Uncertainty in the Netherlands' greenhouse gas emissions inventory

Estimation of the level and trend uncertainty

using the IPCC Tier 1 approach

Background Studies

Netherlands Environmental Assessment Agency

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Netherlands Environmental Assessment Agency

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PBL publication number 500080013

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Acknowledgments

Many colleagues from a number of organisations (CBS, EC-LNV, LEI, PBL, TNO and SenterNovem) are involved in the annual updates of the Netherlands greenhouse gas inventory, which is part of the Netherlands *Pollutant Release and Transfer Register* (PRTR). This annual project is led by the *Netherlands Environmental Assessment Agency* (PBL). The emission calculations, including those on greenhouse gas emissions, are performed by members of so-called PRTR Task Forces. Subsequently, the greenhouse gas emissions and activity data of the Netherlands' inventory are converted by TNO into the IPCC source categories contained in the CRF files, which are a supplement to the National Inventory Report ('NIR') on greenhouse gas emissions. The estimated uncertainty about the different sources is part of the source description and an analysis of emission trends has been made in cooperation with the following experts:

- 1A: stationary energy: Jos Olivier (PBL) with the assistance of Joost Huurman and Bas Guis (CBS);
- 1A: transport, bunkers: Anco Hoen (PBL);
- 1B: fugitive emissions: Kees Peek with the assistance of Jos Olivier (both PBL);
- 2: industrial processes: Kees Peek with the assistance of Jos Olivier
- 3: solvent and product use: Durk Nijdam (PBL) with the assistance of Jos Olivier;
- 4: agriculture: Marian van Schijndel (PBL);
- 5: LULUCF: Gert-Jan van der Born (PBL), and Nynke Schulp (WUR), with the assistance of Gert-Jan Nabuurs and Peter Kuikman (Alterra);
- 6A and 6C (=1A1a) solid waste: Guus van den Berghe, Marco Kraakman, Timo Gerlagh (SenterNovem);
- 6B, 6D: waste water, other waste: Kees Baas (CBS).

In addition, Laurens Brandes and Romuald te Molder were responsible for the key source analysis and Jos Olivier for the coordination of the uncertainty estimates. We greatly appreciate the contributions by each of the groups and individuals named above, to the uncertainty estimates used in the key source analysis and reported in the *National Inventory Report*.

Abstract

The Netherlands signed the United Nations Framework Convention on Climate Change (UNFCCC), and, therefore, is bound to report its greenhouse gas emissions annually in a National Inventory Report (NIR). Within the framework of this NIR, an annual uncertainty assessment is made for both national total annual emissions and the trend, from the base year 1990 (1995 for F-gases) to the current year. The present report documents uncertainty estimates in the assessment performed for the NIR 2006 and (minor) updates made in the later submissions (2007 and 2008).

Uncertainty estimates were made using the simplified IPCC Tier 1 uncertainty analysis following the Intergovernmental Panel on Climate Change (IPCC) *Good practice Guidance*. In addition, assumptions and results of two more comprehensive analyses are presented in this report, based on IPCC Tier 2 Monte Carlo assessments. These Tier 1 and Tier 2 assessments were used for identifying areas for improvement within the emissions inventory. Both studies showed that Tier 2 and Tier 1 uncertainty analyses, using similar underlying uncertainty data, resulted in similar magnitudes of overall uncertainty calculations, both for level and trend uncertainty. Therefore, using Tier 1 as the main method for uncertainty analysis in the NIR is justified, also because it is unlikely that the uncertainties will change quickly over the years.

Key words: Uncertainty, emissions, greenhouse gas, National Inventory Report

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Samenvatting

Nederland ratificeerde het Klimaatverdrag van de Verenigde Naties (United Nations Framework Convention on Climate Change (UNFCCC)), en verplichtte zich daarmee tot een jaarlijkse rapportage over broeikasgasemissies via een NIR (National Inventory Report).

Een vast onderdeel hiervan is de onzekerheidsanalyse, die gebruikt wordt om mogelijkheden tot verbetering van de emissieberekeningen in beeld te brengen. De onzekerheidsanalyse richt zich op zowel de emissiehoeveelheid (nationaal totaal) voor het rapportagejaar als op de trend ten opzichte van het basisjaar 1990 (1995 voor F-gassen).

Voor de analyse wordt door Nederland de Tier 1- methodiek toegepast, zoals beschreven in de IPPC *Good practice Guidance and Uncertainty Management in Greenhouse Gas Inventories*. De Tier 1- methode gebruikt standaard vergelijkingen voor de foutenvoortplanting, en gaat uit van ongecorreleerde data met een normale verdeling voor de onzekerheden. Dit rapport geeft een overzicht en een onderbouwing van de gemaakte inschattingen voor de onzekerheidsanalyse in het NIR 2006, waarbij een vergelijking wordt gemaakt met eerdere jaren (vanaf 1999). Tevens is er een aanvulling met (kleine) actualisaties voor de jaren 2007 en 2008.

Naast de standaard Tier 1 analyse zijn ook uitgebreidere studies uitgevoerd (Tier2, Monte Carlo analyse). Deze hebben een groter detailniveau, houden rekening met mogelijke correlaties tussen de basisdata en beschouwen ook niet-normale verdelingen in de onzekerheden. Een door het Instituut voor Milieustudies (Olsthoorn and Pielaat, 2003) uitgevoerde studie gaf, uitgaande van dezelfde basisdata , voor de Tier 1- en Tier 2-analyse vergelijkbare uitkomsten voor de onzekerheden. In 2006 werd, in opdracht van SenterNovem, een nieuwe Tier 2-studie uitgevoerd door het Copernicus Instituut van de Universiteit Utrecht (Ramírez, 2006). Reden om een nieuwe studie te laten uitvoeren was een belangrijke wijziging in diverse methoden voor het berekenen van de emissies, waardoor ook de Tier 1-uitkomsten sterk waren gewijzigd. Ondanks dat bleek opnieuw dat de uitkomsten van Tier 1- en Tier 2, gegeven dezelfde basisdata, maar weinig van elkaar verschilden.

Het blijven toepassen van Tier 1 is dan ook goed te verdedigen, ook omdat het onwaarschijnlijk is dat de beschouwde onzekerheden snel (binnen enkele jaren) zullen veranderen.

Summary

The Netherlands signed the United Nations Framework Convention on Climate Change (UNFCCC), and, therefore, is bound to report its greenhouse gas emissions on an annual basis. Within the framework of the National Greenhouse Gas Inventory (NIR), annual uncertainty assessments are made, for both national total emissions and the trend, from the base year (1990, 1995 for F-gases) to the current year. These uncertainty assessments are used for identifying areas for improvement within the emissions inventory, as required by the Kyoto Protocol. Recommended methods for carrying out these assessments are incorporated in the IPCC report *Good practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*.

For the Dutch NIR, the simplified IPCC Tier 1 uncertainty analysis was used. This type of analysis uses standard error propagation equations and assumes that uncertainties in the potential key sources are all uncorrelated and have normal distributions. This report documents the uncertainty estimates which were used in the uncertainty assessment performed for the NIR 2006, and the changes made compared to previous NIRs, since the start of these assessments in 1999. It also documents the (limited) updates made in later submissions (2007 and 2008).

Next to the standard Tier 1 analysis, more comprehensive ones (Tier 2, Monte-Carlo based) were also carried out, with a more detailed level of aggregation, correlations between emission sources, and specific probability density functions. A study carried out by IVM (Institute for Environmental Studies, Olsthoorn and Pielaat 2003) showed that Tier 2 and Tier 1 uncertainty analyses, using similar underlying uncertainty data, result in similar magnitudes of overall uncertainty, in both level and trend.

A second Tier 2 project, commissioned by SenterNovem, was carried out by the Dutch Copernicus Institute for Sustainable Development and Innovation (Ramírez-Ramírez, 2006). The main reason for a new Tier 2 study was that, in 2004 and 2005, the methods for calculating emissions changed substantially. This resulted in large differences in the outcomes of the Tier 1 uncertainty analysis, before and after the recalculations. Despite the changes in emission calculation methods and outcomes, the new study again showed that the results of the Monte-Carlo analysis were of the same order of magnitude as the outcomes of Tier 1. In this way, the 2006 study supported the conclusion that it is justified to use Tier 1 as the main method for uncertainty analysis in the Dutch NIR.

1 Introduction

The purpose of this report is to document the uncertainty estimates used in the uncertainty assessment which was performed for the National Inventory Report (NIR) 2006, and the changes made compared to previous NIRs, since the start of these assessments in 1999. This report focuses on documenting the uncertainty estimates used in the NIR 2006, because that report was also used in the Kyoto Protocol for determining the so-called Assigned Amount, which is based on the base-year emissions (1990; 1995 for F-gases). Furthermore, this report also documents the limited updates in uncertainty estimates made in the later NIR submissions of 2007 and 2008.

Uncertainty assessments are a means of providing inventory users with a quantitative judgements on the inventory quality, and of directing the inventory preparation team to priority areas where improvements are warranted and may be feasible. The uncertainty estimates in the annual national total emissions and in the trend from the base year to the current year presented in the NIRs, are based on simplified uncertainty analyses that use error propagation equations, and, assuming that the uncertainties in the potential key sources are all uncorrelated, have normal distributions and are less than 60%. This is called the IPCC Tier 1 uncertainty analysis, as described in the report *Good practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000). This guideline also offers countries the possibility to choose a more comprehensive Monte Carlo based analysis, on a more detailed level of aggregation (Tier 2), but as this analysis is very resource intensive, the Netherlands annually reports uncertainties according to the Tier 1 method.

In 2002, a first Tier 2 analysis 'Sources of Uncertainties in the Dutch Emission Registration', commissioned by the Working Group Emissions Greenhouse Gases (in Dutch abbreviated 'WEB'), was carried out by the Institute for Environmental studies IVM (Olsthoorn and Pielaat, 2003). The broad objective was to investigate the viability of the IPCC Tier 2 uncertainty approach, within uncertainty management related to the annual production of the Dutch NIR. This Tier 2 uncertainty analysis, using a Monte Carlo method, took into account correlations between emission sources and specific probability density functions. The study showed that the Tier 2 and Tier 1 uncertainty analyses, using similar underlying uncertainty data, resulted in similar magnitudes of overall uncertainty calculations, both for level and trend uncertainty. The study concluded that there was no need to repeat a Tier 2 every year, because of the unlikelihood of uncertainties changing quickly over the years.

At the end of 2005, a second Tier 2 project, commissioned by SenterNovem, was carried out by the Copernicus Institute for Sustainable Development and Innovation (Ramírez-Ramírez et al., 2006). The main reason for a new Tier 2 study was that, in 2004 and 2005, the methods for calculating emissions changed substantially, resulting in substantial differences in the outcomes of the Tier 1 uncertainty analysis, before and after the recalculations. This Tier 2 study again showed that the results of the Monte-Carlo analysis are of the same order of magnitude as the Tier 1 outcomes. The study concluded that it seemed justified to use Tier 1 as the main method for uncertainty analysis in the NIR.

It should be stressed that most uncertainty estimates are ultimately based on expert judgments and, therefore, inevitably show a high degree of subjectivity. However, the reason for using these estimates was to identify the most important uncertain sources. For this purpose, an estimate of a reasonable order of magnitude of the uncertainty in activity data and in emission factors, proved to be sufficient. Moreover, the purpose of the uncertainty assessment was to help identify areas for improvement of the emissions inventory, as recommended by the IPCC *Good Practice Guidance* (IPCC, 2000), and as required by the national system requirements of the Kyoto Protocol. The protocol describes key quality assurance aspects of the emission estimation and reporting activities of industrialised countries that annually submit an updated inventory.

Structure of this report

First the different types of data sources of uncertainty estimates are provided, followed by the hierarchy of sources used in the Netherlands. Next, an overview is provided of the evolution of the uncertainty estimates since 1999. In chapter 2, the uncertainty in the NIR 2006 is presented, including some detailed assessments of particular source categories. In chapter 3, a summary is given of the changes in uncertainty estimates made from the NIR 2004 to the NIR 2005, and from the NIR 2002 to the NIR 2004. Finally, chapter 4 summarises recent information that is available to update the present uncertainty estimates. In the annexes, more details are provided about the derivation of some uncertainties (for road transport, agriculture and waste), the uncertainty estimates for the energy statistics, a summary of the IPCC default values from IPCC (1997), and the more detailed uncertainty assumptions made for the Tier 2 uncertainty assessment performed in 2005 to 2006.

1.1 Types of data sources

In general, there are six types of data sources of uncertainties in activity data and emission factors used in greenhouse gas emission inventories:

1. IPCC defaults from the Good Practice Guidance;
2. Country-specific values based on information about measurement accuracy or on the spread in multiple measurement values;
3. Country-specific reports that provide uncertainty estimates;
4. Other reports that provide estimates of the uncertainty in particular source categories;
5. Expert judgement by a group of experts;
6. Expert judgement by one expert, for example, the one responsible for the documentation of the source category in the NIR.

1.2 Approaches and data sources used in the Netherlands

Uncertainty estimates aim to show the uncertainties at the aggregation level of potential key sources suggested by the IPCC Good Practice Guidance. This enables a Tier 2 level and trend key source analysis of the greenhouse gas inventory, including the uncertainty in the emission estimates.

In the case of the Netherlands, the basis for the uncertainty estimates was the collective expert judgement of groups of experts – consisting of members of the PER Task Forces, other national sectoral experts, and RIVM/MNP/PBL experts responsible for the NIR report. The groups of experts participated in two workshops held in 1999 (one on emissions and one on the LUCF sector), the conclusions of which formed the basis for the greenhouse gas inventory improvement programme that started in 2000 (data source types 3,4, and 5, see above). Other country-specific uncertainty estimates were made in so-called factsheets compiled by RIVM[1)] as part of the quality assurance of the assessments made in the framework of the annual Environmental Balance of RIVM (type 5). For some sources, some reports documented uncertainty estimates from particular sources, for example, for energy consumption statistics by the statisticians from CBS (type 4 and 5), and for the uncertainty in the CO_2 emission factor for natural gas and coal (type 3). For CO_2 from petrol and diesel used in transport, the uncertainty in the country-specific CO_2 emission factors could be determined from the measurement data (type 2). In most cases, the uncertainty estimates were determined in the following order of preference:

1. country-specific expert judgements in the two workshops held in 1999;
2. other country-specific reports with documented uncertainty estimates;
3. IPCC Good Practice defaults;
4. other reports, when available, providing uncertainty estimates;
5. expert judgement by the author's team responsible for the documentation in the NIR.

In the last years, new information has become available, for example, through the Tier 2 uncertainty assessment projects conducted by IVM in 2003 and by the Utrecht University in 2006.

It is very important to know *that all uncertainty figures should be interpreted as corresponding to a confidence interval of 2 standard deviations (2σ), or 95%. For example, given an uncertainty of 10%, for a certain emission, this gives a total range of the given emission plus or minus ten percent.In cases where asymmetric uncertainty ranges were assumed, the largest percentage was used in the calculation.*

1.3 Procedures and history of uncertainty estimates used for the Dutch NIR

1. In 1999, in two workshops, Dutch experts from the PRTR and others from research institutes debated the quality of the then current inventory to quantify the uncertainties, identify the largest areas of uncertainty, and priority areas for improvement within the inventory. The uncertainties were partly country-specific and partly adopted from IPCC default values. Discussion papers and a summary of conclusions were published in workshop proceedings by Van Amstel et al. (ed.) (2000a/b).
2. To meet the UNFCCC reporting guidelines for the NIR (IPCC Tier 1 estimation of the annual and trend uncertainties per sector and per gas, and in the national total), and for an IPCC Tier 2 identification of key sources, NIR coordinator Olivier compiled a first set of uncertainties for activity data (AD) and emission factors (EF) for all (uncorrelated) sources used in the key source identification. For fossil-fuel use, this took into account the correlation between the sectoral energy data and CO_2 emission factors, so it was decided to split total stationary energy use and energy feedstocks, each into three fuel categories: natural gas, oil and coal.
3. These uncertainties were determined by expert judgment, by consulting the the following sectoral NIR and PER experts: Spakman and Montfoort (stationary energy and energy feedstocks); Van den Brink (transport); Peek (industrial sources); Van der Hoek (agriculture); Van der Born (LUCF); Beker and Van den Berghe (landfills); and Baas (wastewater).
4. The uncertainty values used were basically documented in:
   a. summary spreadsheet with source categories and uncertainty figures for AD and EF, possibly different for base year and current year, and a reference source for the value;
   b. spreadsheet for CH_4 and N_2O from transport (1A3);
   c. spreadsheet for agriculture (CH_4 from 4A, CH_4 from 4B, and N_2O from 4D);
   d. spreadsheet for CH_4 from landfills (6A).
5. The uncertainties used are based on the following inputs, in this order:

1) Now PBL

a. the outcome of these workshops (Van Amstel et al. (ed.), 2000a/b) with country-specific estimates of the uncertainty, for particular sources;
b. if no country-specific judgment was available: supplemented with IPCC default uncertainties from the IPCC Good Practice Guidance 2000;
c. more recent insights, if available;
d. own expert judgment, if no IPCC default were available.

6. Uncertainties were determined by order-of-magnitude estimates, for example, chosen from the following series: 1%, 2%, 5%, 10%, 20 to 25%, 50%, 100%, 200%.
7. The uncertainty values in this report are presented as half the 95% confidence interval (2 standard deviations) divided by the total (i.e. mean) and expressed as a percentage. In a few cases, where emission factors were based on many samples, we used the standard deviation of the mean (also called the standard error of the mean) as an expression of the uncertainty.
8. For some sources, such as enteric fermentation (CRF 4A), animal waste (CRF 4B), and landfills (6A), the uncertainty in the overall AD and EF is an aggregate of the uncertainty in the more detailed parameters, which were first selected at the lower level, and, subsequently, a calculated (4A, 4B) or heuristic (6A) estimate was made for the higher level uncertainties.
9. The uncertainties used were also documented in a number of RIVM/LAE factsheets for major emission sources (RIVM, 1999).
10. In subsequent years, the uncertainties in the list of EF were slightly updated for a few sources, when improved EF data was starting to be used.
11. In parallel, to gain insights into the limitation of the IPCC Tier 1 uncertainty assessment and the added value of a Tier 2 assessment, SenterNovem commissioned an IPCC Tier 2 uncertainty assessment project, carried out by IVM (Olsthoorn and Pielaat, 2003). For this project, IVM compiled its own list of uncorrelated source categories for which they wanted to make the Tier 2 assessment. Also, they consulted other experts than the ones who estimated the IPCC Tier 1 uncertainties. Unfortunately, this sometimes resulted in other uncertainty values, inconsistent with the uncertainty values reached at a higher aggregation level for the IPCC Tier 1 uncertainty assessment. IVM did not include any correlations between emission sources in their calculation. However, this project did result in new insights into the actual uncertainty and uncertainty causes for a number of sources.
12. In the NIR 2005, additional and updated values were used for some of the newly introduced key sources and for a number of old ones. This was based on consultation with the PRTR expert, for sources where major changes were made in the methodology, activity data, or emission factors used. This update included major NO_x, NH_3 and non-methane volatile organic compounds (NMVOC) sources (Van Gijlswijk et al., 2004). For NMVOC sources, an uncertainty estimate was made based on a more detailed assessment of underlying uncertainties. This resulted in updates of NMVOC from solvents (activity data for indirect CO_2 reported in sector 3), and in national total NO_x and NH_3 emissions (activity data for indirect N_2O in source category 2G).
13. When all the major inventory improvements were carried out and new information on the background and quality of activity data and emission factors had become available – for the new ones but also for some of the older ones – it was time to update the set of uncertainties used for prioritising the future monitoring of greenhouse gas emissions and the Tier 2 key source identification. This new set of uncertainties is presented in Annex 7 of the NIR 2006.
14. In 2006, new information on the CO_2 emission factor for natural gas led to the selection of a new national average emission factor and a new uncertainty estimate for this value.
15. In 2005 and 2006, a second Tier 2 uncertainty assessment of the Netherlands greenhouse gas inventory was carried out by Utrecht University (Ramírez et al., 2006, 2008), bearing in mind the lessons learned from the previous activities: (1) use uncertainty estimates compatible with the Tier 1 assessments made for the NIR; (2) for final determination of the uncertainty values consult the same experts as were responsible for these estimates; (3) explicitly include correlations (if they can be identified and were not taken into account in the Tier 1 approach); (4) as a follow-up, organise a new expert review to update the uncertainties in view of any new material available.

Uncertainties in the NIR 2006

2

The uncertainties used for the key source assessment in the NIR 2006 are summarised in Table 2.1. In the remainder of this chapter, the uncertainties are discussed per IPCC sector, as well as the underlying assumptions to calculate them, when applicable.

2.1 Energy sector

2.1.1 Stationary combustion, activity data

The five most important fuels that cover the largest part of fossil-fuel consumption in the Netherlands, are:

1. natural gas (all sectors), covering 45 to 47% of total CO_2 from fuel combustion;
2. hard coal (mainly in public power generation) and coke (mainly in iron and steel production), covering almost 20% of the 1A total CO_2, of which 16 to 17% in public power generation (including BF and CO gas);
3. petrol and diesel (mainly in transport, predominantly in road transport), accounting for 17 to 20% of the fuel combustion total (including LPG).

