landelijk Bodemmeetnet" and "Landelijk Grondwatermeetnet" of RIVM, will be most efficient (i) for the establishment of accurate emission factors for CO_2, CH_4 and N_2O and (ii) for the evaluation of policies and measures, and the achievement of emission reduction targets.
11. Improving the accuracy of the emission factors for *indirect*_N_2O emissions has high priority; coordinated international actions are necessary to provide a basis for acceptation and economically effective implementation of measures at the farm level
12. The ideal greenhouse gas emission inventory is sufficiently detailed and transparent to enable justification of policies and measures and to facilitate implementation in practice. Proper dissemination of the results of the inventories to the actors involved will also facilitate successful implementation of policies and measures and generate a reduction of greenhouse gas emissions.

Session 4: Agriculture - Conclusions

Peter Kuikman, Alterra
Klaas van der Hoek, RIVM

Participants present:
Oene Oenema (Wageningen UR – AB/Alterra, vz.), Klaas van der Hoek (RIVM, report) en Peter Kuikman (Wageningen UR – AB/Alterra, report), Edwin Koekkoek (VROM – DGM/LE), Olaf van Kooten (Wageningen UR - PPT), Carolien Kroeze (Wageningen UR – Environmental Systems Analysis Group), Joanne Maaskant (LNV), Pieter van der Most (VROM – HIMH), Paul Spiertz (Wageningen UR – TPE), Gijs van Tol (IKC nature management), Leo Vleeshouwers (Wageningen UR – TPE), Jan-Willem Erisman (ECN).

1. Activities dealt with in the sessions

Magnitude of uncertainty (Table l)

- Sources
- Activities
- Emission factors

How can the uncertainty be reduced and to what extent?
Who can contribute to reducing this uncertainty?

2. Magnitude and uncertainty

Table 1 shows the uncertainty (twice the standard deviation) in 3 classes: 0-10%, 10-50% and 50 -100 %. In the discussion it is suggested to distinguish between uncertainty surrounding the activity (amount from source or sink) and surrounding the emission factor. This has led to the following (see Table 1):

Table 1: Expert judgement on the uncertainties in the activity data and emission factors for different sectors within agriculture in the Netherlands.

	Source of greenhouse gases	Activity	Emission factor
CO_2	Heating greenhouses	<5	<5
	Transport within agriculture	<5	0-10
	Mineralisation of peat soils	<5	50-100
	Organic matter in soils	Estimate n.a.	10-50
CH_4	Enteric fermentation in ruminants	<5	0-10
	Storage of animal manure	10-50	10-50
	Wetlands	<5	0-10
	Upland	<5	0-10
N_2O	Crop production		
	• Fertiliser, animal manure, crop residues, compost, legumes	0-10	50-100
	• Net mineralisation of peat soils	10-50	50-100
	Animal production		
	• Storage of animal manure, grazing animals	10-50	50-100
	Indirect sources after N losses		
	• Ammonia volatilisation, nitrate leaching	50	50-100
	Additional sources		
	Non-greenhouse energy use	0-10	0-10
	Conversion of crop- and grassland and vice versa		
	Land-use (changes), i.e. clover grassland, deforestation, transforming crop- to grassland and vice versa	Not available	Not available
	• CO_2 & N_2O	0-10	50-100
	• CH_4	0-10	10-50

Concluding remarks:

CO_2: Heating (and cooling) in non-greenhouse horticulture and land-use changes have not yet been quantified;

CH_4: Reporting on land use is unclear, uncertainty in estimates can be highly variable as a consequence of uncertainty in rations in feeding of animals, and uncertainty in length of storage and conditions during manure storage;

N_2O: Converting crop- into grassland is not included here; emission from nature areas and forest, as well as indirect emissions, are surrounded with uncertainty, emission factors are influenced by both management and the environment (pH, rain).

3. Reducing uncertainty

- Reducing the uncertainty in estimates to 5% or even lower is seen as an extremely difficult task, which will not be accomplished in the short term. The uncertainty can be reduced by increasing data availability on magnitude of activities. This is relatively simple but will lead to a limited reduction in uncertainty.

- An important contribution to the reduction of uncertainty may be expected from representative measurements. New emission factors can then be developed for clustered activities. A more accurate determination of emission factors and dose response curves for different processes and sectors may represent an important contribution to the estimates of emissions and sinks from different processes and sectors.
- Coupling monitoring to system analysis can lead to the categorisation of the sources into low, middle and high.

4. Who can contribute and when?

- A group called the Agricultural task force from Wageningen (AB, Alterra), IMAGE, RIVM in Bilthoven and ECN in Petten, who can potentially carry out this task wants to set up a plan of action to include a step-by-step plan, and prioritising and phasing of activities.

- Concern about the (limited) input from the actors (from the target groups): special attention should be given to public information and base sectors. It is important to develop a transparent and understandable methodology for both measurements and reporting.

4.5 SESSION 5: OTHER SOURCES: WASTE, RESIDENTIAL, TRADE AND SERVICE SECTORS

Discussion paper

Dick Nagelhout, Jos Olivier and Trudy Rood
RIVM

Introduction

This session concentrates on the process emissions of CO_2, CH_4 and N_2O from the following sectors:
- Solid and liquid waste treatment (removal/sewage treatment)
- Residential
- Trade, services and government
- The highest source is methane from waste treatment.

Therefore this session will mainly concentrate on this source. Emissions from combustion will mainly be treated in session 1 on Energy.

The aim of this session is:
- To make a quantitative estimate of the uncertainty in the emissions per sector and per gas.
- To make an inventory of the largest sources of uncertainty.
- To make an inventory of the possibilities to reduce these uncertainties.
- To map the information flows and suggest improvements for the current national system.
- To make a plan of action for the reduction of uncertainties.