These coal and coke uses capture 95 to 99% of total CO_2 from solid fuel combustion, whereas petrol, diesel and LPG in road transport capture 60% of total CO_2 from liquid fuel combustion. The major part of the remaining CO_2 from liquid fuel combustion stems from refineries (decreasing from 20 to 17%) and the chemical industry (varying around 10%), including the use of refinery gas, but not taking into account residual chemical gas.

The uncertainties for gaseous fuels relate to natural gas only; uncertainties for other fuels relate to the fossil-fuel waste component in waste incineration. Liquids in the road transport sector refer to petrol, diesel and LPG. Liquid and solid fuels in stationary combustion include an explicit estimate for so-called derived gases:

- refinery gas and residual chemical gas, which are part of liquid fuels;
- blast furnace gas or oxygen furnace gas, and coke oven gas, which are part of solid fuels.

The uncertainties in the activity data for the energy sector were updated in 2005, based on uncertainty estimates from the energy statistics division of CBS (Statistics Netherlands) which were published in the report on the Protocol on Energy Conservation, and on new insights gained from the energy and CO_2 recalculation project, performed by CBS (Huurman, 2005). Table 2.2 shows the most recent uncertainty estimates, as used in the uncertainty assessment of the NIR 2006.

The accuracy of fuel consumption data in power generation (1A1a) and oil refineries (1A1b), generally, is considered to be very high. The used volumes of natural gas are (very) well known, therefore, the uncertainty was estimated by CBS at 0.5%. Both solid fuels used in power generation and liquid fuels used in refineries have a larger estimated uncertainty of 1% and 10%, respectively, based on the share of blast furnace gas in total solid consumption, and the 'unaccounted-for liquids' calculated for refineries. For other fuels, we used a 10% uncertainty, which refers to the amount of fossil-fuel waste being incinerated and, thus, to the uncertainties in the total amount of waste and the fossil and biomass fractions.

The consumption of gas and liquid fuels in the 1A1c category is mainly by the oil and gas production industry itself, where splitting the consumption into use and venting/flaring proved to be quite difficult. Thus this carries a large uncertainty of 20%.

The large uncertainty in activity data in the 1A4 source category, in particular, in the service sector (subcategory 1A4a), is due to the allocation of the remainder of total national energy consumption per fuel type – that is, after subtraction of the amounts attributed to the subcategories 1A1, 1A2, 1A3, 1A4b/c, and 1A5.

An uncertainty of 20% is assumed for liquid fuel use in 'Off-road Machinery and Fisheries', and in the other categories under 1A4.

2.1.2 Stationary combustion, emission factors

CO_2 Natural gas

The 1% uncertainty in the emission factor of 56.1 kg CO_2/GJ from natural gas, is based on information by Gasunie. Van Harmelen and Koch (2002) analysed the emission factor for standard Groningen gas (G-gas, a mixture of gas from the Slochteren reservoir and high calorific gas from other small gas fields), and so-called High calorific gas (H-gas), produced

Emissions and uncertainty estimates in the key source analysis of the NIR 2006

Table 2.1

IPCC	Category	Gas	CO_2 eq 1990 (Gg)	CO_2 eq 2004 (Gg)	AD unc (%)	EF unc (%)	EM 2004 unc (%)
1A1a	Stationary combustion: Public Electricity and Heat Production: liquids	CO_2	206	2,230	0.5	10	10
1A1a	Stationary combustion : Public Electricity and Heat Production: solids	CO_2	25,776	27,004	1	3	3
1A1a	Stationary combustion : Public Electricity and Heat Production: gases	CO_2	13,348	25,488	0.5	1	1
1A1a	Stationary combustion : Public Electricity and Heat Production: waste incineration	CO_2	592	1,750	10	5	11
1A1b	Stationary combustion : Petroleum Refining: liquids	CO_2	9,999	9,556	10	10	14
1A1b	Stationary combustion : Petroleum Refining: gases	CO_2	1,042	2,267	0.5	1	1
1A1c	Stationary combustion : Manuf. of Solid Fuels and Other En. Ind.: liquids	CO_2	2	1	20	2	20
1A1c	Stationary combustion : Manuf. of Solid Fuels and Other En. Ind.: gases	CO_2	1,418	1,978	20	5	21
1A2	Stationary combustion : Manufacturing Industries and Construction, liquids	CO_2	8,788	7,502	1	5	5
1A2	Stationary combustion : Manufacturing Industries and Construction, solids	CO_2	5,195	4,384	2	10	10
1A2	Stationary combustion : Manufacturing Industries and Construction, gases	CO_2	19,020	15,402	2	1	2
1A4	Stationary combustion : Other Sectors, solids	CO_2	189	134	50	5	50
1A4a	Stationary combustion : Other Sectors: Commercial/Institutional, gases	CO_2	6,653	11,057	20	1	20
1A4b	Stationary combustion : Other Sectors, Residential, gases	CO_2	18,696	18,786	5	1	5
1A4c	Stationary combustion : Other Sectors, Agriculture/Forestry/Fisheries, gases	CO_2	8,328	7,041	10	1	10
1A4c	Stationary combustion : Other Sectors, Agriculture/Forestry/Fisheries, liquids	CO_2	2,522	2,656	20	2	20
1A4	Stationary combustion : Other Sectors, liquids excl. From 1A4c	CO_2	1,479	451	20	2	20
1A5	Military use of fuels (1A5 Other)	CO_2	566	437	20	2	20
1A	Emissions from stationary combustion: non-CO_2	CH_4	523	557	3	50	50
1A	Emissions from stationary combustion: non-CO_2	N_2O	218	231	3	50	50
1A3b	Mobile combustion: road vehicles: petrol	CO_2	10,902	13,168	2	0.4	2
1A3b	Mobile combustion: road vehicles: diesel oil	CO_2	11,832	19,542	5	0.2	5
1A3b	Mobile combustion: road vehicles: LPG	CO_2	2,738	1,131	10	0.2	10
1A3	Mobile combustion: waterborne navigation	CO_2	405	832	20	0.2	20
1A3	Mobile combustion: aircraft	CO_2	41	41	50	0.5	50
1A3	Mobile combustion: other (railways)	CO_2	91	109	5	0.2	5
1A3	Mobile combustion: other (non-road)	CH_4	1	1	50	100	112
1A3	Mobile combustion: other (non-road)	N_2O	1	3	50	100	112
1A3	Mobile combustion: road vehicles	CH_4	157	67	3	60	60
1A3	Mobile combustion: road vehicles	N_2O	271	485	5	50	50
1B2	Fugitive emissions venting/flaring	CH_4	1,252	310	2	25	25
1B2	Fugitive emissions from oil and gas operations: gas distribution	CH_4	255	268	2	50	50
1B2	Fugitive emissions from oil and gas operations: other	CH_4	162	149	20	50	54
1B1b	CO_2 from coke production	CO_2	403	509	50	2	50
1B2	Fugitive emissions venting/flaring: CO_2	CO_2	769	124	50	2	50
2A1	Cement production	CO_2	416	446	5	10	11
2A3	Limestone and dolomite use	CO_2	276	297	25	5	25
2A7	Other minerals	CO_2	308	411	25	5	25
2B1	Ammonia production	CO_2	3,096	3,086	2	1	2
2B2	Nitric acid production	N_2O	6,330	5,617	10	50	51
2B5	Caprolactam production	N_2O	1,240	759	50	50	71
2B5	Other chemical product manufacture	CO_2	717	786	50	50	71
2C1	Iron and steel production (carbon inputs)	CO_2	2,514	1,105	3	5	6
2C3	CO_2 from aluminium production	CO_2	395	479	2	5	5
2C3	PFC from aluminium production	PFC	1,901	106	2	20	20
2F	SF6 emissions from SF6 use	SF6	301	328	50	25	56
2F	Emissions from substitutes for ozone depleting substances (ODS substitutes): HFC	HFC	249	1,023	10	50	51
2E	HFC-23 emissions from HCFC-22 manufacture	HFC	5,759	354	10	10	14
2E	HFC by-product emissions from HFC manufacture	HFC	12	99	10	20	22
2F	PFC emissions from PFC use	PFC	37	179	5	25	25
2G	Other industrial: CO_2	CO_2	347	342	5	20	21
2G	Other industrial: CH_4	CH_4	297	309	10	50	51
2G	Other industrial: N_2O	N_2O	3	7	50	50	71
2G	Indirect N_2O from NH_3 from combustion and industrial processes	N_2O	52	56	50	200	206
2G	Indirect N_2O from NO_2 from combustion and industrial processes	N_2O	883	637	15	200	201
3	Indirect CO_2 from solvents/product use	CO_2	316	144	25	10	27
4A1	CH_4 emissions from enteric fermentation in domestic livestock: cattle	CH_4	6,767	5,712	5	20	21
4A8	CH_4 emissions from enteric fermentation in domestic livestock: swine	CH_4	439	351	5	50	50
4A	CH_4 emissions from enteric fermentation in domestic livestock: other	CH_4	319	286	5	30	30

IPCC	Category	Gas	CO_2 eq 1990 (Gg)	CO_2 eq 2004 (Gg)	AD unc (%)	EF unc (%)	EM 2004 unc (%)
4B	Emissions from manure management	N_2O	694	707	10	100	100
4B1	Emissions from manure management : cattle	CH_4	1,574	1,475	10	100	100
4B8	Emissions from manure management : swine	CH_4	1,141	919	10	100	100
4B9	Emissions from manure management : poultry	CH_4	243	56	10	100	100
4B	Emissions from manure management : other	CH_4	12	16	10	100	100
4D1	Direct N_2O emissions from agricultural soils	N_2O	4,597	4,839	10	60	61
4D3	Indirect N_2O emissions from nitrogen used in agriculture	N_2O	4,861	3,209	50	200	206
4D2	Animal production on agricultural soils	N_2O	1,308	651	10	100	100
5A1	5A1. Forest Land remaining Forest Land	CO_2	-2,505	-2,289	25	61.8	67
5A2	5A2. Land converted to Forest Land	CO_2	-11	-159	25	57.9	63
5B2	5B2. Land converted to Cropland	CO_2	-36	-36	25	50	56
5C1	5C1. Grassland remaining Grassland	CO_2	4,246	4,246	25	50	56
5C2	5C2. Land converted to Grassland	CO_2	-51	-51	25	61.2	66
5E2	5E2. Land converted to Settlements	CO_2	-152	-152	25	50	56
5F2	5F2. Land converted to Other Land	CO_2	717	717	25	50	56
5G	5G. Other (liming of soils)	CO_2	183	79	25	1	25
5A1	5A1. Forest Land remaining Forest Land	N_2O	0	0	25	20	32
6A1	CH_4 emissions from solid-waste disposal sites	CH_4	12,011	6,521	30	15	34
6B	Emissions from wastewater handling	CH_4	290	225	20	25	32
6B	Emissions from wastewater handling	N_2O	513	399	20	50	54
6D	OTHER CH_4	CH_4	1	72	20	25	32
3, 6D	OTHER N_2O	N_2O	250	139	20	50	54
	TOTAL EMISSIONS		216,700	220,151			

Uncertainties for 2B2 (N_2O emissions from nitric acid production) and 2B5 (caprolactam production) have been updated in the NIR 2008 to 10% (AD) and 20% (EF) in 2B2 and to 20% (AD and EF) in 2B5. This results in an uncertainty in the emissions of 22% and 28% (vs. 51% and 71% listed here).

from other, smaller gas fields. The study concluded that the average mix had an emission factor very close to that of pure Slochteren gas (with an emission factor of 56.1 kg CO_2/GJ), since G-gas is the most-used gas in the Netherlands, and analysed H-gases differed only by up to about 0.5% for the 56.1 kg CO_2/GJ value for G-gas. This value falls within the uncertainty range of 1% estimated by Gasunie for Slochteren gas. Also, for one Dutch importer of British H-gas, the average emission factor appeared to be within this uncertainty range. This 1% uncertainty for natural gas was also used in the study by Olsthoorn and Pilaat (2003).

This study also showed the sensitivity of the CO_2 emission factor in the methane/ethane ratio, and, for comparison (in their Table 3.21), presented emission factors for natural gas from other sources: H-gas from Ekofisk (56.7), L-gas Enriched (56.4), and gas from Algeria (56.3).)

Recently, Gasunie Transport Services (GtS) provided new information on the emission factor of natural gas. This information was based on routine measurements carried out in 2003 and 2004, at 35 distribution stations. The results indicate that the average CO_2 emission factor for natural gas (56.1 kg/GJ) is underestimated. Further analyses showed that both qualities of natural gas delivered to customers within the Netherlands – G-gas and H-gas – have significantly larger average CO_2 emission factors than the factor for pure Slochteren gas (Vreuls, 2006). A very detailed analysis of the measurement data showed that, for 2003 and 2004, the national average weighted emission factor was 56.8 kg CO_2/GJ. A second analysis of the data showed that the national average emission factor for 1990 had the same value. Therefore, the value of 56.8 was applied to the whole time series of 1990 to 2004. For natural gas, the uncertainty in the CO_2 emission factor is now estimated to be 0.25%, based on the recent fuel quality analysis reported by Heslinga and Van Harmelen (2006); however this value has not been used yet in the recent NIRs (2006, 2007, 2008).

CO_2 Solid fuels

For hard coal (bituminous coal), an analysis was made of its use in power generation (Van Harmelen and Koch, 2002); for coking coal, the analysis was done for coke ovens (CO) and blast furnaces (BF). For CO gas and BF gas, the emission factors were based on a three-year average (2000 to 2002) of plant-specific values, reported by Corus (2004). For the default power plant factor, 94.7 CO_2/GJ was the mean value of 1270 samples in 2000, with an accuracy of about 0.5%. For 1990 and 1998, the emission factor varied by about 0.9 CO_2/GJ (see Table 4.1 in Van Harmelen and Koch., 2002), so in applying the default factor to other years, the uncertainty is apparently larger, about 1%. For coke production (1B1), based on the variability of the accuracy in the C contents, the uncertainty in the default factors for the coking coal was about 3%, whereas for coking coal injected in blast furnaces. in the iron and steel production (1A2a), the uncertainty was about 7% (average of plant-specific values for three subsequent years). The same analysis for the default CO_2 emission factors for coke oven gas and blast furnace gas showed uncertainties of about 10% and 15%, respectively (data reported by Corus, 2004). Since BF/OF gas has a share of 15 to 20% in total solid-fuel emissions from power generation, the overall uncertainty in the emission factor for that subcategory is about 3%. For the CO_2 emission

Uncertainty estimates for activity data and emission factors in stationary fuel combustion (1A1, 1A2, 1A4) **Table 2.2**

Sector	Activ-ity data	Emission factors			AD unc based on: 6)	EF unc based on: 6)
		CO_2	CH_4	N_2O		
	±2σ (%)	±2σ (%)	±2σ (%)	±2σ (%)		
1A- FUEL COMBUSTION						
	3	–	50	50	R	R
1.A.1-Energy industries						
1.A.1.a. Public electricity and heat production						
Liquid fuels	0.5	10 1)			R (2)	R
Solid fuels	1	3 2)			R	R
Gaseous fuels	0.5	0.25 3)			R (2)	M (3)
Other fuels	10	5			R (1)	R
1.A.1.b. Petroleum refining						
Liquid fuels	10	10			R (2)	R (2)
Gaseous fuels	0.5	0.25			R (2)	M (3)
1.A.1.c. Manufacture of solid fuels and other energy industries						
Liquid fuels	20	2			R	R (1)
Gaseous fuels	20	5			R	R
1.A.2-Manufacturing Industries and construction						
Liquid fuels	1	5 4)			R (2)	R
Solid fuels	2	10 5)			R (2)	R (2)
Gaseous fuels	2	0.25			R (2)	M (3)
1.A.4-Other sectors						
Liquid fuels	20	2			R (2)	R
Solid fuels	50	5			R (2)	R
Gaseous fuels	See 1A4a,b,c.	See 1A1a,b,c.				
Biomass	25	5			R	R
1.A.4.a. Commercial/institutional						
Liquid fuels						
Solid fuels						
Gaseous fuels	20	0.25			R	M (3)
1.A.4.b. Residential						
Liquid fuels						
Solid fuels						
Gaseous fuels	5	0.25			R (2)	M (3)
1.A.4.c. Agriculture/forestry/fisheries						
Liquid fuels	20	2			R (2)	R
Solid fuels						
Gaseous fuels	10	0.25			R (2)	M (3)

1) 0% (1990) to 100% residual chemical gas.
2) 15 to 20% blast furnace gas.
3) In the NIR 2006, 2007, and 2008, an uncertainty of 1% was used for the CO_2 emission factor of natural gas.
4) 50% chemical residual gas.
5) iron and steel sector: 66% blast furnace/oxygen furnace gas
6) Documented as D [= Default of IPCC source category], R [= National Referenced data], or M [= Measurement based].
References: (1) Van Amstel et al., 2000, (2) Huurman, 2005, (3) Heslinga and Van Harmelen, 2006.

factor for solid-fuel use in category 1A4, an uncertainty of 5% was assigned.

CO_2 Liquid fuels
For the other major oil uses in refineries and in the (chemical) industry, the uncertainty is estimated at 10% and 5%, respectively, taking into account that 40 to 50% of the refinery CO_2 from liquid fuel stems from refinery gas (or 70-85% including unaccounted for liquid fuel) and that about half of the CO_2 emissions in the (chemical) industry stem from residual chemical gases. An uncertainty of 2% was assigned to the CO_2 emission factor for liquid fuel use in category 1A4.

CH_4 and N_2O from stationary combustion
The uncertainty in the methane (CH_4) factor for stationary combustion was estimated at 50%, since the emission factors were made up from a multi-sectoral aggregate, except for biofuels where we used the IPCC default uncertainty of 80%. For nitrous oxide (N_2O) from stationary combustion the uncertainty in the emission factor was estimated at 50%.

2.1.3 Emissions from stationary combustion

Energy industries (1A1) and Manufacturing industries (1A2)
The uncertainty in the source categories Energy industries (1A1) and Manufacturing industries (1A2) was estimated to be 4% and 3%, respectively, in annual CO_2 emissions from combus-

Uncertainty estimates for activity data and emission factors in 1A3 transport and 1A5 others — **Table 2.3**

Sector	Activity data	Emission factors			AD unc based on: [1)]	EF unc based on: [1)]
		CO_2	CH_4	N_2O		
	2σ (%)	2σ (%)	2σ (%)	2σ (%)		
1.A.3-Transport						
1.A.3.a. Civil aviation						
Liquid fuels	50	0.5	100	100	R (2)	R (4)
1.A.3.b. Road transportation						
Petrol	2	0.4	76	66	R (4)	CO_2 M (5), R (4)
Diesel oil	5	0.2	77	82	R (4)	CO_2 M (5), R (4)
LPG	10	0.2	96	101	R (4)	CO_2 M (5), R (4)
1.A.3.c. Railways						
Liquid fuels	5	0.2	100	100	R (4)	R
1.A.3.d. Navigation						
Liquid fuels	20	0.2	100	100	R (4)	R
1.A.5-Others						
1.A.5.b. Mobile (Military use)						
Liquid fuels	20	2	100	100	R (2)	R

1) Documented as D [= Default of IPCC source category], R [= National Referenced data], or M [= Measurement based].
References: (1) Van Amstel et al., 2000, (2) Huurman, 2005, (4) Van den Brink (in Olivier et al., 2002), (5) Olivier, 2004

tion. The 'other' manufacturing industry (1A2f) included the use of off-road machinery in building and construction, and other uses (except in agriculture).

Other sectors (services, residential, agriculture and fisheries) (1A4)

The energy consumption data on the total category 1A4 'Other sectors', is much more accurate than the data on the subsectors. In particular, energy consumption in the commercial subsector, and - to a lesser extent - the agricultural subsector, was less accurately monitored than in the residential sector.

Therefore, trend conclusions for these subcategories should be treated with some caution. The uncertainty for the 1A4 category as a whole was estimated to be 10% in annual emissions of CO_2, the uncertainty in CH_4 and N_2O emissions was estimated to be much larger (about 50% and 100%, respectively)

2.1.4 Activity data on mobile combustion

Table 2.3 shows the uncertainty estimates used in the transport sector. The uncertainty in fuel use by road vehicles was estimated to be 2% for petrol, 5% for diesel oil, and 10% for LPG. These uncertainty estimates were based on an analysis according to the national approach (based on vehicle-kilometre statistics), and the IPCC approach (based on fuel deliveries to fuelling stations). For petrol, the differences between the two approaches were found to be in the range of 0 to 3%. If we assume the uncertainty in fuel used to be 0%, then the uncertainty can be calculated as ((3-0)/2) = 1.5% and rounded at 2% (see bullet 6 in section 1.3). For diesel oil, the differences between the two approaches were in the range of 9 to 18%. Using the same assumption as for petrol, the uncertainty was calculated at 4.5% and rounded at 5%. For LPG, the differences between the two methods were found to be in the range of 9 to 35%. From this range, the uncertainty was calculated to be 13%; rounded at 10%. The uncertainty in fuel used by 'Civil Aviation' was estimated to be about 50%, while for 'Navigation', this was 20%. The accuracy of military fuel consumption data (1A5) was tentatively estimated at 20%.

2.1.5 Emission factors for mobile combustion

For petrol and diesel fuel, the national default was determined from the C contents of 50 fuel samples of both fuels, covering summer and winter qualities and the uncertainty in the mean value: 0.4 and 0.2% for petrol and diesel fuel, respectively. For LPG in road transport, the uncertainty was estimated at 0.2%. For the uncertainty in the CO_2 emission factor for railways and navigation, the same value was chosen as that for diesel in road transport.

For the uncertainty in emissions factors of CH_4 and N_2O from road transport, the overall emission-factor uncertainty was estimated from uncertainties in the emission factors for petrol, diesel and LPG used in passenger cars, with and without catalytic converter, in freight vans, and for diesel used in trucks, buses, and other road transport, resulting in an uncertainty of about 60% for CH_4 and about 50% for N_2O, from the total road transport (see Tables 2.4 and 2.5). In all other transport modes, the uncertainty in the CH_4 and N_2O emission factor was estimated at 100%.

2.1.6 Emissions from mobile combustion

Road transport (1A3b)

The uncertainty in CO_2 emissions from road transport was estimated to be 3% in annual emissions. For CH_4, this was estimated to be about 50%. Data on the share of CH_4 in VOC were based on information in Veldt and Van der Most (1993) and have not been validated since.

Possibly, the mass fraction of CH_4 has changed, for example, because of recent changes in the aromatic content of road-transport fuels or improvements in exhaust after-treatment

Uncertainty estimates for N2O emission factors for 1A3 transport

Table 2.4

N_2O	Activity data uncert. 2σ (%)	Emission factor uncert. 2σ (%)	Emissions in 1990 (Gg) (NIR 2001)	Emissions in 1999 (Gg) (NIR 2001)
Road transportation				
passenger cars petrol with catalytic conv.	25	100	1.08	2.03
passenger cars petrol without catalytic conv.	25	50	0.54	0.19
passenger cars diesel	25	50	0.29	0.29
passenger cars LPG	25	100	0.46	0.64
freight vans petrol	25	100	0.03	0.04
freight vans diesel	25	50	0.25	0.37
freight vans LPG	25	50	0.01	0.04
freight trucks and buses	25	100	2.08	1.59
Other road transport	50	50	0.09	0.06
Road transport total			4.84	5.26
per fuel type (calculated for 1990)				
Petrol	2	66	1.75	2.32
diesel	5	82	2.62	2.25
LPG	10	101	0.47	0.69

Uncertainty estimates for CH4 emission factors for 1A3 transport

Table 2.5

CH_4	Activity data uncert. 2σ (%)	Emission factor uncert. 2σ (%)	Emissions in 1990 (Gg) (NIR 2001)	Emissions in 1999 (Gg) (NIR 2001)
Road transportation				
passenger cars petrol with catalytic conv.	25	100	0.48	1.42
passenger cars petrol without catalytic conv.	25	100	4.19	1.26
passenger cars diesel	25	100	0.16	0.09
passenger cars LPG	25	100	0.50	0.14
freight vans petrol	25	100	0.37	0.14
freight vans diesel	25	100	0.15	0.11
freight vans LPG	25	100	0.04	0.03
freight trucks and buses	25	100	0.80	0.31
Other road transport	50	100	0.83	0.70
Road transport total			7.52	4.19
per fuel type (calculated for 1990)				
petrol	2	76	5.87	3.51
diesel	5	77	1.11	0.51
LPG	10	96	0.53	0.17

technology. The uncertainty in N_2O emissions from road transport was estimated to be 50% in annual emissions. Current emissions from heavy-duty diesel vehicles were probably overestimated, but, for the whole period, the overestimation affected the emission trend only slightly.

Other modes of transport (shipping, aviation, other) (1A3d, a and e)

The uncertainty in CO_2 emissions from domestic aviation and from other transport was estimated to be about 50% in annual emissions from aviation, and 20% in annual shipping emissions. The uncertainty in CH_4 and N_2O emissions from non-road transport was estimated to be about 100% in annual emissions. Data on the share of CH_4 in total VOC were based on information in Veldt and Van der Most (1993) and have not been validated since.

Others (military shipping and military aviation) (1A5)

The uncertainty in CO_2 emissions from military shipping and military aviation was tentatively estimated to be about 20% in annual emissions. For the negligible CH_4 and N_2O emissions this was estimated to be about 100%.

Uncertainty estimates for activity data and emission factors in the non-combustion and fugitive emissions sector (1B) **Table 2.6**

Sector	Activity data	Emission factors			AD unc based on: [1)]	EF unc based on: [1)]
		CO_2	CH_4	N_2O		
	2σ (%)	2σ (%)	2σ (%)	2σ (%)		
1.B.1.b-Solid fuel transformation[2)]						
Coke production	50	20*	50	--	R (1)	R (1)
1.B.2-Fugitive emissions from venting and flaring						
1.B.2.b. ii Distribution						
CH_4	2	--	50	--	R (2)	M (2)
1.B.2.c. Venting and flaring						
CO_2	50	2	--		R (1)	R (1)
CH_4	2		25		R (1)	R (1)
1.B.2. Other						
CH_4	20	--	50	--	R (1)	R(1)

1) Documented as D [= Default of IPCC source category], R [= National Referenced data], or M [= Measurement based].
2) To be corrected in the NIR 2007: uncertainty in CO_2 emission factor of 20% instead of 2% (as used in the NIR 2006).
References: Huurman and Olivier (pers. comm., 2007), Gastec/KIWA (2005); this report.

2.1.7 Non-combustion or related sources of fugitive emissions (1B)

Fugitive emissions from solid fuels (coke manufacture) (1B1), activity data

CO_2 emissions were calculated from the calculation model below: a carbon balance with coking coal as input, and coke and coke oven gas as output:

CO_2 from coke and coal inputs = amount of coke * EF_{coke} + amount of coal * EF_{coal} – (blast furnace gas + oxygen oven gas produced) * EF_{BFgas}

The uncertainty in coking coal input was estimated at 1% (assuming the same accuracy as for coal use in power plants), and the coke and coke oven gas outputs at 2% and 20%, respectively. The uncertainty of 20% in the amount of coke oven gas produced, reflected the interannual variation in resulting net CO_2 emissions per tonne of coke produced, which can be up to 25% (see Table 3.42 in NIR 2005). The accuracy of the C content in these fuels was estimated at 3% for coking coal, vs. 1% for coke and 15% for coke oven gas (Corus, personal communication 2004). This resulted in an overall uncertainty in the activity data of about 45% (rounded at 50%), which is quite large given the relatively low uncertainties for the separate terms in the carbon balance.

Fugitive emissions from solid fuels (coke manufacture) (1B1), emission factors

The uncertainty in the implied emission factor of CO_2 was estimated at 20%, based on the interannual variation of the CO_2 emissions per tonne of coke produced (see Table 3.42 in NIR 2005). The large uncertainty in the CO_2 emission factor also reflects the way in which these emissions were calculated. The uncertainty in the CH_4 emission factor was estimated at 50%.

Methane from gas distribution (1B2), activity data and emission factors

The IPCC Tier 3 approach for CH_4 from 'gas distribution' (1B2) was based on two country-specific emission factors: 610 m^3 (437 Gg) methane from grey cast iron, and 120 m^3 (86 Gg) from other materials per 1000 kilometres of pipeline, both due to leakages. These emission factors were based on seven measurements of leakage per hour from grey cast iron, at one pressure level, and on 18 measurements, at three pressure levels, from other materials (PVC, steel, nodular cast iron and PE). Subsequently, the results were aggregated to factors for the material mix in 2004. From 2004 onwards, the gas distribution sector annually recorded the number of leaks found per substance, and any future trends in the emission factors will be derived from these data.

For CH_4 from gas distribution, the uncertainty in the emission factors was estimated at 50%. This uncertainty referred to the limited number of measurements, per gas leak, for different types of substances and pressures, on which the Tier 3 approach of methane emissions from gas distribution was based. The uncertainty in the length of pipeline, per substance, was estimated at 2% (based on apparent inconsistencies in the time series of subsequent surveys).

Emission factors for venting and flaring) (1B2)

The uncertainty in the emission factor of CO_2 from gas flaring and venting (1B2) was estimated at 2%, for flaring, taking into account the variability in the gas composition at the smaller gas fields, and, for venting, taking into account the variability in CO_2 gas produced at a few locations where CO_2 is extracted and subsequently vented.

For CH_4 from fossil fuel production, the uncertainty in the emission factors was estimated at 25% for gas venting, and 50% for gas distribution. These uncertainties referred to the changes in reported emissions from venting in the oil and gas production industry, over the previous years, and to the limited number of measurements, per gas leak, for different types of substances and pressures, on which the Tier 2 approach for methane emissions from gas distribution was based.

Emissions from non-combustion or related sources

The uncertainty in annual CO_2 emissions from coke production (1B2) was estimated to be about 50%. For the annual CO_2 emissions from gas flaring and venting this was about 50%. The uncertainty in annual methane emissions was estimated to be 25% from oil and gas production (venting), and 50% from gas transport and distribution (leakage).

2.1.8 Feedstocks and use of residual chemical gas

CO_2 emissions from this group comprise:

- industrial process emissions (sector 2), with a share decreasing from a third to a fifth;
- combustion emissions from blast furnace gas and residual chemical gas (sector 1A), which share increased to about 70%;
- fossil waste incineration (in 1A1a), which share increased from 3 to 7%;
- product-use emissions (sector 3).

Uncertainty in emissions from the production of soda ash and ammonia, was estimated at about 5% For most other sector 2 sources, this was about 10%. Emissions from residual chemical gas combustion, reported in sector 1A, were also less accurate, about 10%, due to the variability of their carbon content. CO_2 emissions from waste incineration may have a similar uncertainty, due to the limited accuracy of both total activity data and the underlying composition and fossil carbon fraction of the various waste types

2.1.9 International marine and aviation bunkers

The uncertainty in CO_2 emissions from international bunkers was estimated to be about 2%, annually (Boonekamp et al., 2001).

2.2 Industrial processes (2)

Table 2.7 shows the uncertainty estimates used for activity data and emission factors. for the key source assessment in industry, sector 2. Most of these estimates were made in 2002, except for the ones that were identified or recalculated for the NIR 2005.

2.2.1 Mineral products (2A)

Uncertainty estimates were based on expert judgements, since no detailed information was available for assessing the uncertainties in the emissions reported by the producers (Cement clinker production, Limestone and dolomite use, and Soda ash production).

The uncertainty in CO_2 emissions from cement production was estimated to be about 10%, annually (IPCC Tier 2 default uncertainty); based on 5% uncertainty in activity data – concerning the production of cement clinkers, as reported by the only Dutch company that produces them – and 10% in the CO_2 emission factor.

For limestone/dolomite use and 'other minerals' (soda ash use and glass production), an uncertainty of 25% was used, as a result of the relatively large uncertainty in the activity data (25%). The uncertainty in the CO_2 emission factor was estimated at 5%.

2.2.2 Chemical industry (2B)

Uncertainty estimates were based on expert judgements, since no accurate information was available for assessing the uncertainties in the emissions reported by the producers (i.e. ammonia, nitric acid, caprolactam production). Emissions from HCFC-22 manufacture were reported under category 2E.

CO_2 from ammonia production

The uncertainty in CO_2 emissions from ammonia was estimated to be about 2%,(2% in activity data and 1% in emission factor). For other chemicals production, this uncertainty was estimated to be about 70%, as the result of a 50% uncertainty in activity data and a 50% uncertainty in the CO_2 emission factor.

N_2O from nitric acid and caprolactam production

The uncertainty in N_2O emissions from nitric acid was estimated to be about 50%, resulting from an uncertainty in activity data of 10% and 50% in the N_2O emission factor. The uncertainty in annual N_2O emissions from caprolactam production was estimated to be about 70% (based on uncertainties of 50% in activity data and 50% in the N_2O emission factor).

2.2.3 Metal production (2C)

The uncertainty in annual CO_2 emissions was estimated at about 5% for iron and steel production (carbon inputs); based on 3% uncertainty in activity data and 5% in the CO_2 emission factor.

For aluminium production, the uncertainty in annual CO_2 emissions was also estimated at about 5%, with an uncertainty in activity data of 2% and 5% in the CO_2 emission factor. The uncertainty in PFC emissions from aluminium production was estimated to be about 20% (2% in activity data and 20% in the PFC emission factor).

2.2.4 Food and drink (2D)

The uncertainty in CO_2 emissions was estimated at about 5%. Since this is a very small emission source, the uncertainties in this category were not analysed in more detail, and not included separately in the Tier 1 uncertainty analysis.

2.2.5 Production of halocarbons and SF6 [2E]

Because of confidentiality, only emissions from HFC-23 by-products were reported by the producer. An estimate of activity data and emission factors would be required for a Tier 1 or Tier 2 uncertainty assessment, associated with reported emissions.

First, the uncertainty in the activity data was estimated at 2%. Next, from a default uncontrolled emission factor and the annual operation time of the thermal afterburner, an estimate of the emission factor over time could be estimated. From this, the implied activity data could be derived.

In the 1990 to 1997 period, no end-of-pipe emission control was used. The uncontrolled emission factor for this period could be estimated, based on a) IPCC default of 4% (based on

Uncertainty estimates for activity data and emission factors in sector 2 Industrial Processes and sector 3 Solvents and other Product Use — Table 2.7

Sector	Activity data	Emission factors						AD unc based on: 1)	EF unc based on: 1)
		CO_2	CH_4	N_2O	HFC	PFC	SF_6		
	2σ (%)	2σ (%)	2σ (%)	2σ (%)	2σ (%)	2σ (%)	2σ (%)		
2 – Industry									
2 A Mineral products									
2 A 1 Cement production	5	10						R (1)	D
2 A 3 Limestone and dolomite use	25	5						R	R (1)
1 A 7 Other minerals	25	5						R	R
2 B Chemical industry									
2 B 1 Ammonia production	2	1						R	R
2 B 2 Nitric acid production	10			50				R	R
2 B 5 Other chemicals	50	50						R	R
Caprolactam production	50			50				R	R
2 C Metal production									
2 C 1 Iron and steel production	3	5						R	R
2 C 3 Aluminium production	2	5				20		R, PFC :D	R
2 E Production of halocarbons and SF_6									
2 E 1 By-product emissions: HFC-23 emissions from HCFC-22 manufacture	10				10			R	R
2 E 3 Handling activities	10				20			R	R
2 F Consumption of halocarbons and SF_6									
2 F (1-4) HFC Emissions from substitutes for ozone depleting substances	10				50			D	D
2 F 6 PFC emissions from PFC use	5					25		D	D
2 F 9 SF_6 emissions from SF_6 use	50						25	R	R
2 G Other industrial processes									
Indirect N_2O from NO_2 from combustion and industrial processes	15			200				R	R
Indirect N_2O from NH_3 from non agricultural sources	8			200				R	R
Other CO_2 process emissions	5	17						R	R
Other CH_4 process emissions	10		50					R	R
Other N_2O process emissions	50			50				R	R
3 Solvents and other product use									
Indirect CO_2	25	10						R	R
N_2O use	50%			0				R	R

1) Documented as D [= Default of IPCC source category], R [= National Referenced data], or M [= Measurement based].

the US NIR from 1994 compiled for 1990 to 1993); b) EDGAR multi-year average of 2.15% (based on the best fit of atmospheric concentration measurements for the 1978 to 1995 period. We selected the value of 2% for uncontrolled emissions, because it reflected the state of modern production plants.

The thermal afterburner was operational for 84% of the time, in 2000; for 95% in 2001; for 93.6% in 2002; and for 96% in 2004. The effective emission factors for these years were then estimated by: EF_uncontrolled * Abatement_factor, with the abatement factor equal to 1 minus the operation time of the afterburner, expressed as fraction. The calculated (implied) emission factor from 2001 to 2004 was 0.10%, 0.10%, 0.13% and 0.08%, respectively. Therefore, for 2001, we assumed a value for the effective emission factor of 0.10%. The uncertainty in the emission factors were estimated at about 50% for 1990 to 1995, and about 20% for 2004 (based on values observed for 2001 to 2004 of 0.08 to 0.13%). The uncertainty in the activity data was estimated at 2%.

In summary, for the Tier 1 uncertainty assessment, the uncertainty in HFC emissions from HCFC-22 production was estimated to be about 15%, while from handling activities this was about 50%. The uncertainty in the activity data for these sources was estimated at 10%. The uncertainties in the emission factors for HFC23 from HCFC-22 production and for HFC from handling activities were estimated at 10 and 50%, respectively. These figures were all based on experte judgments.

2.2.6 Consumption of halocarbons and SF6 (2F)

The uncertainty in HFC emissions from HFC consumption was estimated to be 50%, and for PFC and SF_6 this was about 25% and 55%, respectively. The uncertainty in the activity data for the HFC, SF_6 and PFC sources was estimated at 10%, 50%, and 5%, respectively. For the emission factors, the uncertainties were estimated at 50%, 25% and 25%. All of these figures were based on expert judgements.

HFC-23 by-product emissions from the production of HCFC-22 (2E) (1000 kg): EF and effective EF in %; operation time of afterburner as fraction; activity data in Gg (kton) Table 2.8

Parameter	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
2E1. HFC-23	378.8	295.0	378.0	422.8	536.6	492.2	588.6	573.4	665.9	294.0	206.9	38.5	58.5	35.5	30.3
Default EF	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Operation time abatement	0	0	0	0	0	0	0	0	0	0.5	0.84	0.95	0.95	0.936	0.96
Eff. EF used	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00	0.32	0.10	0.10	0.10	0.10
Inferred Act. data	18.9	14.8	18.9	21.1	26.8	24.6	29.4	28.7	33.3	29.4	64.7	38.5	58.5	35.5	30.3

(source: NIR 2006).

2.3 Solvents and the use of other products (3)

These sources did not affect the overall total or the trend in the direct greenhouse gas emissions (contribution of less than 1% to total greenhouse gas emissions).

2.3.1 Indirect CO_2 emissions from solvents and their use

This source category comprised: paint application [3A], degreasing and dry-cleaning [3B], and other [3D]. The indirect CO_2 emissions from NMVOC were calculated as follows:

CO_2 (in Gg) = Σ{NMVOC emission in subcategory i (in Gg) * C-fraction subcategory i} * 44/12

The activity data refer to NMVOC emissions from solvent use. These were calculated assuming 100% evaporation of the solvents: NMVOC (in kg) from solvent use = solvent use (in kg) * 1. So the uncertainty in the NMVOC emissions was actually the uncertainty in the amount of solvents used, often calculated as fraction of the total product: consumption data and NMVOC contents of products. Data on the latter mainly originated from trade associations, such as the Vereniging van Verf- en drukinktfabrikanten (VVVF, paints), the Nederlandse Cosmetica Vereniging (NCV, cosmetics), and the Nederlandse Vereniging van Zeepfabrikanten (NVZ, detergents). The NMVOC contents of these products remained the same during the whole period.

The emission factor refers to the carbon contents of the NMVOC emissions, for which the average carbon contents reported in categories 3A, 3B and 3D were used. The fraction of organic carbon (from natural sources) in the NMVOC emissions was assumed negligible.

The following fixed carbon fractions were used for the total time series:

3A	3B	3C	3D
0.72	0.16	0.68	0.69

The carbon contents were based on the composition of compounds responsible for 85 to 95% of the total NMVOC emission within each category. The fractions were calculated based on the 1990 and 2000 emissions.

The uncertainty in indirect CO_2 emissions was not explicitly estimated for this category, but was expected to be fairly low. Based on expert judgments, the uncertainty in the NMVOC emissions was estimated to be 25%, and for the carbon contents this was 10%, resulting in an uncertainty in CO_2 emissions of approximately 25%.

2.3.2 Miscellaneous N_2O emissions from solvents and product use

The uncertainty in annual N_2O emissions was estimated to be approximately 50%, based on expert judgments. Uncertainty in the activity data of N_2O use was estimated to be 50%, and for the emission factor this was 0% (all gas was released).

2.4 Agriculture (4)

Table 2.9 shows the uncertainty estimates used for activity data and emission factors for the key source assessment in the agricultural sector. Most of these estimates were made in 2002, except for a few that were recalculated for the NIR 2005. Table 2.5 presents the underlying uncertainty estimates. Many of these values were documented in the factsheet 'N and P to soils' (RIVM, 1999, p. 155).

The 10% uncertainty in the amount of animal manure was based on a 5% uncertainty in animal numbers and 5 to 10% uncertainty in the excretion per animal, giving a resulting uncertainty of 7 to 11%, which was rounded to 10%.

2.4.1 Enteric fermentation (4A)

The uncertainty in CH_4 emissions from enteric fermentation from cattle was based on expert judgements, and was estimated to be about 20%, annually, using a 5% uncertainty for animal numbers and 20% for the emission factor. The uncertainty in the emission factor for swine and other animals was estimated to be 50% and 30%, respectively.