1. Waste treatment

1.1. Introduction

This UNFCCC/IPCC category consists of landfills, waste incineration plants and sewage treatment plants. A category other is added for countries to use for other relevant sources. The definition of Municipal Solid Waste (MSW) is rather broad. In the emission inventory of the Netherlands the emissions from landfills and waste incineration plants are estimated by the task force group ENINA, and the emissions from sewage treatment are estimated by the task force group MEWAT.

Table 1: Overview of emissions in 1990 in this target group (in Gg and in Mton CO_2-equivalent)

Source	CO_2 (Mton)	CH_4 (Gg)	as CO_2-eq.	N_2O (Gg)	as CO_2-eq.
Landfills	-	568	**11.9**	-	
Waste incineration	**1.2 Mton**	p.m.		0.2	**0.1**
Sewage treatment	-	6	**0.1**	0.5	**0.2**

1.2. Landfills

According to the UNFCCC/IPCC guidelines there should be a difference made between *managed* and *unmanaged* waste disposal. For the Netherlands only ‘controlled dumping sites' have been in existence for years. Illegal dumping takes place, but as far as environmental pressure is concerned this is negligible.

Monitoring puts the emphasis on CH_4. Methane from dumping sites is calculated with a first-order model, which goes further than the IPCC standard. For the algorithm see Appendix 1 (*Fact Sheet on CH_4 from dumping sites*) Uncertainties are: fraction of the biodegradable organic carbon that is actually decomposed, the decay constant and the percentage of oxidation in the top layer. To improve on those expensive research is needed for improvement of data. The emission level is also of less interest than the trend.

Every year information on the amount of dumped waste is collected by the Working Group on Waste Registration (WAR in Dutch), a cooperative effort of Waste Consultation Group (AOO), Cooperation of Waste Handlers (VVAV), Provincial Consultation Group (IPO), (SCG), Ministry of Housing Physical Planning and the Environment and the National Institute of Public Health and the Environment (RIVM). The total amount of dumped waste is hard and fast. The composition of the waste dumped is estimated, but this information cannot be reliably derived from the information from the dumping site owners. By RIVM, with the help of several sources like those of the Central Bureau of Statistics the Netherlands (CBS), the extent to which the waste categories are represented in the dumped waste is estimated. This is followed by an estimate of the composition of dumped waste according to compound using information from Statistics Netherlands, RIVM and other sources. This is determined annually for household waste; for other categories, this takes place less frequently. Data on the composition of the waste are linked to estimates of the organic carbon levels of the different waste compounds from a report made by Ecofys (1994).

Every year the VVAV reports the amount of waste gas extracted (flared and used). There is some uncertainty about the CH_4 content of the waste gas. The annual emissions of CH_4 (and organic CO_2) are obtained by combining the algorithm and the input data. Several greenhouse gases are released during the incineration of the waste gas. We are concerned with small amounts here; however, the information could be improved.

1.3. Waste incineration installations

The incineration plants are incorporated into the Emission Registration. The amount of incinerated waste is derived, in particular, from the WAR data. The contribution of fossil carbon in the incinerated waste (from plastics mainly), is determined analogous to the method described for the dumping sites. This information is used by TNO to determine the amount of biological and non-biological CO_2.

1.4. Other sources

Within the target sector, waste disposal companies, there are still several companies whose contribution to the disposal of some greenhouse gases is minimal. In the spring of 1999 the ENINA Task Force agreed to an investigation later that year (autumn) to determine which companies were in question here. It would also be investigated if the emissions from the industrial target sector should be included. To complete the picture we should mention that several emissions of CH_4 and N_2O from processes make their appearance in liquid sewage treatment plants (RWZI's) but will not be discussed here.

1.5. Closing remarks

The first-order model for CH_4 for dumping sites is probably better than a zero-order model. Uncertainties do not lie in the amount of dumped waste but especially in the estimation of the composition of the dumped waste (material and organic carbon content) Reducing this uncertainty will require a contribution to the tune of several million Dutch guilders yearly. Which with respect to the previous years will, of course, be difficult to realise.

2. Residential, trade and service sectors

The largest part of the emission of greenhouse gases is from combustion of fossil fuels for heating. That is treated in the energy session. Here only some specific emissions are treated like methane from the smouldering of wood and charcoal fires, especially in open hearths and biofuel stoves. The other aspect to be treated here is the new greenhouse gases. The HFC emissions from residential and commercial services are now 4 and 2% respectively of the total HFCs emission in the Netherlands (in CO_2-equivalents). Although the contribution to the total HFC emission from these sources in the Netherlands is small, the uncertainties in the input factors in the models is rather large: amounts used per application, leaking rates, lifetimes of appliances, etc. This is especially the case in cooling in the commercial sector.

Table 2: Overview of process and combustion emissions in 1990 in the Netherlands from the residential, commercial and services sector (in Gg and Mton CO_2-equivalent)

Sector	CO_2	CH_4	as CO_2-eq.	N_2O	as CO_2-eq.	HFC as CO_2-eq.
Process						[in 1995]
Residential	**-**	0		0		**0.3**
Services	**-**	2	**0.04**	0.5	**0.2**	**0.1**
Combustion						
Residential fossil	**19.2**	12.8	**0.3**	0.06	**0**	-
Residential biofuel	**0**	3.7	**0.1**	0	**0**	-
Services fossil	**8.7**	1.1	**0.02**	0.03	**0**	-
Services biofuel	**0**	?	?	?	?	-

2.1. Residential

Process emissions of methane and nitrous oxide in the residential sector are from smoking of tobacco and fire crackers at new year's eve and are negligible. HFC emissions in this sector are from refrigerators and aerosol spraying cans. Until now emissions from spraying cans are estimated based on annual information from KPMG Consultants. This is only HFC-134a. HFC emissions from household refrigerators are negligible at the moment.