2.4.2 Manure management (4B)

The uncertainty in the CH_4 and N_2O emissions from the management of manure from cattle and swine was estimated to be approximately 100%, annually. The uncertainty in the amount of animal manure (10%) was based on a 5% uncertainty in animal numbers and a 5 to 10% uncertainty in excretion per animal (RIVM, 1999). The resulting uncertainty of 7 to 11% was rounded off to 10%. The uncertainty in the CH_4 and N_2O emission factors for manure management, based on expert judgments, was estimated to be 100%.

2.4.3 Agricultural soils (4D)

In the Netherlands, this source consists of the following N_2O source categories:

– Direct soil emissions from the application of synthetic fertilisers, animal waste and sewage sludge, and from

Uncertainty estimates for activity data and emission factors in sector 4 Agriculture — **Table 2.9**

Sector	Activity data	Emission factors			AD unc based on: [1)]	EF unc based on: [1)]
		CO_2	CH_4	N_2O		
	2σ (%)	2σ (%)	2σ (%)	2σ (%)		
4- Agriculture						
4.A. Enteric fermenation						
4 A 1 Cattle	5		20		R (6)	R (7)
4 A 8 Swine	5		50		R (6)	D
4 A 3 Sheep	5		30		R (6)	D
4 A Other	5		30		R (6)	D
4.B. Manure management	10			100	R (7)	D
4 B 1 Cattle	10		100		R (7)	D
4 B 8 Swine	10		100		R (7)	D
4 B 9 Poultry	10		100		R (7)	D
4 B Other	10		100		R (7)	D
4.D. Agricultural soils						
4 D 1 Direct N_2O emissions from agricultural soils	10			60	D	D
4 D 2 Animal production on agricultural soils	10			100	R (7)	R (7)
4 D 3 Indirect N_2O emissions from nitrogen used in agriculture	50			200	R (7)	D

1) Documented as D [= Default of IPCC source category], R [= National Referenced data], or M [= Measurement based].
References: (6) RIVM, 1999, (7) Van der Hoek, 2002

N-fixing crops, crop residues, and the cultivation of histosols (4D1);
- Animal production – meaning animal waste produced during outside grazing (4D2);
- Indirect emissions from nitrogen leaching and run-off, and from deposition (4D3).

The uncertainty in direct N_2O emissions from agricultural soils was estimated to be about 60% (10% in activity data, -as in 4B manure management- and 60% in emission factor). The uncertainty in annual N_2O emissions from animal production on agricultural soils (manure dropped in pastures) was estimated at about 100% (10% in activity data and 100% in emission factor). The uncertainty in indirect N_2O emissions from nitrogen used in agriculture was estimated to be more than double that (50% in activity data and 200% in emission factor).

2.5 Land use, land-use change, and forestry (LULUCF) (5)

Table 2.10 shows the uncertainty estimates used for activity data and emission factors for the key source assessment in the LULUCF sector, for the NIR 2006. Table 2.6 presents the underlying uncertainty estimates, which were documented by Schulp (pers. comm., 19-12-2005), see also this Section.

Uncertainty in activity data for all subcategories

The activity data used represent area changes, calculated by comparing two topographic maps. The type of land use was determined by using digitised topographical maps (scale 1:10,000), allowing the land-use matrix to be completed conform the recommendations in the Good Practice guidance on Land Use, Land Use Change and Forestry (IPCC, 2003). Thus, areas were obtained for the six main categories of land use, as well as for the total land-use changes in (and between) these categories. The uncertainty for one topographic map was estimated at 5% (expert judgement). Therefore, the uncertainty in comparing two topographic maps (1990 and 2000), theoretically, was 5×5=25%. This was without doubt an overestimation, as not all land use would have changed over this decade.

2.5.1 Forest Land [5A]

The uncertainty in the CO_2 emissions from *5A1 Forest Land remaining Forest Land* was calculated at 62%. For *5A2 Land converted to Forest Land* this was 58% (see Table 2.10).

Uncertainty in the implied emission factor of 5A1 Forest Land remaining Forest Land

CO_2 capture and CO_2 emissions as a result of c cchanges in forestry and woody biomass stocks were estimated based on country-specific Tier 2 approaches. The approach chosen followed the *IPCC 1996 Revised Guidelines* and its updates in the *Good Practice guidanceon Land Use, Land Use Change and Forestry* (IPCC, 2003). The basic assumption was that the net flux could be derived from converting the change in growing stock volumes in the forest into carbon.

The Dutch method was based on the carbon cycle of managed forests. Distinguished are: above-ground biomass, below-ground biomass, litter, dead wood, and soil organic carbon. Carbon stock changes were calculated for above-ground biomass, below-ground biomass, and dead wood. For litter and soil organic carbon, and for biomass in other natural terrains, the stock was assumed to remain unchanged, during the period of 1990 to 2000. Calculations for the living biomass carbon balance were carried out at plot level.

In the Tier 1 uncertainty calculation sheet, the uncertainty in the implied CO_2 emission factor was derived from the calculated total uncertainty for this category (67%), and in activity

Uncertainty estimates in activity data and emission factors in sector 5 LULUCF

Table 2.10

Sector	Activity data	Emission factors CO_2	AD unc based on: 1)	EF unc based on: 1)
	2σ (%)	2σ (%)		
5- Land use, land-use change, and forestry				
5.A. Forest land				
5 A 1 Forest land remaining forest land	25	61.8	R	R
5 A 2 Land converted to forest land	25	57.9	R	R
5.B. Cropland				
5 B 2 Land converted to cropland	25	50	R	R
5.C. Grassland				
5 C 1 Grassland remaining grassland	25	50	R	R
5 C 2 Land converted to grassland	25	61.2	R	R
5.E. Settlement				
5 E 2 Land converted to Settlements	25	50	R	R
5.F. Other land				
5 F 2 Land converted for other land uses	25	50	R	R
5.G. Other				
Liming of soils	25	1	R	R

1) Documented as D [= Default of IPCC source category], R [= National Referenced data], or M [= Measurement based].
References: De Groot et al., 2005; Kuikman et al., 2003, 2005; LEI, 2005; Nabuurs et al., 2005.

Parameters and uncertainty estimate for 'living biomass'

Table 2.11

Factor	Uncertainty estimate	References Expert judgement International literature IPCC LULUCF GPG default
Tree biomass (kg DM/tree) *M_{tree} = 700 kg DM / tree*	+/- 10%	Literature
Number of trees (trees/ha^{-1})	+/- 5%	Literature
Carbon content (kg C kg^{-1} DM)	+/- 10%	Literature

data (25%).The uncertainty in implied emission factors of 5A1 *Forest Land remaining Forest Land* concerned forest, and trees outside the forest. As the approach and data sets used were the same for both sources, the uncertainty calculation was performed for forests. The results were considered to be representative of trees outside forests, as well.

The uncertainty in the implied emission factor of *living biomass increment* was calculated at 13% (rounded at 15% in the calculation LULUCF spreadsheet). The uncertainty in the implied emission factor of *decreased living biomass* was calculated at 30%. The uncertainty in the net carbon flux from dead wood was calculated at 30% (rounded at 50% in the LULUCF calculation spreadsheet).

Increment in living biomass

The desired net flux was derived from the calculated difference in tree mass between two years, the basic wood density, and the carbon content of the dry mass. This last step is represented in the following equation:

$$\Delta C(trees)_{plot} = \Delta M \frac{(M_{tree}(t) - M_{tree}(t+1))}{\Delta t} \times N_{trees} \times F_{carbon}$$

with:

$\Delta C(trees)_{plot}$ net C flux in living biomass per stand (kg C ha^{-1}y^{-1})
$M_{tree}(t)$ total tree biomass at time t (kg DW)
N_{trees} number of trees (ha^{-1})
F_{carbon} carbon content (kg C kg^{-1} DW)
Δt time between t and t+1 (year)

The uncertainty in the emission from living biomass was based on the main parameters that determine the net carbon flux. Table 2.11 shows the parameters and the uncertainty estimate.

Combined uncertainty ΔM = $(\sqrt{((M_{tree(t)} * unc_{Mtree}\%)^2 + (M_{tree(t+1)} * unc_{Mtree})^2)})/(M_{tree(t)} + M_{tree(t+1)}) = (\sqrt{((700*10\%)^2 + (700*10\%)^2)})/(700+700) = 7\%$

The overall uncertainty in the emission (sink) from living biomass is ΔC(trees)stand = $\sqrt{((Unc_{\Delta M})^2 + (Unc_{Ntrees})^2 + (Unc_{Fcarbon})^2)} = \sqrt{((7\%)^2 + (5\%)^2 + (10\%)^2)}$ = **13%** (rounded at 15% in the LULUCF calculation sheet).

Decrease in living biomass

This is the loss of biomass through harvest (includes thinning) and natural mortality. The decrease was calculated from the volume of stem loss, expanded to whole tree biomass using biomass expansion factors. Therefore, the rest of the calculation is the same as for the increase of biomass.

Thinning

Thinning was carried out for all stands that met the criteria (age > 110 years, or growing stock exceeding 300 m^3/ha). The amount of trees thinned was based on the total volume of

Parameters and uncertainty estimate for dead wood — Table 2.12

Factor	Uncertainty estimate	Background: Where does estimate come from? E.g. - Expert judgement - International literature - IPCC LULUCF GPG default
Tree biomass (kg DM/tree)	[see increment in living biomass]	
Tree density (trees/ha⁻¹)	[see increment in living biomass]	
Fraction carbon in biomass (kg C kg⁻¹ DM)	[see increment in living biomass]	
Fraction mortality (yr⁻¹)	+/- 30%	Dutch data
Volume of dead wood (standing and lying). This is the result of mortality rate minus decay. Is derived from national inventory data.	+/- 5%	Dutch data
Amount of decay standing and lying dead wood	+/- 30%	Literature
Average dead wood density	+/- 10%	Literature
$V_{dead\ standing} = 4.5\ m^3/ha$ $V_{dead\ liggend} = 5\ m^3/ha$		
$TBP_{staand} = 40\ y$ $TBP_{liggend} = 20\ y$		
$InC \approx 3200\ kg\ C\ /\ ha$ $OutC \approx 275\ kg\ C\ /\ ha$		

trees harvested the year before. The net C flux due to thinning was then calculated from the average biomass of a single tree and the carbon content of dry mass.

Dead wood

The net carbon flux in dead wood mass, was calculated as the remainder of the total amount of dead wood – due to mortality– minus the amount of dead wood which had decayed. Leaves and roots were not taken into account for the build up of dead wood. The mortality rate was assumed to be a fixed fraction of the standing volume (0.4% y^{-1}), and current volume of dead wood was assumed to be 6.6% of the living wood volume. A net build-up may exist, since Dutch forestry started to pay attention to dead wood just a decade ago.

The following equations were used for calculating the net C flux in dead wood mass:

$$\Delta C(\text{dead wood})_{plot} = OutC(\text{dead wood})_{plot} - InC(\text{dead wood})_{plot}$$

$$InC(\text{dead wood})_{plot} = M_{tree}(t) \times N_{tree} \times F_{carbon}\ F_{mortality}$$

$$OutC(\text{dead wood})_{plot} = \left(\frac{V_{dead\_S}}{TBP_S} + \frac{V_{dead\_L}}{TBP_L}\right) + WD_{dead}\ F_{carbon}$$

with

$\Delta C(\text{dead wood})_{plot}$	net C flux in dead wood mass per stand (kg C $ha^{-1}y^{-1}$)
$OutC(\text{dead wood})_{plot}$ trees	C increase in dead wood from dying (kg C $ha^{-1}y^{-1}$)
$InC(\text{dead wood})_{plot}$	C loss per stand from decomposition of dead wood (kg C $ha^{-1}y^{-1}$)
$M_{tree}(t)$	total living tree biomass at time t (kg DW)
N_{tree}	number of living trees (ha^{-1})
F_{carbon}	carbon content of dry mass (kg C kg^{-1} DW)
$F_{mortality}$	mortality (y^{-1})
V_{dead_SL}	volume of standing/lying dead wood
TBP_{SL}	length of complete process of decay of dead wood, standing and lying
WD_{dead}	density of dead wood

The uncertainty in the emission from dead wood was based on the parameters that determine the net carbon flux in dead wood mass. Table 2.12 shows the parameters and the uncertainty estimate.

Uncertainty InC = √((10%)² + (5%)² + (10%)² + (30%)²) = **30%**

Uncertainty OutC = :

1. Uncertainty Vdead/TBP = √((30%)² + (5%)²) = **30%**
2. Uncertainty ΔVdead/TBP = (√(V/TBP_s*30%)²+(V/TBP_L*30%)²)/(V/TBP_s+V/TBP_L) = **21%**.
3. Uncertainty OutC = √(UncΔVdead/TBP)² + (30%)² + (10%)²= **40%**

Uncertainty emission from dead wood: ΔC = (√(UncOutC*OutC)² + (30%*InC)²)/(InC+OutC) = **30%** (rounded at 50% in the LULUCF calculation sheet)

Uncertainty in implied emission factor of 5A2 'Land converted to Forest Land'

In the Tier 1 uncertainty calculation sheet, the uncertainty in the implied CO_2 emission factor was derived from the calculated total uncertainty for this category (5A2) (58%, see Table 2.10) and the uncertainty in activity data (25%). For the increment in living biomass, the same data and calculations were used as for 5A1 *Forest Land remaining Forest Land* and, thus, the same uncertainties were used in the Tier 1 calculation spreadsheet (15%). The uncertainty for the other parameter in the calculation, change in carbon content in mineral soil, was estimated at 50%, see the discussion below.

Uncertainty in carbon stocks

For estimating soil carbon stocks, the 'LSK/HGN' method, as described in (De Groot et al., 2005), was used (Protocol 5_CO2_bodem, see www.greenhousegases.nl). When land use changes, all carbon that is present in the soil is being transferred to the new land-use type and does not change to an other equilibrium. Therefore, the carbon content under a certain land-use type only changes due to area changes. Based on the soil map, combined with soil-profile details based on LSK, it is possible to produce a map and achieve a spatially explicit picture of the carbon stocks in the top soil, using the following formula:

Parameters and uncertainty estimate for 'soil carbon' — Table 2.13

Factor	Uncertainty estimate	References
OM content	5%	De Groot et al., 2005, page 24.
Bulk density	25%	Calculated using pedotransfer functions (De Groot et al., 2005). Estimates of uncertainty (expert judgment): Peat: 25%, Clay: 10-25%, Sand: 10%
C content of OM	10%	50% is used as average value, but is assumed to vary between 45 and 55%.
Thickness of soil	10%	Expert judgment: estimated auger drilling = up to 30 cm. So a few centimeters = around 10%
Area of land-use on a certain soil type	25%	Depends on uncertainty in land-use maps (5%; expert judgement) and uncertainty in soil data. (Kuikman et al., 2003) give max. 80% accuracy for these data). [illegible] 50% is probably too high [illegible] 25%

$$SOC_{(1990\text{-}2000),s1} = \sum_{1}^{n} (\text{Os x Bulk density x average C content x Topsoil } /n\,)$$

with:

- $SOC_{(1990\text{-}2000),s1}$ = soil organic matter between 1990-2000 for soil unit S1 in tonne C ha^{-1}
- Os = organic substance level in dry soil (%)
- Bulk density = kg m^{-3} dry soil
- Average C content = kg C kg^{-1} os (default is 0.5)
- Top soil = tickness of the top soil in metres (default is 0,3 m)
- N = number of soil samples in soil unit S1

Total change in carbon content of mineral soils in the Netherlands:

$$\Delta C_{(c,\, mineral)} = \sum_{S} [(SOC_{(1990\text{-}2000)} \text{ x } A\,]$$

with

- $\Delta C_{(c,\, mineral)}$ = annual change in carbon content of mineral soil (ton C y^{-1})
- $SOC_{(1990\text{-}2000)}$ = stock of soil organic substances in the relevant year (ton C ha^{-1})
- $SOC_{(0\text{-}T)}$ = stocks in soil organic matter in T years for the relevant inventory (ton C ha^{-1})
- T = inventory period in years
- A = land area of a specific land use (ha)
- S = varying and differentiated soil types

The relevant data and calculations can lead to changes in the areas with specific land use, and to changes in the carbon levels, and follow the IPCC requirements concerning methodologies and concepts. Data for the years 1990 and 2000 were based on observations of land use. The values for the period between 1990 and 2000 were obtained through linear interpolations, and the values for the years following 2000 were obtained via extrapolation. More details about the methods used and the emission factors, can be found in the protocols on www.greenhousegases.nl.

The uncertainty in the Dutch analysis of carbon levels depended on the collective factors with which the calculations were implemented (calculation of the organic substances in the soil profile and the conversion to a national level), and the data on land use and land-use change (topographical data). Table 2.13 shows the parameters and the uncertainty estimate.

Thus, the uncertainty in the change in carbon content in mineral soil can be calculated at:

Uncertainty $\Delta C_{(c,\, mineral)} = \sqrt{((5\%)^2 + (25\%)^2 + (10\%)^2 + (10\%)^2 + (25\%)^2} =$ **38%**, this was rounded at 50% in the Tier 1 calculation spreadsheet.

2.5.2 Cropland [5B]

The uncertainties in the Dutch analysis of carbon levels depended on the collective factors with which the calculations were implemented (calculation of the organic substances in the soil profile and the conversion to a national level) and data on land use and land-use change (topographical data). The uncertainty in the CO_2 emissions from 5B2 *Land converted to Cropland* was calculated at 56% (see Table 2.14).

Uncertainty in the implied emission factor for 5B2 Land converted to Cropland

The uncertainty in the implied emission factor for 5B2 *Land converted to Cropland* refered to the change in carbon content of mineral soils. The uncertainty in the change in carbon content of mineral soils was calculated at 38% (rounded to 50% in the Tier 1 calculation spreadsheet, since it is the order of magnitude that is important), see '*Uncertainty in carbon stocks*' in *section 2.5.1*.

2.5.3 Grassland [5C]

The uncertainty in CO_2 emissions in the categories 5C1 *Grassland remaining Grassland* and 5C2 *Land converted to Grassland* was calculated at 56% (see Table 2.14).

Uncertainty in the implied emission factor for 5C1 Grassland remaining Grassland

The uncertainty in the oxidation of organic soils (category 5C1) was calculated at 55%. Combined with the 38% uncertainty in the change in carbon content of mineral soils (see *section 2.5.1*), the overall uncertainty in the implied emission factor for category 5C1 lies in the 50% range (50% used in the Tier 1 calculation spreadsheet) (Table 2.13).

Uncertainty in the implied emission factor for 5C2 Land converted to grassland

For the uncertainty in 5C *Land converted to Grassland*, reference was made to the description of 5B2 *Land converted to Cropland* (*Section 2.5.2*). The calculation for *land converted to Grassland* was based on the same assumptions as those made for 5B2 *Land converted to Cropland,* and the uncertainties, therefore, are identical (38%, rounded to 50% in Table 2.14).

Uncertainty calculation for LULUCF sources/sinks

Table 2.14

													EMISSION					UNCER
						AD	IEF				EF		(H^2+I^2)^0.	(H^2+J^2)^0.:	(H^2+K^2)^0	(H^2+L^2)^0	(H^2+M^2)^0.5	
source category	**gas**	**1990**	**2003**		**diff**		Incr living	Decr living	NetCh dea	NetCh soils	Liming/N-fer	Incr living	Decr living	NetCh dea	NetCh soil	Liming/N-fe	sum(S:W)
5A1. Forest Land remaining Forest Lar	CO2	-2505	-2289	Gg CO2	-9%												**64%**
o.w. trees outside forest		*-209*	*-209*			*25%*	*15%*					*29%*					*29%*
o.w. forest		*-2296*	*-2080*			*25%*	*15%*	*20%*	*50%*			*29%*	*32%*	*56%*			*71%*
5A2. Land converted to Forest Land	CO2	-89	-342	Gg CO2	284%	25%	15%			50%		29%			56%		63%
5B2. Land converted to Cropland	CO2	-35	-35	Gg CO2	0%	25%				50%					56%		56%
5C1. Grassland remaining Grassland	CO2	4246	4246	Gg CO2	0%	25%				50%					56%		56%
5C2. Land converted to Grassland	CO2	536	536	Gg CO2	0%	25%		25%		50%			35%		56%		66%
5E2. Land converted to Settlements	CO2	-151	-151	Gg CO2	0%	25%				50%					56%		56%
5F2. Land converted to Other Land	CO2	710	710	Gg CO2	0%	25%				50%					56%		56%
5G. Other (liming of soils)	CO2	183	86	Gg CO2	-53%	25%					1%					25%	25%
Total LUCF-CO2		**2894**	**2761**	**Gg CO2**	-5%												**103%**
5A1. Forest Land remaining Forest Lar	N2O	7	7	Gg CO2-e	0%	25%					20%					32%	**21%**
Please provide order of magnitude of the uncertainty in the data:								[box]	Most important parameter								
								[box]	Important parameter								
								[dark blue]	Par. for largest emissions								
								[light blue]	Par. for other emissions								

Uncertainty estimate for activity data, emission factors and other factors for CH_4

Table 2.15

		EMISSION = (EF x AD - REC) x OXFAC = EF x AD x OXFAC - RECOV x OXFAC								
			EF	AD	RECOV	OXFAC	CALC EMISSIONS	EMISSION w/o RECOV	EMISSION w/o RECOV and OXFAC	EF = K/E/1000
calculation.:	90	562	0.047	13.9	27	0.9	565	589	654	0.047
	98	444	0.109	5.3	76	0.9	452	520	578	0.109
individual uncertainties:	90		15%	30%	10%	5%				
	98		15%	20%	10%	10%				
				(of: 20 ivm doorwerking verleden?)		(+0; -10%; of zelfs -20%?)				
			Uncertainty AD * EF	Gross Emissions	Uncertainty GROSS EM - RECO'		Uncertainty EMISSIONS =CORR EM * OX FAC			
calc uncertainty:	90		34%	654	35%		**35%**	if 30%->25% in AD'90: 30%		
	98		25%	578	29%		**31%**	if one of the 10% -> 20%: 30%		
								if both of the 10% -> 20%: 35%		

Uncertainty estimates of activity data and emission factors in waste sector 6 — Table 2.16

Sector	Activity data	Emission factors			AD unc based on: [1]	EF unc based on: [1]
		CO_2	CH_4	N_2O		
	2σ (%)	2σ (%)	2σ (%)	2σ (%)		
6- Waste						
6.A. Solid waste disposal on land						
6 A 1 Managed waste disposal on land	30		15		R	R
6.B. Waste water handling	20		25	50	R	R
6.C. Waste incineration	10	5			R (1)	R
6.D. Other waste handling						
Large-scale compost production	20		25	50	R	R

1) Documented as D [= Default of IPCC source category], R [= National Referenced data], or M [= Measurement based].
References: (1) Van Amstel et al., 2000a

2.5.4 Wetland [5D], Settlement [5E] and Other Land [5F]

For information on the uncertainty estimates, the reader is referred to *section 2.5.1*, which discusses the uncertainty in soil carbon and changes in land use.

2.5.5 Other [5G]

The uncertainty in the CO_2 emissions from 5G *Liming of soils* was calculated at 25%. The uncertainty in the activity data was estimated at 25%, and the uncertainty in emission factors was 1%. When considered over a longer timespan, all carbon that is applied through liming will be emitted.

2.6 Waste (6)

Table 2.16 shows the uncertainty estimates used for activity data and emission factors for the key source assessment in the waste sector, for the NIR 2006. Most of these estimates were made in 2002, except for a few that were recalculated for the NIR 2005.

2.6.1 Landfills (6A)

The uncertainty in CH_4 emissions from solid-waste disposal sites was estimated at about 35% in annual emissions. In the Tier 1 uncertainty analysis, we used uncertainty estimates in the activity data and the emission factor of 30 and 15%, respectively.

The main factors influencing the quantity of CH_4 *produced* were the *amount* of waste disposed on land, and the *concentration* of C (carbon) in that waste. The amount of *methane recovery* was the main other factor influencing the actual CH_4 emissions.

To calculate the methane emissions from all the landfill sites within the Netherlands, the simplifying assumption was made that all the wastes are assumed to be landfilled on one landfill site, starting in 1945. However, as stated above, characteristics of individual sites vary substantially. Methane emissions from this 'national landfill' are then calculated by using a first-order decomposition model (first-order decay model, i.e. IPCC Tier 2 methodology) with an annual input of the total amount deposited, and the characteristics of the landfilled waste and the amount of landfill gas extracted. This emission model takes into account that the generation of methane by landfills is not an instantaneous process. Thus, the methodology calculates gross emissions in a specific year as the sum of delayed emissions from all Municipal Solid Waste (MSW) deposited in past years. A variable integration period was used, starting with waste deposited in 1945:

$$\text{Methane generated } G(t) = \sum_{y=1945}^{t} D(y) * k * L_0 * N * e^{-k(t-y)}$$

where:

- $G(t)$ = CH_4 generated in year *t* [Gg/yr]
- $D(y)$ = $MSW_{Tot}(y) * MSW_{Fr}(y)$ [Gg/yr]
- k = methane generation rate constant = ln 2 / HL [1/yr], where HL = Half-Life value
- L_0 = methane generation potential = $MCF*DOC(t)*DOC_{Fr}*F*16/12$ [Gg CH_4/Gg waste]
- N = normalisation factor = $(1 - e^{-k}) / k$; to ensure that the sum of years gives the correct value of the methane generation potential L_0.

Here, the D(y) components and the methane generation potential L_0 factors are defined as:

- $MSW_{Tot}(y)$ = total MSW generated [Gg/yr]
- $MSW_{Fr}(y)$ = fraction of MSW disposed to landfills [fraction]
- MCF = Methane Correction Factor [fraction]
- $DOC(t)$ = Fraction of *Degradable Organic Carbon* in MSW [Gg C/Gg waste]
- DOC_{Fr} = Fraction of DOC ultimately dissimilated (excluding lignin C)
- F = Fraction of CH_4 in landfill gas.

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

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

where:

- $R(t)$ = Recovered amount of CH_4 [Gg/yr]
- OX = Oxidation factor [fraction]

Parameter values used in the landfill emissions model were:
- total amount of landfilled waste;
- fraction of Degradable Organic Carbon (DOC) (see e.g. Table 8.2 in NIR 2005 for a detailed time series);
- methane generation (i.e. decomposition) rate constant (k): 0.094 up to and including 1989, decreasing to 0.0693 in 1995, and constant thereafter; this corresponds to half-life times of 7.4 and 10 years, respectively (see Table 8.2 in NIR 2005 for a detailed time series);
- methane oxidation factor (OX): 10%;
- fraction of DOC actually dissimilated (DOC_F): 0.58;
- methane conversion factor (IPCC parameter): 1.0.

The integration time for the emission calculation was defined as the period from 1945 to the year for which the calculation is made.

The previous description shows that for landfills a simple emission calculation in the form of AD x EF cannot be made. However, to still arrive at an uncertainty in 'activity data' and an 'effective' emission factor for the Tier 1 key source uncertainty assessment, we made an analysis of the uncertainty in the underlying data, which are presented in Table 2.15. The uncertainty in the amount of waste deposited, each year, was assumed to increase from 20% in recent years to 30% in earlier years (e.g. 1990 and before). This is important, since the gross landfill emissions represent the integrated sum of emissions from waste deposited in all years, from the present year to 30 or more years earlier in time (although earlier years carry an exponentially decreasing weight in this sum). The uncertainty in the activity data reflects the total uncertainty in total amount of deposited waste, the organic carbon fraction in it, and the C content of the organic fraction. In addition, the net emissions are the difference between gross emissions and the amount of methane recovered (REC), both multiplied by the so-called oxidation factor (OX). The table shows the calculated uncertainty, for a number of cases of activity data and oxidation factors, giving a resulting uncertainty of 30 to 35%, which was rounded to 35%.

For a Tier 2 uncertainty assessment, which took into account the uncertainty in all factors included in the emission calculation, the following uncertainties were used for landfill emissions, which are sometimes different from the values by Olsthoorn and Pielaat (2003):
- total amount of annually deposited waste: 10% prior to 1980, linearly decreasing to 1% since 1990 (Kraakman, 2005, pers. comm.)
- methane correction factor (MCF = 1.0): -10%; +0% (IPCC default)
- fraction of Degradable Organic Carbon (DOC) (see e.g. Table 8.2 in NIR 2005 for a detailed time series): 20% (combined effect of shares of waste streams and organic C fraction per stream; Kraakman, 2005, pers. comm.)
- fraction of DOC actually dissimilated (DOC_F) (0.58): 10% (IPCC country-specific default)
- fraction of CH_4 in landfill gas (F = 0.6): 5% (IPCC default)
- methane generation (i.e. decomposition) rate constant (k = 0.094 up to and including 1989, decreasing to 0.0693 in 1995 and constant thereafter; see Table 8.2 in NIR 2005 for a detailed time series
- methane oxidation factor in top layer (OX = 0.1): 100% (i.e. between 0.05 and 0.2) (Kraakman, 2005, pers. comm.)
- recovered landfill gas: 10% until 1990, linearly decreasing to 5% by 2000 and after (Kraakman, 2005, pers. comm.)

The uncertainty in DOC and the uncertainty in the total amount deposited in landfills suggested that the uncertainty in the aggregate activity data for a Tier 1 uncertainty analysis was about 30% in 1990, and about 20% in present years.

2.6.2 Waste water (6B)
The uncertainty in annual CH_4 and N_2O emissions from waste water handling were estimated at 30% and 50%, respectively. The uncertainty in activity data was based on expert judgements and estimated at 20%. The uncertainty in emission factors for CH_4 and N_2O were estimated at 25 and 50%, respectively.

2.6.3 Waste incineration (6C, reported under 1A1a other fuel)
The uncertainty in annual CO_2 emissions from *Waste incineration* was estimated at 11%. The main factors influencing these emissions were the total amount being incinerated, the fractions of different waste components used for calculating the amounts of fossil and organic carbon in the waste (from their fossil and organic carbon fraction), and the corresponding amounts of fossil and organic carbon in the total waste incinerated. The uncertainty in the amounts of incinerated fossil waste and the uncertainty in the corresponding emission factor were estimated at 10 and 5%, respectively. These figures were based on expert judgments.

2.6.4 Other waste handling (6D)
The emissions in this source category (large-scale compost production) were calculated using an average emission factor that was obtained from the literature. The uncertainty in activity data was estimated at 20% . The uncertainty in the CH_4 and N_2O emission factor was estimated at 25 and 50%, respectively.

Changes in uncertainties since NIR 2002

3

Over time, the structure of emission sources or calculation methodologies have been improved, resulting in changes in or additions to the previous uncertainty estimates made for the Tier 1 key source analysis. The most important were:

NIR 2002

For estimating the uncertainty in activity data and emission factors in the NIR 2002, the following information sources were used (Olivier et al., 2002):

- At a national workshop in 1999, estimates used for reporting uncertainty in greenhouse gases emissions in the Netherlands were discussed (Van Amstel et al., 2000a);
- Default uncertainty estimates provided in the *IPCC Good Practice Guidance* report (IPCC, 2000);
- RIVM factsheets on calculation methodology and data uncertainty (RIVM, 1999);
- Any other information on the data quality, available at the time.

These were supplemented with expert judgements from RIVM emission experts. Next, emissions in 1990 and 2000 were split according to the IPCC Tier 1 methodology, for estimating uncertainty in both annual emissions, and in the emission trend was applied to that for the Netherlands. The approach for CO_2 from stationary combustion was based on the following considerations.

In 2002, greenhouse gas emissions from stationary combustion by large companies (a large part of source categories 1A1 and 1A2) were calculated, using emissions reported by the individual companies and supplemented when required with an emission estimate for non-reported industrial combustion emissions. Also, CO_2 emissions from feedstocks and non-energy generating use of fossil fuels were calculated. These calculations were based on emissions reported directly by the industrial companies and supplemented with an amount to include an estimate of the CO_2 emissions from the use of the petrochemical products produced (also reported under source category 1A). The uncertainty in the individually reported emissions was very difficult to estimate, but the national sectoral total was rather close to the total calculated in the CO_2 reference approach.

It was known that the uncertainty in emissions and implied emission factors for feedstocks and non-energy generating use of fuels, was much larger than for fossil-fuel combustion. Therefore it was decided that the key source analysis of CO_2 emissions from stationary fossil-fuel combustion should be split into a) stationary fossil-fuel combustion according to fuel type (gas, coal, oil), and b) feedstock use according to fuel type (gas, coal, oil), each with a characteristic uncertainty in the activity data and in the emission factors. Thus, for CO_2 emissions from fossil fuel, we used the CO_2 data from the *IPCC Reference Approach*, including feedstock data (adjusted to match the total in the *National Sectoral Approach*), combined with transport data.

Because of the problems identified in annual environmental reports, an extra uncertainty in national CO_2 emissions was estimated, for 2000, at 2% (Heslinga, 2001b). In addition, delays in compiling (preliminary) statistics for the last-but-one calendar year, notably for energy consumption, caused extra uncertainty for some sectors, due to the use of *estimated* data for the fourth quarter of 2000. For the same reason, the other greenhouse gas emissions were also more uncertain for 2000, but this extra uncertainty was not quantified

In Table 7.2, in the NIR 2002, the basis for the uncertainty estimates in activity data and emission factors in the potential key source list were documented as D [=F Default of IPCC source category], R [=F National Referenced data], or M [=F Measurement based]. Most data refer to the second type. Exceptions were found in (see Table 7.2 in NIR 2002):

- activity data on cement production, enteric fermentation in cattle, direct N_2O from agricultural soils, production of HCFC-22 and aluminium, use of HFCs and of PFCs, for which IPCC defaults were used;
- emission factors for livestock – excluding cattle, for animal manure, emissions from agricultural soils and from HFC use, for which IPCC defaults were used;
- emission factors for manufacture of HCFC-22 and aluminium. and for PFC use, for which partly measurement-based uncertainties were used.

The NIR 2002 gives the following limitations of the uncertainty estimates:
"The uncertainty estimates (..) have been calculated according to the Tier 1 uncertainty estimate of IPCC. In this method uncertainty ranges are 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 ('Gaussian'), b) 2σ smaller than 60%, c) sector to sector, substance to substance are independent. Indeed for a number of sources it is clear that activity data or emission factors are correlated, which increases the overall uncertainty of the sum to an unknown extent. Also, for some sources it is already known that the probability distribution is not normal; in particular when uncertainties are very high (order of 100%) it is clear that the distribution will be skewed towards zero. Even more important is that, although the uncertainty estimates have been based on the documented uncertainties mentioned above, unavoidably uncertainty estimates are in the end based on expert judgement of representativity for the Netherlands' circumstances of the particular source category. Sometimes, however, only limited reference to actual Netherlands data was possible to support these estimates. Focussing on the order of magnitude of the individual uncertainty estimates we believe that this dataset provides a reasonable first assessment of the uncertainty of key source categories in the Netherlands. Furthermore, (..) we have neglected the uncertainty introduced by the emissions from the sources of the ER-I (Individually reporting firms), of which the uncertainty is actually unknown. These sources in the Emission Registration account for about half of the total CO2 emissions in the Netherlands (..). However, as described in Chapter 4, total CO2 emissions per industrial sub-sector cannot be off from the reference calculation by more than 5% (in practice, the group total may show much less deviation)."

NIR 2004

For estimating the uncertainty in activity data and emission factors in the NIR 2004, the following information sources were used, as well as a slightly adjusted IPCC list (Klein Goldewijk et al., 2004):

- estimates used for reporting uncertainty in greenhouse gas emissions in the Netherlands, discussed at a national workshop in 1999 (Van Amstel et al., 2000a);
- default uncertainty estimates provided in the *IPCC Good Practice Guidance* report (IPCC, 2000);
- RIVM factsheets on calculation methodology and data uncertainty (RIVM, 1999);
- Any other recent information on the data quality, available at the time (Boonekamp et al., 2001).

These were supplemented with expert judgements from RIVM emission experts. In view of the importance to the Netherlands of CO_2 emissions from feedstocks, and the relatively large uncertainty in these emissions, we separated CO_2 emissions from non-energy use and fuel combustion. In cases where asymmetric uncertainty ranges were assumed, the largest percentage was used in the calculation.

The NIR 2004 mentions the following limitations of the uncertainty estimates (without repeating those also mentioned in the NIR 2002):

"Because of the problems identified with annual environmental reports (..) an extra uncertainty in national CO2 emissions was estimated for 2000 at 2% (Heslinga, 2001b). This will also be the case with 2001 and 2002 emissions. In addition, delays in compiling statistics for the last but one calendar year, notably for energy consumption, have caused extra uncertainty for some sectors due to the use of estimated data for the 4th quarter of 2002. For the same reason the other greenhouse gas emissions are also more uncertain in 2002, but this extra uncertainty has not been quantified."

"Even more important is that, although the uncertainty estimates have been based on the documented uncertainties mentioned above, uncertainty estimates are unavoidably and in the end based on expert judgement of representativeness for the circumstances of the particular source category in the Netherlands."

"For 2000 and 2001 (..) an extra uncertainty in national CO2 emissions was estimated at 2%. This is in addition to the extra uncertainty introduced in the last year's emission estimates, due to the use of partially estimated statistics as basis for the inventory. In the assessments made above only random errors have been estimated, assuming that the calculation methodology used does not include systematic errors. It is well known that in practice this may well be the case."

"The inventory improvement programme for some of these sources of bringing the methodology in compliance to IPCC Good Practice Guidance, for example indirect emissions of N2O, may result in adjustments of a few percent (..). The impact of these methodological changes on emissions is not included in the uncertainty estimates presented here."

NIR 2005

In the source category list used for the key source analysis, the following changes were made, compared to previous NIRs. New sources are found in:

- 1A – CO_2: Since NIR 2004, CO_2 emissions from stationary combustion are split into subcategories 1A1, 1A2, and 1A4, instead of in stationary totals per fuel type: gas, oil and coal;
- 1A – CO_2 from waste incineration (reported in 1A1a);
- 1B – CO_2 from coke production;
- 1B – Fugitive CO_2 emissions from venting and flaring;
- 2X – CO_2 emissions from limestone and dolomite use, other minerals, ammonia production, manufacture of other chemicals, net carbon inputs in iron and steel production (i.e. subtracting BF/OF gas produced, for which the CO_2 combustion emissions are reported as combustion under 1A2a), from aluminium production, and indirect CO_2 from solvents and product use;
- 2B – N_2O from caprolactam production;
- 2G – Indirect N_2O from non-agricultural sources (replacing 'N_2O from polluted surface waters');
- 2G – N_2O from other industrial sources;
- 5 – CO_2 from LUCF;
- 5 – N_2O, a (very small) new source.

Most of the industrial process sources ('2X') were previously included elsewhere, without being able to separate them. CO_2 emission sources from this sector, except for CO_2 emissions from mineral production, in this NIR replaced the sources 'CO_2 emissions from oil, gas and coal used as feedstocks, which were still used in the NIR 2004. In addition, CH_4 from enteric fermentation in sheep and swine, in NIR 2005, were merged into 'other livestock', whereas evaluated separately in NIR 2004, since both were no key source.

Changed uncertainty estimates are found in:
- 1A – CO_2: uncertainty in AD in 1A4 now 10% (was 3%); in EF now 2%, 1% and 1% for 1A1, 1A2, A4 (was 1%, 2% and 3% for gas, oil, coal);
- 1A3 – CO_2: uncertainty in AD 1A3d now 50% (was 100%);
- 1A – CH_4 and N_2O: uncertainty in AD for stationary combustion (1A1,2,4,5) now 3% (was 2%);
- 1B – CH_4: uncertainty in AD in 1B2 gas production and gas distribution now both 2% (was 1 and 5%, respectively).
- 2X – CO_2: uncertainty in AD and EF, from sources listed above, was previously aggregated to 30 and 5%, respectively, except for net carbon inputs in iron and steel production, of which the EF uncertainty was 3% in NIR 2004;
- 2X – SF_6: uncertainty in AD for SF_6 use now 50% (was 100%);
- 2X – PFC: uncertainty in AD for aluminium production now 2% (was 5%);
- 2X – HFC-23: uncertainty in AD HCFC-22 manufacture now 10% (was 15% in NIR 2002);
- 4A – CH_4: uncertainty in EF for enteric fermentation in other livestock now 30% (was 50%) [in NIR 2005, sheep and swine were merged into this category, since both were no key source, thereby changing the uncertainty in EF for swine to 30% (was 50%)];
- 7X – N_2O: uncertainty in AD now 20% (was 50%).

NIR 2006
In the source category list used for the key source analysis, the following changes were made, compared to the NIR 2005. New sources, to bring the key source list in full compliance with the *IPCC Good Practice*, are found in:
- 1A1 – CO_2: CO_2 emissions from energy industries are split into subcategories 1A1a, 1A1b, 1A1c and per fuel type: gas, oil and coal.
- 1A2 – CO_2: CO_2 emissions are split into subcategories per fuel type: gas, oil and coal.
- 1A4 – CO_2: CO_2 emissions are split into subcategories 1A4a,b,c for fuel type gas and 'other 1A4 – CO_2' (the latter referring to the sum of oil and coal emissions of the total 1A4 source category).
- 1A5 – CO_2: military mobile activities.
- 2G – N_2O: indirect N_2O from NO_x from combustion and industrial processes.
- 4A – CH_4: enteric fermentation in swine.
- 4D2 – N_2O: animal production on agricultural soils.
- 5 – CO_2: CO_2 emissions split into the five subcategories 5A to 5E.

Changed uncertainty estimates are found in:
- 1A – CO_2: uncertainty in AD in 1A4 now 10% (was 3%); in EF CO_2 now for gas, oil, coal in 1A1 1%, 10% and 3%; in 1A2 1%, 5% and 10% and in 1A4 now 1%, 2% and 5%, respectively (was 1%, 2% and 3% for gas, oil, coal , respectively, the same in 1A1, 1A2 and 1A4)
- 1A3b – CO_2: uncertainty in AD now 3% (was 2%) and in EF now 0.1% (was 2%).
- 1A3b – CH_4 and N_2O: uncertainty in AD now 3% (was 2%), and in EF N_2O, for 2003 and 2004, now 50% (was 60%, equal to the uncertainty in 1990).