Methane emissions from households (for space heating, hot water and cooking) are mainly caused by natural gas slip during cooking. Next to this some methane emissions occur during combustion of wood and charcoal in wood stoves, open hearths and barbecues. The uncertainty in the estimate is largely related to the uncertainty in the development in wood and charcoal use. It is not part of the Energy Monitor of CBS (Energy balances of the Netherlands). It has to be monitored separately. Recently a census was made of the number of open fireplaces and wood stoves and their use. This has lead to the revision of the degree of penetration and the assumed use.

The summary of the important emissions in the residential sector is:

- Carbon dioxide from combustion of fossil fuels: See Session 1 for a discussion on the uncertainties.
- HFC emissions: Only HFC-134a from spraying cans is monitored.
- Methane from combustion of fossil fuels, mainly natural gas: Uncertainty mainly in leaking of natural gas during cooking.
- Methane from burning of wood and charcoal: Uncertainties are important in the amounts of biomass used and the emission factors for each type of installation (open fireplace, wood stove with and without certification, barbecue). Trends in the use of wood and charcoal should be monitored.

2.2. Commercial and public service sector

Process emissions from this sector of methane are mainly during the preparation of drinking water. Some drinking water wells contain methane. The process emissions of nitrous oxide are from anaesthesia in hospitals and from spraying cans for example for cream. HFC emissions are from stationary cooling, as solvent and cleaning agent in the electronics and as aerosol. Different HFCs are monitored by KPMG consultants but mainly from the commercial stationary cooling sector. This is based on an inventory of the use per category. The uncertainties in the model factors used for practices is quite large, especially for cooling: factors for use per category, leaking rates, maintenance losses, appliances life cycles, etc. An uncertainty analysis and a sensitivity analysis for the models used could be a point of attention in the estimates of actual HFC emissions.

Most combustion emissions in this sector are from space heating with natural gas. Carbon dioxide is discussed in session 1. Methane emissions are from leaking and natural gas slip. Some small emissions of methane are expected during the use of open fireplaces and the preparation of food on wood or charcoal in restaurants, in recreational parks and hotels. This is not yet monitored. It is expected to be small. The uncertainty is related to the amounts of biomass used. It is not part of the Energy monitor of CBS.

A summary of emissions and uncertainties that are important in this sector:

- Carbon dioxide from combustion of fossil fuels: See session 1 for a discussion of uncertainties in the estimates.
- HFC emissions: Only HFC 134a in the stationary cooling is monitored. The underlying factors used in the models for estimating the actual emissions are rather uncertain.
- N_2O from processes: The largest uncertainty is the amount used for anaesthesia and in spraying cans. In 1990 this is estimated from a factor for consumption per capita.
- Methane from combustion of wood and charcoal: The use of wood and charcoal in open fireplaces, woodstoves and barbecues in restaurants, recreational parks and hotels is unknown.

APPENDX 1: FACTSHEET METHANE FROM LANDFILLS

1	**Compound/ target sector**	**CH_4 / Waste disposal companies (dumping sites)**
2	**Name of reporter / date**	Drs. D. Nagelhout - LAE, 3 February 1999, for small details, supplemented on 13 August 1999.
3	**Policy aim**	There is no separate CH_4 objective for waste disposal. The objective for methane (total for the group) is a 10% reduction in 2000. A waste policy objective is to dump as little waste (including organic material) as possible and extract as much waste gas as possible. A reduction of more than 10% has been realised (taking re-calculation of figures for 1990 into account).
4	**Emission level 1995**	**479 million kg**
5	**Algorithm**	The algorithm is based on a method described earlier by Hoeks (1983) [ref. 2] and more recently in Coops et al. (1995) [ref. 3]. Calculations per dumping site were not carried out. The general form of the equation is shown below: Emission = (gas production - gas extraction) -oxidation in cover layer The method takes the following aspects into account: - the amount of waste dumped per year since 1945 [refs. 4,5,6], - the biodegradable organic carbon content in the waste dumped [refs. 7, 8], - the fraction of the biodegradable organic carbon that is actually decomposed (set at 0.58 for the Netherlands [ref. 3], - decay constant (0.094 per year up to 1990, decreasing to 0.0693 from 1990-1995 because of increased biowaste collection, thereafter assumed constant) [ref.1,3], - the amount of waste gas extracted [ref. 9], - 10% oxidation in the top layer of the dumping site [ref. 3] See report on methods for greenhouse gases [ref.1].