- 1B1 – CO_2: uncertainty in AD and EF for coke production is now 30% and 20%, respectively (was 50% and 2%).
- 2G – N_2O: uncertainty in AD and EF for indirect N_2O from NO_x emissions 25% and 200%, respectively.
- 6A – CH_4: uncertainty in AD and EF are interchanged, now 30% and 15%, respectively (error correction, that does not influence annual uncertainty, but may influence trend uncertainties).

NIR 2007
In the source category list used for the key source analysis, no changes in uncertainty estimates were made, compared to the NIR 2006.

NIR 2008
In the source category list used for the key source analysis, the following changes were made, compared to the NIR 2007:
- 2G – N_2O: It was decided to remove indirect N_2O from the inventory of non-agricultural NO_x and NH_3 emissions, as a result of discussions with the in-country expert review team (ERT), although the ERT agreed on inclusion of this source in the inventory. This means a decrease in the N_2O emissions in the base year, of about 3 Gg.

Changed uncertainty estimates are found in:
- 2B2 - N_2O: uncertainty in EF for N_2O from nitric acid production is now 20% (was 50%)
- 2B2 - N_2O: uncertainty in AD and EF for caprolactam production is now 20% (was 50%) and 20% (was 50%)
- 5A1- N_2O: Forest Land remaining Forest Land N2O: uncertainty in AD and EF is 25% and 20%.

3.1 Expanded uncertainty calculation to include uncertainties larger than 60%

The standard IPCC Tier uncertainty calculation for a multiplication assumes, among other things, that the uncertainties are smaller than 60%. However, several greenhouse gas emission sources have uncertainties much larger than 60%. Therefore, this calculation was improved by removing this condition, using the following approach.

The coefficient of variation (i.e. the standard deviation divided by the mean) of a product of two independent (i.e. uncorrelated) variables is defined as:

$$CV_{X \cdot Y} = \sqrt{CV_X^2 + CV_Y^2 + CV_X^2 \cdot CV_Y^2}$$

Since the percentage uncertainty is defined as %UNC =F 2 CV*1000, the uncertainty for this product is expressed as:

$$\%UNC_{X \cdot Y} = \sqrt{\%UNC_X^2 + \%UNC_Y^2 + \left(\frac{1}{2 \cdot 100}\right)^2 \cdot \%UNC_X^2 \cdot \%UNC_Y^2}$$

$$= \sqrt{\%UNC_X^2 + \%UNC_Y^2 + 0.000025 \cdot \%UNC_X^2 \cdot \%UNC_Y^2}$$

Thus, the IPCC formula is expanded with an extra term, which can be disregarded when the uncertainty is smaller than 60%.

Effects of simplifying Tier 1 assumptions on the uncertainties of emissions for 1999 — Table 3.1

Greenhouse gas	Tier 1 uncertainty*	Tier 2 uncertainty
Carbon dioxide	2.7%	1.6%
Methane	16.2%	14.6%
Nitrous oxide	35.5%	29.3%
F-gases	20.3%	20.0%
Total	4.5%	3.6%

* Calculated in NIR 2001.
Source: Olsthoorn and Pielaat (2003).

Effects of simplifying Tier-1 assumptions on the 1990-1999 emission trend and trend uncertainties — Table 3.2

Emission trend	Tier 1 uncertainty*	Tier 2 uncertainty
CO_2 eq.	6.1%	5.8%
Confidence range	4.5% - 8.4%	3.5%- 8.6%.
Range (±) (relative)	2.6%-pnt. (65%)	2.8%-pnt. (45%)

* Calculated in NIR 2001.
Source: Olsthoorn and Pielaat (2003).

Effects of simplifying Tier 1 assumptions on the uncertainties of emissions for 2004 (without LULUCF) — Table 3.3

Greenhouse gas	Tier 1 annual uncertainty [1)]	Tier 2 annual uncertainty [2)]
Carbon dioxide	1.9%	1.5%
Methane	18%	15.1%
Nitrous oxide	45%	42.0%
F-gases	27%	28.1%
Total	4.3%	3.9%

[1)] Calculated in NIR 2006. [2)] Source: Ramirez-Ramírez et al. (2006, 2008).

Effects of simplifying Tier 1 assumptions on the uncertainty in the emission trend 1990-2004 (without LULUCF) — Table 3.4

Greenhouse gas	Emission trend 1990-2004	Tier 1 trend uncertainty [1)]	Tier 2 trend uncertainty [2)]
Carbon dioxide	+13%	2.7%	2.1%
Methane	-32%	11.3%	14.6%
Nitrous oxide	-16%	15.0%	27.9%
F-gases	-75%	7.0%	9.1%
Total	+1.6%	3.2%	4.5%

[1)] Calculated in NIR 2006. [2)] Source: Ramírez-Ramírez et al. (2006, 2008).

3.2 Comparison of a Tier 1 uncertainty estimate with a Tier 2 uncertainty calculation

In 2003, to assess the limitations of Tier 1 uncertainty estimates, a first Tier 2 uncertainty assessment was conducted, using the emissions data of the NIR 2001 (Olsthoorn and Pielaat, 2003). A comparison of the Tier 2 results for uncertainty in annual emissions, and in the emission trend with Tier 1 uncertainty estimates based on similar data, showed that in the Dutch circumstances the errors made in the simplified Tier 1 approach are quite small (see Tables 3.1 and 3.2, reproduced from the NIR 2004). This conclusion holds for both annual uncertainties and the trend uncertainty. This range of confidence is similar to the trend uncertainty found in comparable studies for the United Kingdom, Norway and Austria (Rypdal and Winiwarter, 2001).

In 2006, a second, more systematic Tier 2 uncertainty assessment was carried out (Ramírez-Ramírez et al., 2006). This study used the same uncertainty assumption as the Tier 1 study, but accounted for correlations and non-Gaussian distributions (see Annex 6 for the list of assumptions). Results revealed that the Tier 2 uncertainty in the total Dutch CO2 equivalent emissions was of the same order of magnitude as those in the Tier 1 results, although a larger trend uncertainty was found (see Tables 3.3 and 3.4). Furthermore, the Tier 2 uncertainty in the 1990 emissions was slightly larger (about 1.5%) than the uncertainty in the 2004 emissions. Finally, the resulting distribution of the total Dutch CO2 equivalent emissions turned out to be clearly positively skewed.

As part of this study, the expert judgments and assumptions made on uncertainty ranges in emission factors and activity data for the Netherlands were compared to the uncertainty assumptions (and their underpinnings) used in Tier 2 studies, carried out by other European countries, in particular Finland, the United Kingdom, Norway, Austria and Belgium (Flanders). The correlations that have been assumed in the various European Tier 2 studies were also mapped and compared.

Comparisons of assumed uncertainty ranges already led to a number of improvements in (and increased underpinning of) the Dutch assumptions for the present Tier 1. Although a straightforward comparison was somewhat blurred, due to differences in the aggregation level at which the assumptions were made, results show that, for CO_2, the uncertainty estimates for the Netherlands were well within the range of European studies.

For non-CO_2 gases, especially N_2O from agriculture and soils, the Netherlands used IPCC defaults which are on the high side, compared to the assumptions used in some of the other European studies. However, this seems quite realistic, in view of the state of knowledge on the processes that lead to N_2O emission. Another finding was that correlations (covariance and dependencies in the emission calculation) seemed somewhat under-addressed in most present-day European Tier 2 studies, and may require more systematic attention in future Tier 2 studies.

In the assessments made above, only random errors were estimated, assuming that the methodology used for the calculation did not include systematic errors. It is well known that, in practice, this may well be the case. Therefore, a more independent verification of the emission level and emission trends by, for example, comparisons with atmospheric concentration measurements is encouraged by the IPCC Good Practice Guidance. In the Netherlands, these approaches have been studied for several years, funded by the National Research Programme on Global Air Pollution and Climate Change (NOP-MLK), and by the Dutch Reduction Programme on Other Greenhouse Gases (ROB). The results from these studies can be found in Berdowski et al. (2001), Roemer and Tarasova (2002) and Roemer et al. (2003). In 2006, the research programme '*Climate change and spatial planning*' started, aiming to strengthen the knowledge on the relation between greenhouse gas emissions, land-use and spatial planning.

Correlation between sources

4

The uncertainties calculated in Tier 1 for the total of greenhouse gas emissions in the Netherlands were increased with a correction factor. The argumentation for this correction factor was that Tier 1 did not account for correlations and asymmetrical distributions, and there were gaps in knowledge which increased the uncertainty in the calculated emission figures. The Tier 2 analysis by Ramírez-Ramírez et al. (2006, 2008) showed that accounting for correlations and asymmetrical distribution functions does not necessarily lead to a significant increase in uncertainty in total greenhouse gas emissions. However, accounting for correlations had a stronger influence on the trend uncertainty than on the uncertainty in total greenhouse gas emission. This was caused by correlations between years which were not fully accounted for in the Tier 1 analysis .

The following correlations existed between source categories used in the key source analysis, which were ignored in the Tier 1 calculation of annual and trend uncertainties:

4.1 Fuel combustion sector (1A)

Correlations in activity data:

- CO_2, CH_4 and N_2O from the same source category. However, in practice, the uncertainty in non-CO_2 emissions was dominated by the uncertainty in the emission factors for CH_4 and N_2O, so the impact from accounting for correlations would have been negligible.
- gas consumption during combustion in the chemical industry (1A2c) was dependent on the amount estimated for chemical feedstock use, of which the CO_2 emissions were calculated and reported in sector 2.
- gas consumption in the service sector (1A4a) was dependent on total consumption in all other source categories, as it was calculated as the difference between total national domestic gas consumption and the consumption allocated to the other source categories.

Correlations in emission factors:

- CO_2 from gas: a large part of the 1A1 and 1A2 subcategories will use natural gas with a relatively high calorific value, instead of gas with 'Groningen field' quality. However, the error made by considering the various subcategories of the 1A fuel combustion sector as being independent, was not large. Natural gas delivered to different industries came from various so-called 'small' gas fields, and the emission factors for h-gas only differed up to 1% from the national default, which was also used as the uncertainty estimate of the emission factor for natural gas (Van Harmelen et al., 2002). The error may even be negligible, since the uncertainty in the activity data on several sources was larger than the uncertainty in the emission factor (Olsthoorn and Pielaat, 2003).
- CO_2 from residual chemical gas: the same value was used in 1A1a and 1A2(c).
- CO_2 from blast furnace and oxygen furnace gas: the same value was used in 1A1a and 1A2(a).
- CO_2 from unaccounted refinery gas combustion: this term was used in 1A1b (refineries) and is dependent on the uncertainty in the activity data and emission factor for the refinery gas that *is* accounted for, because the related CO_2 was calculated as the difference between carbon inputs in refineries (crude oil, NGL) and the amount of total oil products produced.
- CO_2 from coke oven gas: the same value was used in 1A1c and 1A2(c).
- CO_2 from coke: the same value was used in 1A1a and 1A2(c).

Other aspects of the uncertainties in this sector:

- the uncertainty in the emission factor for CO_2 from fossil waste incineration (1A1a) was considered larger for the years from 2000 onwards, since there are indications that the component fractions and carbon fraction per waste stream have changed; this may enhance the uncertainty in the emission factor, from 5% to, for instance, 20%.
- the uncertainty in the emission factor for CO_2 from liquid fuel combustion at refineries (1A1b), for 2003 and 2004, might have been larger, since recently reported emission factors for refinery gas, used for these years, differ significantly from the values currently used, for example 20%, instead of the value of 10%, used for other years.

4.2 Fugitive emissions from fuels (1B)

Correlations in activity data:

- the CO_2 from net carbon losses in coke ovens (1B1) was calculated from the amount of coking coal input, and coke and coke oven gas produced, and the CO_2 emission factor for these three fuels. Thus, the amount of coke and coke oven gas produced was correlated with the combustion in the fuel combustion sector 1A, notably in 1A2a.

- the amount allocated to venting and flaring (1B2) by the oil and gas production companies was correlated with the amount of own fuel-use for combustion, by the oil and gas production companies (included in 1A1c). The latter was calculated from their total apparent consumption (=F production minus sales), minus the amount allocated to venting and flaring (1B2). The amount of gas flared and vented, to some extent, was also correlated, since – together with their own-use – this is equal to the more accurately known apparent consumption by the gas production companies.
- for CO_2 and CH_4 from the same source category, in case of coke production and gas venting and flaring.
- the total length of the gas distribution network (1B2) is more accurately monitored than the length per type of material. Since, in the NIR 2005 and the NIR 2006, two material types were distinguished, the activity data of both were correlated through the lower uncertainty in the total.

Correlations in emission factors:

- the CO_2 factors used for the 1B sources were the same as those for the fuel combustion sources in 1A.

4.3 Industrial processes and product uses (2 and 3)

Correlations in activity data:

- 2B: gas used as feedstock in ammonia production was correlated with the gas combustion in 1A2c.
- 2B5: CO_2 emissions from other chemical product manufacture is the sum of production of industrial gases, carbon electrodes, and activated carbon, as described in detail in the NIRs and the protocols. These subprocesses are generally uncorrelated, thereby reducing the uncertainty in the total source category considered in the key source analysis.
- 2C: net fossil fuel carbon inputs into blast furnaces: primary coke as input was correlated with coke production in 1B1, and the subtracted BF/OF gas produced was correlated with the sum of combustion of this gas in 1A1a and 1A2(a).
- 2X: CO_2 emissions from limestone and dolomite use and from other minerals, and indirect CO_2 emissions from solvents and product use, are a mixture of several smaller subprocesses, described in detail in the NIRs and in the protocols for sectors 2 and 3. These subprocesses are generally uncorrelated, thereby reducing the total uncertainty in these source categories considered in the key source analysis.
- 2X: CO_2 from miscellaneous industrial processes are a mixture of several smaller processes, described in detail in the NIR and in the protocols for sectors 2/3. These are generally uncorrelated, thereby reducing the uncertainty in the total source category '2X – other industrial CO_2' considered in the key source analysis.
- 2X: CO_2 from aluminium production and 2X: PFC from aluminium production: these were based on the same activity data and, therefore, correlated. However, since the uncertainty in PFC emissions is mainly caused by the uncertainty in the emission factors, the impact of this correlation will be rather small.
- 2X: HFC consumption per application was used, as activity data on the emission calculation and the share of total HFC use per compound of the various applications, may be quite uncertain. However, the total use per HFC compound was determined separately, and is mostly rather accurate. Thus, the sum of HFC use per compound over all applications was correlated to total domestic consumption per compound. Principally, the same holds for PFC usage, but the amounts are much lower, in comparison with HFC usage.

Correlations in emission factors:

- also the emission factor for CO_2 from natural gas, coke and BlastFurnace/OvenFurnace gas was correlated with the same factors used in the fuel combustion sector 1A.

Other aspects of the uncertainties in these sectors:

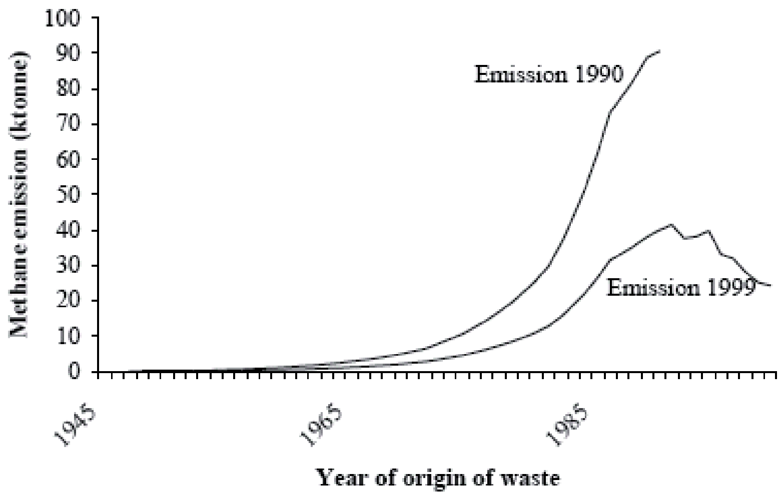
- Uncertainties in the activity data for 2A – CO_2 emissions from limestone and dolomite use were asymmetric (for example, -5% and +100%.),since miscellaneous uses and lime production were not included

4.4 Agriculture (4)

Correlations in activity data:

- 4A: for dairy and non-dairy cattle, total livestock was subdivided into 6 or 7 subtypes; the same was applied to swine, where the number of small piglets were included in total swine numbers by a correspondence rule. Both groups of animal numbers may, therefore, have been correlated.
- 4A: Some cattle subtype numbers may have been correlated across subsequent years, since, for example, for calves a distinction was made between the age groups <1 yr and > 1yr. However, the impact on the uncertainty in emission trends would have been minimal, when considering trends in time periods with a length of ten years or more.
- 4A and 4B: the amount of manure per type of livestock in 4B was calculated from the animal numbers and the amount of manure produced, per year, per animal. The first activity data was also used to calculate enteric fermentation in 4A, so these variables were correlated. However, since 4A only referred to CH_4, and the 4B category to results for both CH_4 and N_2O, in which the second term dominated and the uncertainty in the emission factors was much larger than the uncertainty in the activity data, the impact of neglecting these correlations is expected to be quite small.
- 4B: the total amount of animal waste produced was split into animal waste deposited on pasture land during grazing, and waste produced in two types of stables: liquid and solid storage; Subsequently, the amount produced in stables was distributed over a number of applications: the main application being domestic use as fertiliser – either by surface spreading or by incorporation into both organic and inorganic soils – but a small fraction is exported. Clearly, these elements were correlated in that the totals are confined.

Methane emissions from landfills in 1990 and 1999 **Figure 4.1**



Contribution of waste deposited in past years to total methane emissions from landfills in 1990 and in 1999. Source: Olsthoorn and Pielaat, 2003.

- 4D: the amounts of animal waste being spread on grassland and incorporated into the grassland soil were correlated, since the total amount is more accurate than the two individual subcategories.
- 4D: the activity data for indirect N_2O emissions were to a large extent correlated to the direct N_2O emissions from this source category. Another correlation of indirect N_2O emissions was found in the N_2O emissions from 4B, which also acted as activity data for part of the indirect N_2O from agriculture.

Correlations in emission factors:
- 4A: a number of default CH_4 emission factors was primarily based on the weight of the different animal types. For these types, the emission factor could be considered as (partially) correlated.
- 4B: the emission factors for N_2O from manure dropped on the soil was the same for every animal type, thus correlated.

4.5 Land use, land use change and forestry (LULUCF) (5)

Correlations in activity data:
- the amounts of land remaining grassland and forest, and land converted to these land-use types, may be correlated

Correlations in emission factors:
- the carbon contents factor per land-use category for C storage and C emissions and the resulting net changes will generally be correlated.

4.6 Waste (6)

Correlations in activity data:
- 6A: since the annual emissions were the integral sum of emissions resulting from the amounts of municipal solid waste, deposited annually in all previous years in the landfills, in this case the activity data were correlated between different years, although mostly the last ten years or so (see Figure 4.1). Waste deposited in older years does not contribute very much to emissions ten years or so later. Also, the fraction of fossil carbon per waste stream, which is assumed to be constant over time, if considered as a parameter for calculating the annual emissions, was correlated between different years.
- 6C: CO_2, CH_4 and N_2O emissions from the same source category The uncertainty in non-CO_2 emissions, however, were dominated by the uncertainty in the *emission factors,* so the impact is likely to have been negligible.

Correlations in emission factors:
- 6A and 6B: CH_4 from landfills and WWTPs. A number of factors, used in the emission calculations (for example, the methane oxidation and conversion factor) were assumed constant over time and thus correlated Actual emissions from categories 6A and B, however, were not so much influenced by the factors mentioned above but basically by the amount of CH_4 recovered (single, uncorrelated). This will strongly reduce the influence of the correlation mentioned before.

5

Emission factors and implied emission factors

In the Common Reporting Format (CRF) files, so-called Implied Emission Factors (IEFs) are presented for each source category. They are essentially 'effective' emission factors, determined by dividing reported emissions by an amount indicating the activity level of the source category. If the IEFs are constant over time, this usually indicates that either they correspond directly with one constant, source-specific emission factor or shares of sub-activities did not change.

For fuel combustion (1A), IEFs were calculated for each of the five main fuel types of each source category (including subcategories). For liquid and solid fuels in stationary combustion (1A1, 1A2, 1A4), the IEFs for CO_2 did change over time, so they consisted of a mix of different fuels.

Of the fuels used, in particular the derived gases (within solids) and the gases and residual fuel oil (within the liquids) have emission factors which differ strongly from those of the other fuels within this category. Therefore, in power generation (1A1a) and manufacturing industry (1A2), solid fuels were distinguished as coal, coke oven gas and blast furnace gas. In transport (1A3), liquid fuels were split into main subtypes, such as petrol, diesel and LPG in road transport. In gas distribution, two fuels were distinguished (for more details, see Annex 6).

In agriculture, calculated IEFs for CH_4 from enteric fermentation in cattle, howed a mix of 6 or 7 subtypes (animal types), each with a different emission factor. In practice, this category was split up into three categories only, with cattle and swine being distinguished separately (being the most important categories in the Netherlands). The rest was classified under the category 'other animals'. A similar procedure was followed for CH_4 and N_2O from animal waste (4B).