6	**Input**	Estimates on the amount of waste dumped since 1945 [refs. 4, 5, 6] Estimates on the composition of waste dumped [refs. 7,8] Amounts of extracted waste gas reported by the VVAV [ref. 9]
7	**Uncertainty of emission estimate**	Uncertainty margin: **30 %** (ref. 10). Relevant factors: time lag, biodegradable organic C content in various waste substances, mechanisms on the dumping site.
8	**Validation input:**	Measurements were carried out to determine waste gas released from dumping sites [see, for example, ref. 3]. The biodegradable organic C content is set down in a stocktaking study [ref. 7]. Figures on the amount of waste dumped have in the last few years become more reliable (annual inventory of the Working Group on Waste Registration) . Figures on the composition of (dumped) waste have been more accurate the last few years compared to 1990 [refs. 7, 8, 11, 12, 13 and 14]. The amount of waste gas extracted is reported yearly to the VVAV by the owners of the extraction installations. Validation of input figures takes place within the ENINA Task force of the CEI.
9	**Current actions**	• No actions planned for financial reasons
10	**References**	1 J.Spakman et al., *Methode voor de berekening van broeikasgas-emissies*. VROM - Hoofdinspectie Milieuhygiéne, Publicatiereeks Emissieregistratie nr. 37, The Hague, July 1997. 2 J.Hoeks, Significance of biogas production in waste tips. *Waste Management and Research,* 323-335, 1983. 3 O.Coops, L Luning, H.Oonk, J.Boom, *Emissies van stortplaatsen.* VROM-Hoofdinspectie Milieuhygiëne, Publicatiereeks Emissieregistratie nr. 28, The Hague, December 1995. 4 Stichting Verwijdering Afvalstoffen, *Overzicht afvalverwijdering*. SVA 3000, Amersfoort, 1979. 5 Stichting Verwijdering Afvalstoffen, *Inventarisatie benodigde stortruimte*. SVA, Amersfoort, 1973 *6* Werkgroep Afvalregistratie, *Afval in Nederland. Utrecht* 7 D. de Jager, K. Blok, *Koolstofbalans van het afvalsysteem in Nederland*, Ecofys, Utrecht, 1993. 8 A.A.J.Cornelissen, *Onderzoek naar de fysische samenstelling van het Nederlandse huishoudelijk afval*. RIVM, Bilthoven, The Netherlands. Annual reports. 9 VVAV, *Jaarverslagen* (annual reports for several years). 10 VROM, *Second Netherlands' National Communication on Climate Change Policies*. VROM, The Hague, 1997 11 RIVM, *Rapportage prioritaire afvalstoffen*, diverse jaren, RIVM, Bilthoven, The Netherlands. *12* CBS, *Van gemeentewege ingezameld afval*, CBS,Voorburg, The Netherlands 13 CBS, *Bedrijfsafvalstoffen.*.CBS, Voorburg, the Netherlands 14 RIVM, *Industrieel afval*. RIVM, Bilthoven, The Netherlands

Session 5: Other sources - Conclusions

Report of Session 5 of the Workshop 'Monitoring of greenhouse gas emissions in the Netherlands, 1 September 1999, including the follow-up session on 4 November 1999.

André van Amstel, Wageningen University, Institute for Environment and Climate Research and Hans Oonk, TNO-MEP

Discussion session members: Mieke Bakker (VROM/DGM/ICB/PC), Albert Faber (RIVM/LLO), Johan Apeldoorn (VROM/LE), Peter Builtjes (TNO/IMSU), Mariëlle Vosbeek (KEMA), Trudy Rood (RIVM/LAE), Hans Oonk (TNO/MEP), Dick Nagelhout (RIVM/LAE), Johan Apeldoorn (VROM/LE), Paul Ruyssenaars (VROM/LE), André van Amstel (Wageningen Universiteit/WIMEK).

This session concentrated on process emissions of carbon dioxide, methane and nitrous oxide from solid and liquid waste treatment, residential, and commercial/services/government.

The discussion followed the instructions below separately for solid waste and residential, commercial/services/government:

1. Quality of documentation:
   - Methods, activities, emission factors and uncertainty estimates
   - Are IPCC revised guidelines applied, are all sources reported?
2. Uncertainty estimates
3. Identification of important causes of uncertainty
4. Technical possibilities to improve quality
5. Proposal to improve the quality of greenhouse gas monitoring of other sources

1. Solid waste

The methane emissions from landfills are estimated using a method that was developed by Hoeks (1983). In Coops et al. (1995) this method is applied to all individual landfills in the Netherlands. This study used information on MSW landfilled at each site. The estimate in the National Communications considers the aggregate of all landfills in the Netherlands. Input parameters are described in Spakman et al. (1997). Information on the trend in time of the quantity and quality of the waste and the organic and fossil carbon content is from ECOFYS (De Jager and Blok, 1993). The method is based on a time dependent degradation function of the carbon in the waste.

$$A = f * k * P * e^{-kt}$$

Where:

A = gas production (in ton C per ton landfilled waste per year)
f = the fraction of the biodegradable waste that actually takes part in the degradation (in the Netherlands this fraction is set at 0.58)
k = the degradation constant of 0.094 per year (half-life is 7.4 year) until 1990. From 1990 to 1995 k is decreasing to 0.0693 (half-life is 10 year) because of a decrease of carbon in the landfilled waste because of recycling of organic waste.

P = the concentration of biodegradable organic carbon in landfilled waste (0.132 ton/ton of waste in 1990 decreasing to 0.120 ton/ton of waste in 1996 because of recycling of organic waste)
t = time after landfilling.

It is assumed that only 58 % of the carbon in the landfill are actually degrading. What remains can be regarded as a carbon sink. This is discussed in the sinks workshop held in Wageningen 24 November 1999.
Once degraded, the assumption is that 60% of the carbon in the landfill gas escapes as methane, the other 40% escapes as carbon dioxide (short cycle). The mass of C to mass of methane recalculation factor is 16/12. The gross methane production t year after landfilling can be calculated as follows:

Gross Methane (t) (kton) = A(t) * landfilled waste (kton) * 0.6 * 16/12

A growing amount is captured for energy purposes or flared. It is assumed that 10% of the methane in the uncaptured gas is oxidised in the landfill cover and that 90% is emitted. The methane emission is calculated as follows:

Methane emission = [Gross methane – captured methane] * 0.9

The total gross production of landfill gas in a year from waste that was landfilled in the past is calculated by integration over all years. The methane formed is mainly from earlier landfilled waste.

1.1. Quality of documentation

Methane emissions from solid waste disposal are calculated using the method as described above (Spakman et al., 1997). Landfill owners now measure the quantity of solid waste disposed of in landfills. All waste lorries coming in are weighted. To get more information on the waste composition, this information is combined with information from the Central Bureau of Statistics (CBS) per economic sector on quantities burned, landfilled and composted. From a study by ECOFYS (De Jager and Blok, 1993) on the carbon balance of the waste we know more about the quality of the organic fractions in the waste and from carbon from fossil origin (plastics etc.). A total of 14 Mton, or 0.93 ton/capita is landfilled in 1990 as estimated by RIVM. This includes inert demolition waste. This waste does not generate much methane. Only 8 Mton municipal solid waste (MSW) is landfilled in 1990 according to RIVM. This equals about 0.53 ton/capita. In Europe the average amount of MSW landfilled per capita is 0.6 ton. In the Netherlands there is a sharp decrease of landfilled waste between 1989 and 1995 (13.9 to 8.5 Mton). This can be explained by policy measures. Much demolition waste is recycled since 1990. Recycled organic waste is about 1 Mton in that period. Landfill gas that is collected for energy use is subtracted from the emission. Bart van Zanten reports the recovered landfill gas quantity in the yearly report of the VVAV (the landfill owners). It is important that this reporting is made structural. 10% of the unrecovered methane is oxidised in the coverlayer of the landfill. The amount of the methane that is oxidised in the cover layer is estimated based on Coops et al. (1995).

1.2. Uncertainty

The uncertainty has increased between 1990 and 1999. In 1990 the estimated uncertainty in the emission factor was 15%. The estimated uncertainty in the activity data was 10%. In 1999 the uncertainty in the emission factor is estimated 30% because of the poor knowledge on waste composition. The uncertainty in the activity data is about 1% in 1999 because the quantities are weighted now. The quantity of demolition waste and sewage sludge is well known. The quality of some waste categories is less well known. An example is sweeping waste.

1.3. Identification of important sources for uncertainty.

In the first order decay function the estimate is based on an average degradation time constant k of 0.094 in 1990 and 0.0693 in 1995 of the organic carbon in the waste (Half of the carbon is degraded in 7.4 years in 1990 and in 10 years in 1995). This is very uncertain. The oxidation in the top layer is uncertain as well.

If in the future a more detailed method is used with three different degradation constants for the different organic carbon fractions in the waste, then even more information is needed on the amounts of fast, medium and slowly degradable organic carbon. The most important source for uncertainty is the poor knowledge on waste composition, and thus on the amount of carbon in the vegetable/fruit (fast), paper (medium) and wood (slowly degradable) fractions in the waste.

1.4. Technical options to improve the quality of estimates

We need more measurements for monitoring to validate the time constants in the first order decay function but this is costly and takes time. Afvalzorg Noord-Holland (Hajo Scharf) will start measurements on all 7 bigger landfills in North Holland. The VAM in Drenthe needs to measure as well. A good measurement program on extracted landfill gas is needed to validate the time dependent methods for methane emission estimates in the Revised IPCC Guidelines. This is possible. We now have about 50 waste gas projects and all are in operation for more than 7 years. Something could be done with the information on total waste gas collected per year. It is suggested to use this information for a validation of the first order decay function. It can also be used in the future to develop a second order decay function with a multiphase approach with three time constants for the decay of the three most important carbon sources in waste (vegetable/fruit, paper and wood) with different decay behaviour: fast, medium and slow decay. Monitoring of oxidation is needed. Monitoring of waste composition is needed. It is done by RIVM but the activity is victim of budget cuts.

Johan Apeldoorn of the Ministry of VROM has formulated a small project for TNO to clarify the following questions:

1. What are the effects of the policy to ban landfilling of organic waste on the methane emissions? Can the projection of methane emissions for 2010 be updated with better information on the change in composition of the waste to landfills?
2. Can a multiphase model be used for methane emission estimation? Are the costs for development and use in the future reasonable compared to the improvement of the quality of the estimates?
3. What are the options for redesign for new landfills for zero methane emissions?
4. Can a list be made of important landfills where 80% of the methane emissions in 2010 are expected? What is the order of importance with respect to reduction measures?

Results of this study will be published by Hans Oonk in early 2000.

The waste policy in the Netherlands is to prevent and reuse as much as possible. The dry organic fraction is burned. This reduces the amount of organic waste to landfills. Much is already used to generate energy. However, no increase in capacity of waste incinerators in the Netherlands is foreseen. Therefore, there is a risk that the organic waste will be exported and burned in countries outside the Netherlands.

Is it necessary to develop new policies on landfills as the organic fraction is going down? Yes, it is suggested that a landfill with organic material could be considered as a sink in the Kyoto protocol.

1.5. Proposal for improvement of the quality of monitoring of greenhouse gases in landfills

- Improvement of existing list of landfill sites, including information on quantity and quality of waste. Make it available for use for monitoring per landfill site.
- Development of a new list of landfills that are expected to still be important in 2010 (80% of methane emissions in 2010).
- Improvement of reporting of landfill gas recovery, including methane content. Not only in VVAV yearly report because not all landfill owners are members. Make it a WAR survey question?
- Monitoring of the waste composition by RIVM.
- Feasibility study for development of multiphase model for monitoring of emissions by TNO.
- Use of information on recovered amounts of methane at landfill gas recovery sites to validate first and second order decay model to estimate methane emissions by TNO.
- Develop a measurement programme with interested parties. Not only Waste Care North Holland.