Appendix 1 Uncertainty ranges for energy consumption

Uncertainty in energy consumption (Boonekamp et al., 2001) **Table A1**

	Energy 1999 (PJ)	Uncertainty (%)
Extraction	2484	0.5
Import	6842	0.5
Export	5812	1.1
Bunkers	677	2.1
Total domestic consumption	2974	2.6
Total energy companies	593	3
Refineries	171	10
Power plants	242	1
Waste incineration	32	2
Energy distribution companies	33	2
Total consumers	2381	1.5
Industry	1027	1
Transport	457	2
Residential	421	3
Others	476	6

Source: Tinbergen, CBS, 2001, pers. comm.

Uncertainty in the relation between energy-relevant quantity and referential consumption **Table A2**

	Quantity	Uncertainty heat (%)	Uncertainty electricity (%)
Paper	Physical production	5	15
Synthetic fertiliser	Physical production	15	15
Metal, other	Production in Euro	20	15
Industry, other	Energy efficiency index (part sector)	30	30
building materials	Energy efficiency index (part sector)	10	10
Other sectors	Energy efficiency index	5	5
Transport	p-km or ton-km	10	20
Households	Dwellings	40	20
Trade and services	Sales volume	40	30
Greenhouse farming	Energy efficiency index (MJA)	10	10
Refining	Energy efficiency index (MJA)	5	5

Source: Tinbergen, CBS, 2001, pers. comm.

Appendix 2 Detailed uncertainty assumptions

ONZEKERHEIDSSCHATTING 95-02	EF CO2	p-s EF?	Activity Data						AVI etc	geel = cf. CBS tabel	
Basis: expert judgement (CBS, RIVM)						ook t->TJ		ook t->T	ook t->T	blauw = own estimate Jos	
1.A. Fuel Combustion			Producti	Gas	Liquid	Restgas	Solids	Derived	Other fu	bruin = NEU t.b.d.	
1. Energy Industries										groen = own estimate Joost/Jos	
a. Public Electricity and Heat Production										Hok: belangr. disc. punten	
Public				0.5%	0.5%		0.5%	0.5%	10%	% schaal:	
Autoproducers JVs				0.5%			1%			0.5	
b. Petroleum Refining	10%	ref. gas		0.5%	10%					1	
Added saldo of unaccounted in E-balance					?%					2	
c. Manufacture of Solid Fuels and Other Energy Industries										5	
Coke ovens	0.5%	C conter	3 yr stdev				1%	10%		10	
	2%	CO gas	3 yr stdev							20	
Own fuel use oil/gas production firms				50%	50%					50	
2. Manufacturing Industries and Construction				2%	1%		2%	2%	10%	100	
a. Iron and Steel							….	….			
NEU subtracted	2%	BF+OX	3 yr stdev				2%	2%			
b. Non-Ferrous Metals											
c. Chemicals				….	….		….				
NEU subtracted	10%	chem. gas		2%	5%		5%				
d. Pulp, Paper and Print											
e. Food Processing, Beverages and Tobacco											
f. Other *(please specify)*											
NEU subtracted				10%	10%		20%				
off-road vehicles construction					20%						
3. Transport											
a. Civil Aviation											
Aviation Gasoline					100%						
Jet Kerosene					50%						
b. Road Transportation											
Gasoline					2%						
Diesel Oil					2%						
LPG					2%						
c. Railways											
d. Navigation											
e. Other Transportation *(please specify)*											
Transport pipelines	IE										
4. Other Sectors											
a. Commercial/Institutional				10%	20%		50%	30%			
b. Residential				5%	5%						
c. Agriculture/Forestry/Fisheries				10%	20%		50%	30%			
off-road vehicles agriculture					10%						
5. Other *(please specify)* [1]											
a. Stationary				10%							
b. Mobile											
Military fuel use					20%						
1B. Fugitive emissions											
B. Fugitive Emissions from Fuels											
1. Solid Fuels											
b. Solid Fuel Transformation											
Coke production			2%	coking coal minus cokes							
2. Oil and Natural Gas											
a. Oil											
Oil production			0.5%								
Oil refining											
- Inputs			0.5%								
- Outputs			0.5%								
Added saldo of unaccounted in E-balance			10%								
b. Natural Gas											
Gas production			0.5%								
c. Venting and Flaring			20%								
Venting			20%								
Flaring			20%								
d. Other *(please specify)*											
Not specific attributable to sectors a to c											
Memo Items: [2]											
International Bunkers											
Aviation											
Aviation Gasoline											
Jet Kerosene											

Assumptions on uncertainties in agriculture

Table A2.2

	Klaas' update to 25% CH4 and 75% N2O			Em (Gg CO2-eq.)		Uncertainty: AD	EmF	EMISSION (G^2+H^2)^0.5	Hulp D^2+I^2	Remark	
4A	CH4 emissions from enteric fermentation: cattle	CH4		7.678	1990	5%	20%	21%	2505186	EmF 10->30%: 11->23% (10->20%: 16%	
4A	CH4 emissions from enteric fermentation: swine	CH4		439	1990	5%	50%	50%	48640		
4A	CH4 emissions from enteric fermentation: sheep	CH4		286	1990	5%	30%	30%	7545		
4A	CH4 emissions from enteric fermentation: other	CH4		40	1990	5%	30%	30%	147		
4B	Emissions from manure management : cattle	CH4		897	1990	10%	100%	100%	812112	AD: number animals 5% x N excretion/animal 5-10% = 7% to 11% say 10%	
4B	Emissions from manure management : swine	CH4		1.033	1990	10%	100%	100%	1078177	AD: number animals correlated with numbers used for enteric fermentation	
4B	Emissions from manure management : poultry	CH4		216	1990	10%	100%	100%	47254	->30: 23%	
4B	Emissions from manure management : other	CH4		17	1990	10%	100%	100%	285	->25%: no effect	
										->100: 11->16%	
Total CH4				**10.605**				**20%**	2121	**Compare Factsheet: 25%**	**"Add 5% for correlati**
4B	Emissions from manure management	N2O		217	1990	10%	100%	100%		AD: see CH4	
4D	Direct N2O emissions from agricultural soils	N2O		5.208	1990						
	Manure dropped in meadows		3,8	1178		10%	100%	100%	1401561	AD: Manure in meadows, on soils and in manure manag	
	Synt fertilisers		7	2170		10%	100%	100%	4755989		
	Manure to soils		6	1798		10%	100%	100%	3265132	AD: Manure in meadows, on soils and in manure manag	
	N-fixing crops		0,2	62		5%	100%	100%	3854		
	Crop residues			NE		NE	NE				
4D	Indirect N2O emissions from N used in agriculture	N2O		1.457	1990	50%	200%	206%	9022108		
Total N2O				**6.882**				**62%**	4295	**Compare Factsheet: 75%**	**"Add 10% for correla**
										N.B. Animal numbers/manure in CH4 and N2O are als	
7	Polluted surface water	N2O		**1.178**	1990	50%	200%	**206%**			

Appendix 3 Estimating uncertainties for the key source analysis

This annex documents the value, type, and source of uncertainty estimated for the Activity Data and Emission factors, for identified possible Key Sources (Tier 1), for the Netherlands. Its purpose was subsequent usage in Tier 2 Key Source identification and comparison with any Tier 2 uncertainty assessments carried out.

The basic approach by the NIR experts was to use the values reported in

(a) Proceedings of the workshop held on 01-09-1999 (Van Amstel et al. (eds.), 2000);
(b) IPCC Good Practice Guidance;
(c) Other reports;
(d) Own estimates.

Table A3.1 lists the uncertainties used and experts who were responsible for the uncertainty estimates in the NIR 2006 (in collaboration with the NIR coordinator, Brandes).

To facilitate these estimates and make them uniform, experts were asked to pick the uncertainty values from a list with the following values: 1%, 2%, 5%, 10%, 25%, 50%, 100%, 200% (see Table 3.2). It should be kept in mind that the order of magnitude is meant, rather than the exact value. For the interpretation of this typical order-of-magnitude value, see the ‘remarks’ to the table at the end of this annex.

Uncertainty estimates for key source analysis, NIR 2006 — **Table A3.1**

IPCC	Category	Gas	CO2-eq 1990	CO2-eq 2004	Activity data uncertainty	Emission factor uncertainty	Uncertainty estimate	Expert
1A1a	Stationary combustion: Public Electricity and Heat Production: liquids	CO_2	207	2198	0.5%	10.0%	10%	Jos Olivier
1A1a	Stationary combustion : Public Electricity and Heat Production: solids	CO_2	25776	26919	1.0%	3.0%	3%	Jos Olivier
1A1a	Stationary combustion : Public Electricity and Heat Production: gases	CO_2	13348	25576	0.5%	1.0%	1%	Jos Olivier
1A1a	Stationary combustion : Public Electricity and Heat Production: waste incineration	CO_2	592	2114	10.0%	5.0%	11%	Jos Olivier
1A1b	Stationary combustion : Petroleum Refining: liquids	CO_2	9999	9556	10.0%	10.0%	15%	Jos Olivier
1A1b	Stationary combustion : Petroleum Refining: gases	CO_2	1042	2267	0.5%	1.0%	1%	Jos Olivier
1A1c	Stationary combustion : Manuf. of Solid Fuels and Other En. Ind.: liquids	CO_2	2	1	20.0%	2.0%	20%	Jos Olivier
1A1c	Stationary combustion : Manuf. of Solid Fuels and Other En. Ind.: gases	CO_2	1526	1987	20.0%	5.0%	20%	Jos Olivier
1A2	Stationary combustion : Manufacturing Industries and Construction, liquids	CO_2	8993	7282	1.0%	5.0%	5%	Jos Olivier
1A2	Stationary combustion : Manufacturing Industries and Construction, solids	CO_2	5033	4515	2.0%	10.0%	10%	Jos Olivier
1A2	Stationary combustion : Manufacturing Industries and Construction, gases	CO_2	19020	15369	2.0%	1.0%	2%	Jos Olivier
1A4	Stationary combustion : Other Sectors, solids	CO_2	189	134	50.0%	5.0%	50%	Jos Olivier
1A4a	Stationary combustion : Other Sectors: Commercial/Institutional, gases	CO_2	6634	11003	20.0%	1.0%	20%	Jos Olivier

IPCC	Category	Gas	CO2-eq 1990	CO2-eq 2004	Activity data uncertainty	Emission factor uncertainty	Uncertainty estimate	Expert
1A4b	Stationary combustion : Other Sectors, Residential, gases	CO_2	18696	18786	5,0%	1,0%	5%	Jos Olivier
1A4c	Stationary combustion : Other Sectors, Agriculture/Forestry/Fisheries, gases	CO_2	8328	7041	10,0%	1,0%	10%	Jos Olivier
1A4c	Stationary combustion : Other Sectors, Agriculture/Forestry/Fisheries, liquids	CO_2	2544	2581	20,0%	2,0%	20%	Jos Olivier
1A4	Stationary combustion : Other Sectors, liquids excl. From 1A4c	CO_2	1476	629	20,0%	2,0%	20%	Jos Olivier
1A5	Military use of fuels (1A5 Other)	CO_2	566	437	20,0%	2,0%	20%	Jos Olivier
1A	Emissions from stationary combustion: non- CO_2	CH_4	522	565	3,0%	50,0%	50%	Johanna Montfoort
1A	Emissions from stationary combustion: non- CO_2	N_2O	215	240	3,0%	50,0%	50%	Johanna Montfoort
1A3b	Mobile combustion: road vehicles: gasoline	CO_2	10902	13168	2,0%	0,4%	2%	Gerben Geilenkirchen
1A3b	Mobile combustion: road vehicles: diesel oil	CO_2	11832	19542	5,0%	0,2%	5%	Gerben Geilenkirchen
1A3b	Mobile combustion: road vehicles: LPG	CO_2	2738	1131	10,0%	0,2%	10%	Gerben Geilenkirchen
1A3	Mobile combustion: water-borne navigation	CO_2	405	832	20,0%	0,2%	20%	Gerben Geilenkirchen
1A3	Mobile combustion: aircraft	CO_2	41	41	50,0%	0,5%	50%	Gerben Geilenkirchen
1A3	Mobile combustion: other (railways)	CO_2	91	109	5,0%	0,2%	5%	Gerben Geilenkirchen
1A3	Mobile combustion: other (non-road)	CH_4	1	1	50,0%	100,0%	110%	Gerben Geilenkirchen
1A3	Mobile combustion: other (non-road)	N_2O	1	3	50,0%	100,0%	110%	Gerben Geilenkirchen
1A3	Mobile combustion: road vehicles	CH_4	157	67	3,0%	60,0%	60%	Gerben Geilenkirchen
1A3	Mobile combustion: road vehicles	N_2O	271	486	5,0%	50,0%	50%	Gerben Geilenkirchen
1B2	Fugitive emissions venting/flaring	CH_4	1252	310	2,0%	25,0%	25%	Gerben Geilenkirchen
1B2	Fugitive emissions from oil and gas operations: gas distribution	CH_4	255	268	2,0%	50,0%	50%	Gerben Geilenkirchen
1B2	Fugitive emissions from oil and gas operations: other	CH_4	162	149	20,0%	50,0%	55%	Gerben Geilenkirchen
1B1b	CO_2 from coke production	CO_2	403	509	50,0%	2,0%	50%	Gerben Geilenkirchen
1B2	Fugitive emissions venting/flaring: CO_2	CO_2	775	125	50,0%	2,0%	50%	Gerben Geilenkirchen
2A1	Cement production	CO_2	416	446	5,0%	10,0%	10%	Kees Peek
2A3	Limestone and dolomite use	CO_2	276	297	25,0%	5,0%	25%	Kees Peek
2A7	Other minerals	CO_2	308	414	25,0%	5,0%	25%	Kees Peek
2B1	Ammonia production	CO_2	3096	3086	2,0%	1,0%	2%	Kees Peek
2B2	Nitric acid production	N_2O	6330	5617	10,0%	50,0%	50%	Kees Peek
2B5	Caprolactam production	N_2O	1240	759	50,0%	50,0%	70%	Kees Peek
2B5	Other chemical product manufacture	CO_2	606	571	50,0%	50,0%	70%	Kees Peek
2C1	Iron and steel production (carbon inputs)	CO_2	2514	1313	3,0%	5,0%	5%	Kees Peek
2C3	CO2 from aluminium production	CO_2	395	479	2,0%	5,0%	5%	Kees Peek
2C3	PFC from aluminium production	PFC	1901	106	2,0%	20,0%	20%	Kees Peek
2F	SF_6 emissions from SF_6 use	SF6	301	328	50,0%	25,0%	55%	Kees Peek
2F	Emissions from substitutes for ozone depleting substances (ODS substitutes): HFC	HFC	249	1023	10,0%	50,0%	50%	Kees Peek
2E	HFC-23 emissions from HCFC-22 manufacture	HFC	5759	354	10,0%	10,0%	15%	Kees Peek
2E	HFC by-product emissions from HFC manufacture	HFC	12	99	10,0%	20,0%	20%	Kees Peek
2F	PFC emissions from PFC use	PFC	37	179	5,0%	25,0%	25%	Kees Peek
2G	Other industrial: CO_2	CO_2	305	342	5,0%	20,0%	20%	Kees Peek
2G	Other industrial: CH_4	CH_4	297	312	10,0%	50,0%	50%	Kees Peek
2G	Other industrial: N_2O	N_2O	3	7	50,0%	50,0%	70%	Kees Peek
2G	Indirect N_2O from NH_3 from combustion and industrial processes	N_2O	52	56	50,0%	200,0%	200%	Kees Peek
2G	Indirect N_2O from NO2 from combustion and industrial processes	N_2O	883	637	15,0%	200,0%	200%	Kees Peek
3	Indirect CO_2 from solvents/product use	CO_2	316	144	25,0%	10,0%	25%	Kees Peek
4A1	CH_4 emissions from enteric fermentation in domestic livestock: cattle	CH_4	6767	5712	5,0%	20,0%	20%	Klaas van der Hoek
4A8	CH_4 emissions from enteric fermentation in domestic livestock: swine	CH_4	439	351	5,0%	50,0%	50%	Klaas van der Hoek
4A	CH_4 emissions from enteric fermentation in domestic livestock: other	CH_4	319	286	5,0%	30,0%	30%	Klaas van der Hoek
4B	Emissions from manure management	N_2O	694	707	10,0%	100,0%	100%	Klaas van der Hoek
4B1	Emissions from manure management : cattle	CH_4	1574	1475	10,0%	100,0%	100%	Klaas van der Hoek
4B8	Emissions from manure management : swine	CH_4	1141	919	10,0%	100,0%	100%	Klaas van der Hoek

IPCC	Category	Gas	CO2-eq 1990	CO2-eq 2004	Activity data uncer-tainty	Emission factor un-certainty	Un-certainty estimate	Expert
4B9	Emissions from manure man-agement : poultry	CH_4	243	56	10,0%	100,0%	100%	Klaas van der Hoek
4B	Emissions from manure management : other	CH_4	12	16	10,0%	100,0%	100%	Klaas van der Hoek
4D1	Direct N_2O emissions from agricultural soils	N_2O	4597	4839	10,0%	60,0%	60%	Klaas van der Hoek
4D3	Indirect N_2O emissions from ni-trogen used in agriculture	N_2O	4861	3209	50,0%	200,0%	205%	Klaas van der Hoek
4D2	Animal production on agricultural soils	N_2O	1308	651	10,0%	100,0%	100%	Klaas van der Hoek
5A1	Forest Land remaining Forest Land	CO_2	-2505	-2289	25,0%	62,0%	65%	GertJan van den Born
5A2	Land converted to Forest Land	CO_2	-11	-159	25,0%	58,0%	60%	GertJan van den Born
5B2	Land converted to Cropland	CO_2	-36	-36	25,0%	50,0%	55%	GertJan van den Born
5C1	Grassland remaining Grassland	CO_2	4246	4246	25,0%	50,0%	55%	GertJan van den Born
5C2	Land converted to Grassland	CO_2	-51	-51	25,0%	61,0%	65%	GertJan van den Born
5E2	Land converted to Settlements	CO_2	-152	-152	25,0%	50,0%	55%	GertJan van den Born
5F2	Land converted to Other Land	CO_2	717	717	25,0%	50,0%	55%	GertJan van den Born
5G	Othher (liming of soils)	CO_2	183	79	25,0%	1,0%	25%	GertJan van den Born
5A1	Forest Land remaining Forest Land	N_2O	0	0	25,0%	20,0%	30%	GertJan van den Born
6A1	CH_4 emissions from solid waste disposal sites	CH_4	12011	6521	30,0%	15,0%	35%	Durk Nijdam
6B	Emissions from wastewater handling	CH_4	290	225	20,0%	25,0%	30%	Durk Nijdam
6B	Emissions from wastewater handling	N_2O	513	399	20,0%	50,0%	55%	Durk Nijdam
6D	OTHER CH_4	CH_4	1	72	20,0%	25,0%	30%	Durk Nijdam
3, 6D	OTHER N_2O	N_2O	250	139	20,0%	50,0%	55%	Durk Nijdam

Uncertainty interpretation **Table A3.2**

Uncertainty interpretation of Expert Judgement (EJ):		
reported value (%)	means unc. in range:	corresponding unc. factor
1%	0.5-1.5	1.01
2%	1.5-3	1.02
5%	3-7.5	1.05
10%	7.5-15	1.1
25%	15-35	1.25
50%	35-75	1.5
100%	750-150	2
200%	>150	3

Remark to the table:

Pick a value from range: 1%, 2%, 5%, 10%, 25%, 50%, 100%, or 200%, since it is the order of magnitude that is important.

Appendix 4 Uncertainties used for Tier 2 assessment in 2006

Uncertainty data and probability distribution functions (PDFs) used by Ramírez-Ramírez et al. (2006, 2008) in the Tier 2 uncertainty assessment, to estimate the uncertainty in greenhouse gas emissions.