2. Residential, trade and service sectors: Methane from burning of wood and charcoal

2.1. Quality of documentation

Fossil fuel use is covered in the Energy session. Methane emissions from burning of wood and woodstoves in the Netherlands are estimated from the quantity of woody material used and an emission factor as described in (Spakman et al. 1997).

2.2. Uncertainty

The uncertainty in the emission factor is 100%.

2.3. Identification of important sources for uncertainty.

The emission factor is based on an estimate of 0.25 of the fraction of the total VOC emissions from wood.

2.4. Technical possibilities to improve the quality of estimates

The quality of the estimate can be improved by developing a better estimate of the total quantity of wood and charcoal burned in the Netherlands. The estimate is now based on residential burning only. Missing sources are barbecues in restaurants and recreational parks. More difficult will be the improvement of the emission factor. Measurements are needed.

2.5. Proposal for improvement of the quality of monitoring of greenhouse gases

New estimate of total quantity of wood and charcoal burned in the Netherlands. Measurements of methane release from smouldering fires.

3. Some other small sources: HFCs from cooling and spraying cans; N_2O from different small sources

3.1. Quality of documentation

Missing sources are HFCs from leaking refrigerators, HFCs from residential air-conditioning, HFCs from fire extinguishers. N2O as a party drug. N2O for balloons. N2O from spraying cans e.g. for whipped cream.

3.2. Uncertainty

The uncertainty is large. Small sources so inventory is lacking.

3.3. Identification of important sources for uncertainty.

Uncertainties because of uncertain activity data and uncertain leakage rates.

Technical possibilities to improve the quality of estimates

KPMG is looking into the bookkeeping of companies for CFCs, HCFCs and HFCs. Improvement by better data on the sales to residents of cooling and air-conditioning for the use and leakage of HFCs from residential cooling and air-conditioning. Sources too small to make a large effort.

3.5. Proposal for improvement of the quality of monitoring of greenhouse gases

Fast and cheap may be an inventory of unknown sources and gases. Literature search for the discovery of new sources and gases and their GWPs.

5. WORKSHOP CONCLUSIONS

André van Amstel and Jos Olivier

General conclusions

The national system of the Netherlands for the Kyoto protocol is described in different reports, some of which are in the Dutch language. This workshop on the monitoring of greenhouse gases in the Netherlands was organised to improve the national system and make this material available in the English language. Reporting by the Netherlands is done through the national Emission Registration project. An additional project is formulated next to the national Emission Registration to improve on the monitoring of the greenhouse gases. The recommendations from this report will be used to improve the monitoring in the Netherlands over the coming years. Current monitoring activities have resulted in reasonably accurate emission inventories and the emission estimates, methods and processes are rather well described. However, systematic review and documentation of procedures, methods and data will result in a more efficient emission compilation process and a quantitatively more accurate and qualitatively better greenhouse gas emission inventory. The next general items were recognised for further review and improvement during the workshop:

- the **reporting and documentation** on emission factors and activity data used each year to report greenhouse gas emissions and sinks.
- the **uncertainty estimates** for each subcategory in the emission inventory and to make a separate estimate for the uncertainty in the emission factor - when different from IPCC defaults - and in the activity data.
- the **quality control** on each new years estimates and on recalculations based on new methodology or better activity data and/or emission factor data and document the basis of these estimates.
- the **maintenance of time series**. For example, it should be clear for which reason and at what moment in time new methods were introduced that effected the time series. A decision may be needed on frequency and timing of recalculations: for example recalculations only after three or five years or specific criteria to be met e.g. on minimum differences between subsequent versions.
- **knowledge gaps** should be closed. Large sectoral emissions with large uncertainties should be made top priority (e.g. gas distribution leakage, agriculture, SF_6 use). Thereby improving the monitoring of emissions that can have a great impact on the time trend.
- in some cases **improved application of the *Revised IPCC Guidelines*** will produce more comparable emission estimates (e.g. in the estimates of CO_2 from feedstocks, non-CO_2 from bunker fuels and nitrous oxide from agriculture and polluted surface waters).
- the **cooperation with the target groups** to enhance the monitoring of emissions in particular when reductions are expected. It should be avoided that each target group develops its own methodologies. If measurements are commissioned, e.g. in the policy plan for the reduction of greenhouse gases, new emission factors may be developed for specific sub-sectors.

More specifically, country-specific emission factors and, where applicable, their time trend could be better documented and justified. An emission factor can be reduced by improved process technology and by end-of-pipe measures. It is important to have documentation on the moment of introduction, the degree of penetration and of other technology and measures and their effect on emission factors. Activity data and, where relevant, time trends in sub-activities, could be documented better. Data sources and data collection methods should be clear including an uncertainty estimate preferably based on statistical analysis of the sample. The uncertainty estimates on activity data and emission factors could be completed and be made subject to external review. The same applies to the methodologies used for emission estimations.

The process of information flow for the emission registration and the calculation of the actual emission estimates should be analysed (e.g. for road transport and individual point sources). An assessment of the weak points could be made. Implementation of Quality Assurance and Quality Control (QA/QC) in the Emission Registration process could be pursued by including explicit QA/QC procedures within the process steps.

In some sectors measurements may be needed to reduce uncertainties. Priorities are large emissions with large uncertainties. Examples are: carbon dioxide from process emissions (feedstocks); methane emissions from natural gas production and distribution; methane from animals; HFC, PFC and SF_6 emissions from all sectors. Some methods used to estimate emissions are not sensitive to planned reduction measures. These methods could be improved. Cooperation is needed to implement improvements in the annual Emission Registration. For a good monitoring of planned reductions and for an internalisation of the need for these reductions a very good cooperation is needed with the sectors in the economy: the ' target groups' to which environmental policy plans are directed.. They are the most important players when it comes to lasting emission reductions.

A new *Common Reporting Format* (CRF) has been developed for reporting to the Climate Convention and the Kyoto protocol. This CRF was adopted for a trial period of two years. The monitoring in the Netherlands should be adapted to the new data needs of this CRF. This may result in new data gathering streams at the institutes involved in the monitoring. These international reporting obligations may have repercussions for the Emission Registration, especially with respect to the individual companies. Monitoring activities of industries and companies should comply with international obligations.

Priorities

Priorities for the improvement of emission estimates can be derived from the following selection criteria *either* for the national total CO_2-eq. emissions *or* per greenhouse gas *and/or* per sector:

- **Importance.** The important sources can be selected from the share in the total emissions in the Netherlands expressed in Mton CO_2-equivalent, and from the absolute uncertainty in source expressed in CO_2-equivalents (see the table with initial uncertainty estimates in the introduction).
- **Effect on trends.** The sources that have the largest contribution to the uncertainty in emission trends are those identified in the IPCC Tier 1 trend uncertainty calculation or those thought to be heavily influenced by methodological change, complexity of methodology.
- **Planned reduction measures.** The monitoring should be best developed in source sectors where the largest reductions can be achieved. Monitoring should be part of the measure.

Conclusions from the sessions

We note that due to time constraints during the sessions, the reader should keep in mind that the issues addressed in the sectoral conclusions may not always be complete.

SESSION 1: ENERGY

Documentation
The emission factor documentation on CO_2 emissions from combustion of coal, oil and gas can be improved. The uncertainties in the emission factors can be documented better. In the activity data the documentation should be improved on the amount of feedstocks used in the petrochemical industry each year. The statistical difference between demand and supply statistics should be documented. This statistical difference can be regarded as a measure of uncertainty in the activity data. The quality of documentation in the Emission Registration for individual companies can be improved.

Uncertainties
The group agreed on the uncertainties as given in the discussion paper, with one exception: the uncertainty in the feedstock CO_2 emissions is larger and should be documented better.

Methodology
Improvements in the methodology and in the application of existing methodology are needed in the individual registration of CO_2 emissions by companies. Improvements in the methodology are needed in the emission estimation for CO_2 and CH_4 from flaring and venting. A new inventory is needed of the length and types of pipelines for the transport and distribution of natural gas in the Netherlands. Then an update can be made of methane emissions from transport and distribution. The results of European measurements by the industry can be incorporated.

Ranking of uncertainties
The group agreed on the ranking as given in the discussion paper with some exceptions: feedstock emissions are more uncertain; also other industrial process emissions are more uncertain.

Plan of action for reduction of uncertainties
1. Action should be taken to improve emission factors for coal and natural gas.
2. Research should be started to improve the estimates on feedstock emissions and sinks from the petrochemical industry.
3. The energy statistics of the Netherlands as a whole can be improved. Although the uncertainty is only 5% in the Netherlands, much can be gained with better energy statistics, because the absolute emission is very large compared to the other emissions.

SESSION 2: INDUSTRY

Documentation
Quality of documentation is deteriorating because of recent developments in the flow of information. Earlier a group of experts discussed draft estimates with the companies, now annual environmental reports are made by the companies for the authorities. No expert group exists to checks the consistency and the methodology. Difficulties are expected with the common reporting format, because of confidentiality.

Uncertainties
A distinction can be made between emissions from combustion and from processes in industry. The uncertainties in the process emissions are larger. Research is needed to improve on uncertainty estimates within industry.

Methodology
In the Netherlands the annual environmental reports from companies contain only emission estimates. Companies do not report the methodologies and other information on how estimates were made.

Ranking of uncertainties
The uncertainty is large in the nitrous oxide emissions from nitric acid plants. The uncertainties are large in the new gases, especially the potential emissions from stocks and finished products.

Plan of action for reduction of uncertainties
It is vital that provincial authorities are more involved in the data gathering from companies. In principle they are involved in the Emission Registration, but recent developments made this link weaker, because the group of experts are no longer involved in checking. Central financing to improve the provincial authority is needed.

SESSION 3: TRANSPORT

Documentation
Two methods are currently used to estimate CO_2 emissions from transport. The first is based on fuels sold. This method is from the *Revised IPCC Guidelines*, the second is based on the fuels used on the Dutch territory. The methods are described in a draft methodology report (in Dutch). The meeting recommended to finish this report and to make it subject to scientific review.

Uncertainties
A statistical analysis is recommended based on the two methodologies to estimate the uncertainties. In estimating uncertainties, bunker emissions should be included. It is possible that the current definitions on national and international transport differ somewhat from the IPCC definitions. This should be solved.

Methodology
It is stressed that both methodologies have their pros and cons. A detailed methodology with vehicle categories is needed for estimates of emissions of all kinds of pollutants.

Ranking of uncertainties
The meeting identified six important causes for uncertainty in order of decreasing importance:
1. The quality of activity data on car kilometres and energy use per car is decreasing because of poor insight in the lease and business car market. The share of lease cars in the fleet is increasing.
2. The quality of the same activity data in the freight transport sector (of vans and lorries) is also decreasing because of poor responses to surveys.
3. Fuel sales data for off-road vehicles, rail and inland shipping are rather poor.
4. Nitrous oxide emission factors are highly uncertain.
5. HFCs use and emissions are highly uncertain.
6. Methane emission factors are highly uncertain.

An uncertainty analysis using both fuels sales and fuel use methods is needed. The present uncertainty estimate for N_2O from vehicles ($\pm$50%) is probably too low. Measurements are currently carried out to improve the estimate.

Plan of action for reduction of uncertainties
The following actions are proposed:
1. Finalise methodology report by Task Group Transport before spring 2000.
2. Statistical uncertainty analysis by RIVM before the end of 2000.
3. Improvement of CBS activity data by CBS, ongoing action.
4. Improvement of data on energy use per kilometre for road transport by Task Group Transport before summer 2000.
5. Estimate nitrous oxide and methane emissions of bunker use by Task Group Transport before summer 2000.
6. Measurements of nitrous oxide from road transport by VROM before the end of 2000.
7. Desk research on HFC emissions from road transport by Task Group Transport before summer 2000.

SESSION 4: AGRICULTURE

Documentation
The emission estimates from agriculture have used IPCC methodology mainly. Documented in different methodology reports in the Netherlands. Documentation is not centralised; documentation of differences with IPCC methods/sources could be improved.

Uncertainties
The uncertainty in the estimates of greenhouse gas emissions from agricultural sources (i.e. other than fuel combustion) is large. In general the activity data are more precise than the emission factors. It is not easy to reduce the uncertainties in the emission factors to 5% because of the variability in space and time.

Methodology
Recently the Wageningen University at the request of IPCC organised a Good Practice meeting to improve the application of the IPCC methodology. Results were published in a Good Practice Report from IPCC. This report is currently under review and will be published in spring 2000.

Ranking of uncertainties
The meeting made a table in which the uncertainties were estimated separately for activity data and emission factors. In general the uncertainties are large for land use related emissions and sinks. The uncertainties are large in emissions from animals and manure because no good data are available on the actual management of the farmers. For example, what do they feed their animals, what kind of manure management is applied? How long is the manure stored?

Plan of action for reduction of uncertainties
The Wageningen University and Research Centre proposes to install an Agricultural Task Force to set up an action plan for reduction of uncertainties. The group was concerned that input from the actors was limited in these discussions.

SESSION 5: OTHER SOURCES

WASTE

Please note that emissions from waste combustion, in particular CO_2, were not discussed at the session.

Documentation
The methodology is documented in various reports from RIVM and TNO. The documentation of the activity data has improved over the last years. The documentation of the amount of methane recovered from landfill gas is done by the Group of landfill owners in their yearly report. This should be continued.

Uncertainties
The uncertainties in the estimates of methane from landfills have decreased. The quality of the activity data has improved, that is, we know the quantities of waste landfilled, but the measurements have not improved because of the poor knowledge on the composition of the waste.

Methodology
A more detailed methodology with three different degradation coefficients is not recommended, because information on the composition of the waste is lacking to implement such detailed methodology.

Ranking of uncertainties
The most uncertain factors are the composition of the waste in landfills, the degradation factor, the composition of the landfill gas and the oxidation of methane in the top layer.

Plan of action for reduction of uncertainties
1. It is suggested to validate the first order decay function with the information on landfill gas formation from seven years of experience with 50 waste gas recovery projects. Monitoring of landfill gas formation and methane emission could be developed by co-operation between the different landfill owners. Monitoring of waste management is needed in Groningen where new techniques are developed.
2. Improvement of existing list of landfill sites, including information on quantity and quality of waste. Make it available for use for monitoring per landfill site.
3. Development of a new list of landfills that are expected to still be important in 2010 (80% of methane emissions in 2010).
4. Improvement of reporting of landfill gas recovery, including methane content. Not only in VVAV yearly report because not all landfill owners are members. Make it a WAR survey question?
5. Monitoring of the waste composition by RIVM. P.M. Monitoring waste composition of combusted waste.
6. Feasibility study for development of multiphase model for monitoring of emissions by TNO.
7. Use of information on recovered amounts of methane at landfill gas recovery sites to validate first and second order decay model to estimate methane emissions by TNO.
8. Develop a measurement programme with interested parties, not only by the firm ‘Waste Care North-Holland’ .

RESIDENTIAL, TRADE AND SERVICE SECTORS (NON-FOSSIL FUEL)

Documentation
The estimate of methane emissions from wood and charcoal burning in the Netherlands could be improved.

Uncertainties
The uncertainty in the emission factor of methane is large. However, also consumption data of biofuels are very uncertain.

Methodology
The methane emission factor is based on an estimate of 0.25 of the total VOC emissions from wood burning.

Ranking of uncertainties
The largest uncertainty is in the methane emission factor. Activity data on wood and charcoal use could be improved.

Plan of action for reduction of uncertainties
1. A new estimate could be made of methane from wood and charcoal use. Measurements could be made of methane release from smouldering fires.
2. To cover the gaps that could still exist in the inventory of the Netherlands, an inventory could be made of unknown sources and gases.

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Appendix C: Selected publications on emission inventories by various organisations

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Information on reports published by the minstry can be found at: http://www.minvrom.nl.

Government, 1994: *Netherlands' First National Communication on Climate Change Policies.* Prepared for the Conference of the Parties under the Framework Convention on Climate Change. Ministry of Housing, Spatial Planning and the Environment, The Hague.

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Emission Registration (HIMH)
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All official documents are electronically available at: www.unfccc.de.

UNFCCC, 1997a, *Kyoto Protocol to the United Nations Nations Framework Convention on Climate Change*. UNFCCC Secretariat, Bonn. Doc. no. FCCC/CP/1997/L.7/Add.1.

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Many official documents, such as guidelines and meeting reports, are currently available electronically at: http://www.ipcc-nggip.iges.or.jp

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