Sector 1. Energy: combustion and fugitive sources **Table A4.1**

	Activity data		Emission factors					
			CO_2		CH_4		N_2O	
Category	2σ (%)	PDF	2σ (%)	PDF	2σ (%)	PDF	2σ (%)	PDF
1A- FUEL COMBUSTION								
1.A.1-Energy industries								
a. Public electricity and heat production								
Liquid fuels	0.5	Normal	10.0	Normal	50.0	Normal	100.0	Log-Normal
Solid fuels					50.0	Normal	200.0	Log-Normal
Coke Oven gas and BF gas	1.0	Normal	15.0	Normal				
Coal	1.0	Normal	1.0	Normal				
Gaseous fuels	0.5	Normal	1.0	Normal	50.0	Normal	100.0	Log-Normal
Biomass	10.0	Normal	---		80.0	Log-Normal	100.0	Log-Normal
Other fuels	10.0	Normal	5.0	Normal	50.0	Normal	100.0	Log-Normal
b. Petroleum refining								
Liquid fuels	10.0	Normal	10.0	Normal	50.0	Normal	100.0	Log-Normal
Solid fuels	0.5	Normal	2.0	Normal	50.0	Normal	100.0	Log-Normal
Gaseous fuels	0.5	Normal	1.0	Normal	50.0	Normal	100.0	Log-Normal
c. Manufacture of solid fuels and other energy industries								
Liquid fuels	20.0	Normal	2.0	Normal	50.0	Normal	100.0	Log-Normal
Solid fuels	5.0	Normal	2.0	Normal	50.0	Normal	100.0	Log-Normal
Gaseous fuels	20.0	Normal	5.0	Normal	50.0	Normal	100.0	Log-Normal
1.A.2-Manufacturing Industries and construction								
Liquid fuels	1.0	Normal	5.0	Normal	50.0	Normal	100.0	Log-Normal
Solid fuels					50.0	Normal	100.0	Log-Normal
Coke Oven gas and BF gas	2.0	Normal	15.0	Normal				
Coal	2.0	Normal	5.0	Normal				
Gaseous fuels	2.0	Normal	1.0	Normal	50.0	Normal	100.0	Log-Normal
Biomass	100.0	Log-Normal	5.0	Normal	80.0	Log-Normal	100.0	Log-Normal
Other fuels	10.0	Normal	5.0	Normal	50.0	Normal	100.0	Log-Normal
1.A.3-Transport								
a. Civil aviation								
Aviation Petrol	50.0	Normal	0.5	Normal	100.0	Log-Normal	100.0	Log-Normal
Jet Kerosene	50.0	Normal	0.5	Normal	100.0	Log-Normal	100.0	Log-Normal
b. Road Transportation								
Petrol	2.0	Normal	0.4	Normal	76.0	Log-Normal	66.0	Log-Normal
Diesel	5.0	Normal	0.4	Normal	76.0	Log-Normal	66.0	Log-Normal
LPG	10.0	Normal	0.2	Normal	96.0	Log-Normal	101.0	Log-Normal
c. Railways								
Liquid fuels	5.0	Normal	0.2	Normal	100.0	Log-Normal	100.0	Log-Normal
Diesel oil	5.0	Normal	0.2	Normal	77.0	Log-Normal	82.0	Log-Normal

	Activity data		Emission factors					
			CO_2		CH_4		N_2O	
Category	2σ (%)	PDF	2σ (%)	PDF	2σ (%)	PDF	2σ (%)	PDF
d. Navigation								
Residual oil	20.0	Normal	0.2	Normal	100.0	Log-Normal	100.0	Log-Normal
Gas/diesel oil	20.0	Normal	0.2	Normal	100.0	Log-Normal	100.0	Log-Normal
1.A.4-Other sectors								
Liquid fuels	20.0	Normal			50.0	Normal	100.0	Log-Normal
Solid fuels	50.0	Normal			50.0	Normal	100.0	Log-Normal
Gaseous fuels	5.0	Normal			50.0	Normal	100.0	Log-Normal
Biomass	25.0	Normal			80.0	Log-Normal	100.0	Log-Normal
Other fuels								
a. Commercial/institutional								
Liquid fuels			2.0	Normal				
Solid fuels			5.0	Normal				
Gaseous fuels			1.0	Normal				
b. Residential								
Liquid fuels	20.0	Normal	2.0	Normal				
Solid fuels	50.0	Normal	5.0	Normal				
Gaseous fuels	5.0	Normal	1.0	Normal				
Biomass	25.0	Normal						
c. Agriculture/forestry/fisheries								
Liquid fuels	20.0	Normal	2.0	Normal				
Solid fuels	50.0	Normal	5.0	Normal				
Gaseous fuels	10.0	Normal	1.0	Normal				
1.A.4-Others (not-specified elsewhere)								
b. Mobile (Military use)								
Liquid fuels	20.0	Normal	2.0	Normal				
1B- NON-COMBUSTION OR FUGITIVE RELATED SOURCES								
1.B.1.b Solid fuel transformation	50.0	Normal	2.0	Normal	50.0	Normal		
1.B.2 Fugitive emissions from venting and flaring								
a. Oil								
Refining and storage	20.0	Normal			50.0	Normal		
b. Natural gas								
Transmission	20.0	Normal			50.0	Normal		
Distribution			50.0	Normal				
Grey cast iron	2.0	Normal			50.0	Normal		
Other materials	2.0	Normal			50.0	Normal		
c.Venting								
Oil	2.0				25.0	Normal		
Combined	2.0		50.0	Normal	25.0	Normal		
Flaring								
Oil	2.0				25.0	Normal		
Gas	2.0				25.0	Normal		

Sector 2. Industrial processes (excl. 2E and 2F) — Table A4.2

	Activity data		Emission factors					
			CO_2		CH_4		N_2O	
Category	2σ (%)	PDF	2σ (%)	PDF	2σ (%)	PDF	2σ (%)	PDF
2A- MINERAL PRODUCTS								
2.A.1- Cement production	5.0	Normal	10.0					
2.A.3- Limestone and dolomite use	25.0	Normal	5.0					
2.A.7- Others (soda ash and gas production)	25.0	Normal	5.0					
2B- CHEMICAL INDUSTRY								
2.B.1- Ammonia production	2.0	Normal	1.0	Normal				
2.B.2- Nitric acid production	10.0	Normal					50.0	Normal
2.B.5- Others								
Caprolactam	50.0	Normal					50.0	Normal
2C- METAL PRODUCTION								
2.B.1- Iron and steel production	3.0	Normal	5.0	Normal				
2.B.3- Aluminium production	2.0	Normal	5.0	Normal				
2D- OTHER								
Fireworks and candles	50.0	Normal					50.0	Log-Normal
Indirect N_2O from combustion and industrial processes	15.0	Normal					200.0	Log-Normal
Indirect N_2O from non-agricultural NH_3 sources	50.0	Normal					200.0	Log-Normal

Categories 2E and 2F. Emissions of HFCs, PFCs and SF6 — Table A4.3

	Activity data		Emission factors					
			CF_4		C_2F_6		HFC-23	
Sector	2σ (%)	PDF	2σ (%)	PDF	2σ (%)	PDF	Min-max	
PFCs AND SF_6 FROM METAL PRODUCTION								
PFCs from aluminium production	2.0	Normal	20.0	Normal	20.0	Normal		
PRODUCTION OF HALOCARBONS AND SF_6								
By product emissions								
HFC-23	2.0	Normal					Min:20%	Triangular
							Max:30%	Triangular

Sector 3. Solvents and other product use — Table A4.4

	Activity data		Carbon fractions		N_2O emission factors	
Category	2σ (%)	PDF	2σ (%)	PDF	2σ (%)	PDF
3-TOTAL SOLVENTS AND OTHER PRODUCT USE						
3A. Paint application	25.0	Normal	10.0	Normal		
3B. Degreasing and dry cleaning	25.0	Normal	10.0	Normal		
3D. Other	25.0	Normal	10.0	Normal		
Use of N_2O for anaesthesia	20.0	Normal			50.0	Normal
N_2O from aerosol cans	20.0	Normal			50.0	Normal

Sector 4. Agriculture

Table A4.5

Category	Activity data 2σ (%)	Activity data PDF	CH_4 emission factors 2σ (%)	CH_4 emission factors PDF	Emission factor per animal waste management system N_2O 2σ (%)	Emission factor per animal waste management system N_2O PDF
4-AGRICULTURE						
4A. Enteric fermentation						
Cattle	5.0	Normal	20.0	Normal		
Sheep	5.0	Normal	30.0	Normal		
Goats	5.0	Normal	30.0	Normal		
Horses	5.0	Normal	30.0	Normal		
Swine	5.0	Normal	50.0	Normal		
4B. Manure management						
Cattle	5.0	Normal	100.0	Log-Normal		
Sheep	5.0	Normal	100.0	Log-Normal		
Goats	5.0	Normal	100.0	Log-Normal		
Horses	5.0	Normal	100.0	Log-Normal		
Swine	5.0	Normal	100.0	Log-Normal		
Poultry	10.0	Normal	100.0	Log-Normal		
Nitrogen excretion per animal waste management						
Liquid system	10.0	Normal			100.0	Log-Normal
Solid storage and dry lot	10.0	Normal			100.0	Log-Normal
4C. Agricultural soils						
1. Direct soil emissions						
Synthetic fertilisers	10.0	Normal			100.0	Log-Normal
Animal manure applied to solids	10.0	Normal			100.0	Log-Normal
N-fixing crops	5.0	Normal			100.0	Log-Normal
Cultivation of histosols	10.0	Normal			100.0	Log-Normal
2. Pasture, Range and Paddock manure	10.0	Normal			100.0	Log-Normal
3. Indirect emissions						
Atmospheric deposition	50.0	Normal			200.0	Log-Normal
Nitrogen leaching and run-off	50.0	Normal			200.0	Log-Normal
4. Other						
Sludge application on land	20.0	Normal			50.0	Normal

Categories 5A-5F. Land-Use Change and Forestry (LUCF)

Table A4.6

Category	Activity data 2σ (%)	Activity data PDF	Emission factors: Increase living biomass per area 2σ (%)	Increase living biomass per area PDF	Decrease living biomass per area 2σ (%)	Decrease living biomass per area PDF	Net carbon stock change in dead organic matter per area 2σ (%)	Net carbon stock change in dead organic matter per area PDF	Net carbon stock change in soils per area 2σ (%)	Net carbon stock change in soils per area PDF
5A-CHANGES IN FOREST AND OTHER WOODY BIOMASS STOCKS										
1-Forest land remaining forest land										
Trees outside forest	25	Normal	15	Normal						
Forest	25	Normal	10	Normal	30	Normal	50	Normal		
2-Land converted to forest land	25	Normal							50	Normal
5B-FOREST AND CROPLAND CONVERSION-TOTAL CROPLAND										
2-Land converted to cropland	25	Normal							50	Normal
5C-TOTAL GRASSLAND										
1.-Grassland remaining grassland	25	Normal							50	Normal
2- Land converted to grassland	25	Normal			61	Lognormal			50	Normal
5E-TOTAL SETTLEMENTS										
2-Land converted to settlements	25	Normal							50	Normal
5F-TOTAL OTHER LAND										
2-Land converted to other land	25	Normal							50	Normal

Other categories belonging to LUCF

Table A4.7

Category	Activity data		Emission factors (carbon emission per unit of lime)	
	2σ (%)	PDF	2σ (%)	PDF
5G- OTHER CATEGORY				
Liming of soils	25	Normal	1	Normal

Sector 6. Waste

Table A4.8

Category	Activity data		CH_4 emission factors		N_2O emission factors	
	2σ (%)	PDF	2σ (%)	PDF	2σ (%)	PDF
6A-WASTE-WATER MANAGEMENT						
2-Domestic and commercial waste water						
Waste water	20	Normal	25	Normal	50	Normal
6D-OTHER WASTE HANDLING						
Compost production	20	Normal	25	Normal	50	Normal

Appendix 5 Tables 6.1 and 6.2 of the IPCC Good Practice guidance (NIR 2008)

Uncertainty estimates for Tier 1-trend — **Table A5.1**

	Uncertainty in emission level	Uncertainty in emission trend
CO_2-eq.	±5%	±3%-points of 3% decrease
CO_2	±3%	±3%-points of 8% increase
CH_4	±25%	±10%-points of 36% decrease
N_2O	±50%	±16%-points of 15% decrease
F-gases	±50%	±8%-points of 75% decrease

A Tier 1 uncertainty assessment was made to estimate the uncertainty in total national greenhouse gas emissions and in their trend. Tier 1 here means that non-Gaussian uncertainty distributions and correlations between sources have been neglected[1]. The uncertainty estimates for activity data and emission factors as listed in Table A5.2. were also used for a Tier 1-trend uncertainty assessment as shows in Table A5.1. Uncertainties for the activity data and emission factors are derived from a mixture of empirical data and expert judgment and presented here as half the 95% confidence interval. The reason for halving the 95% confidence interval is that the value then corresponds to the familiar plus or minus value when uncertainties are loosely quoted as 'plus or minus x%'.

Details on this calculation can be found in Table A7.2. It should be stressed that most uncertainty estimates are ultimately based on (collective) expert judgement and therefore also rather uncertain (usually of the order of 50%). However, the reason to make these estimates is to identify the relative most important uncertain sources. For this purpose, a reasonable order-of-magnitude estimate of the uncertainty in activity data and in emission factors is usually sufficient: uncertainty estimates are a means to identify and prioritise inventory improvement activities, rather than an objective in itself.

This result may be interpreted in two ways: part of the uncertainty is due to inherent lack of knowledge on the sources that can not be improved; another part, however, can be attributed to elements of the inventory of which the uncertainty could be reduced in the course of time. The latter may be a result of either dedicated research initiated by the Inventory Agency or by other researchers. When this type of uncertainty is in sources that are expected to be relevant for emission reduction policies, the effectiveness of the policy package could be in jeopardy if the unreduced emissions turn out to be much less than originally estimated.

The results of this uncertainty assessment for the list of potential key sources can also be used to refine the Tier 1 key source assessment discussed above.

1 We note that a Tier 2 uncertainty assessment and a comparison with a Tier 1 uncertainty estimate based on similar data showed that in the Dutch circumstances the errors made in the simplified Tier 1 approach for estimating uncertainties are quite small (Olsthoorn and Pielaat, 2003 and Ramírez-Ramírez et al., 2006). This conclusion holds for both annual uncertainties and the trend uncertainty .

Tier 1 level and trend uncertainty assessment 1990-2007 (for F-gases with base year 1995) with the categories of the IPCC potential key source list (without adjustment for correlation sources). **Table A5.2**

IPCC	Category	Gas	CO2-eq base year abs	CO2-eq last year abs	AD unc	EF unc	Uncertainty estimate	Combined Uncertainty as % of total national emissions	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty
4D3	Indirect N_2O emissions from nitrogen used in agriculture	N_2O	4975	3124	50%	200%	206%	30%	-16%	10%
4D1	Direct N_2O emissions from agricultural soils	N_2O	4674	4868	10%	60%	61%	14%	01%	03%
5C1	Grassland remaining Grassland	CO_2	4246	4246	25%	50%	56%	11%	00%	07%
1A4a	Stationary combustion : Other Sectors: Commercial/Institutional, gases	CO_2	6634	9970	20%	1%	20%	09%	00%	13%
6A1	CH_4 emissions from solid waste disposal sites	CH_4	12011	5260	30%	15%	34%	08%	-04%	10%
4B1	Emissions from manure management : cattle	CH_4	1571	1471	10%	100%	100%	07%	00%	01%
5A1	Forest Land remaining Forest Land	CO_2	2529	2167	25%	62%	67%	07%	-01%	03%
1A1b	Stationary combustion : Petroleum Refining: liquids	CO_2	9999	9060	10%	10%	14%	06%	00%	06%
4B8	Emissions from manure management : swine	CH_4	1140	1082	10%	100%	100%	05%	00%	01%
1A3b	Mobile combustion: road vehicles: diesel oil	CO_2	11832	20496	5%	0%	5%	05%	00%	07%
2B2	Nitric acid production	N_2O	6330	4305	10%	20%	22%	04%	-02%	03%
4A1	CH_4 emissions from enteric fermentation in domestic livestock: cattle	CH_4	6783	5636	5%	15%	16%	04%	-01%	02%
4B	Emissions from manure management	N_2O	814	872	10%	100%	100%	04%	00%	01%
1A1a	Stationary combustion : Public Electricity and Heat Production: solids	CO_2	25776	26068	1%	3%	3%	04%	00%	02%
1A4b	Stationary combustion : Other Sectors, Residential, gases	CO_2	18696	15747	5%	1%	5%	04%	00%	05%
2F	Emissions from substitutes for ozone depleting substances (ODS substitutes): HFC	HFC	249	1471	10%	50%	51%	03%	03%	01%
1A4c	Stationary combustion : Other Sectors, Agriculture/Forestry/Fisheries, gases	CO_2	8328	6585	10%	1%	10%	03%	00%	04%
1A	Emissions from stationary combustion: non- CO_2	CH_4	586	1226	3%	50%	50%	03%	01%	00%
4D2	Animal production on agricultural soils	N_2O	1449	603	10%	100%	100%	03%	-04%	00%
1A2	Stationary combustion : Manufacturing Industries and Construction, solids	CO_2	5014	4550	2%	10%	10%	02%	00%	01%
1A2	Stationary combustion : Manufacturing Industries and Construction, liquids	CO_2	8644	9051	1%	5%	5%	02%	00%	01%
1A1c	Stationary combustion : Manuf of Solid Fuels and Other En Ind: gases	CO_2	1526	2208	20%	5%	21%	02%	00%	03%
1A4c	Stationary combustion : Other Sectors, Agriculture/Forestry/Fisheries, liquids	CO_2	2893	2153	20%	2%	20%	02%	00%	03%
2B5	Other chemical product manufacture	CO_2	606	606	50%	50%	71%	02%	00%	02%
5A2	Land converted to Forest Land	CO_2	3	575	25%	58%	63%	02%	01%	01%
5C2	Land converted to Grassland	CO_2	394	542	25%	61%	66%	02%	00%	01%
1A2	Stationary combustion : Manufacturing Industries and Construction, gases	CO_2	19020	14148	2%	1%	2%	01%	00%	02%
1A3b	Mobile combustion: road vehicles: gasoline	CO_2	10902	13000	2%	0%	2%	01%	00%	02%
1A1a	Stationary combustion : Public Electricity and Heat Production: gases	CO_2	13348	23675	1%	1%	1%	01%	00%	01%
6B	Emissions from wastewater handling	N_2O	466	456	20%	50%	54%	01%	00%	01%
1A1a	Stationary combustion : Public Electricity and Heat Production: waste incineration	CO_2	592	2184	10%	5%	11%	01%	00%	01%
1B1b	CO_2 from coke production	CO_2	403	444	50%	2%	50%	01%	00%	01%
1A3	Mobile combustion: road vehicles	N_2O	271	438	5%	50%	50%	01%	00%	00%
4A8	CH_4emissions from enteric fermentation in domestic livestock: swine	CH_4	438	367	5%	50%	50%	01%	00%	00%
5E2	Land converted to Settlements	CO_2	212	292	25%	50%	56%	01%	00%	00%
1A	Emissions from stationary combustion: non- CO_2	N_2O	226	313	3%	50%	50%	01%	00%	00%
2G	Other industrial: CH_4	CH_4	297	302	10%	50%	51%	01%	00%	00%
2B5	Caprolactam production	N_2O	766	497	20%	20%	28%	01%	00%	01%
2A7	Other minerals	CO_2	275	485	25%	5%	25%	01%	00%	01%
1A3	Mobile combustion: water-borne navigation	CO_2	405	606	20%	0%	20%	01%	00%	01%

IPCC	Category	Gas	CO2-eq base year abs	CO2-eq last year abs	AD unc	EF unc	Uncertainty estimate	Combined Uncertainty as % of total national emissions	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty
1B2	Fugitive emissions venting/flaring	CH_4	1252	479	2%	25%	25%	01%	-01%	00%
2F	SF6 emissions from SF6 use	SF6	301	214	50%	25%	56%	01%	00%	01%
1A3b	Mobile combustion: road vehicles: LPG	CO_2	2738	962	10%	0%	10%	00%	00%	01%
2C1	Iron and steel production (carbon inputs)	CO_2	2514	1647	3%	5%	6%	00%	00%	00%
4A	CH4 emissions from enteric fermentation in domestic livestock: other	CH_4	319	315	5%	30%	30%	00%	00%	00%
1A4	Stationary combustion : Other Sectors, liquids excl From 1A4c	CO_2	1476	446	20%	2%	20%	00%	00%	01%
1B2	Fugitive emissions from oil and gas operations: other	CH_4	162	158	20%	50%	54%	00%	00%	00%
1A1a	Stationary combustion: Public Electricity and Heat Production: liquids	CO_2	207	741	1%	10%	10%	00%	00%	00%
1B2	Fugitive emissions venting/flaring: CO_2	CO_2	775	140	50%	2%	50%	00%	00%	00%
1B2	Fugitive emissions from oil and gas operations: gas distribution	CH_4	255	272	2%	25%	25%	00%	00%	00%
2B1	Ammonia production	CO_2	3096	3016	2%	1%	2%	00%	00%	00%
2A3	Limestone and dolomite use	CO_2	232	261	25%	5%	25%	00%	00%	00%
4B9	Emissions from manure management : poultry	CH_4	273	66	10%	100%	100%	00%	-01%	00%
3, 6D	OTHER N_2O	N_2O	250	121	20%	50%	54%	00%	00%	00%
6B	Emissions from wastewater handling	CH_4	290	203	20%	25%	32%	00%	00%	00%
1A5	Military use of fuels (1A5 Other)	CO_2	566	317	20%	2%	20%	00%	00%	00%
2G	Other industrial: CO_2	CO_2	305	307	5%	20%	21%	00%	00%	00%
2F	PFC emissions from PFC use	PFC	37	226	5%	25%	25%	00%	00%	00%
2A1	Cement production	CO_2	416	403	5%	10%	11%	00%	00%	00%
1A4	Stationary combustion : Other Sectors, solids	CO_2	189	86	50%	5%	50%	00%	00%	00%
3	Indirect CO_2 from solvents/product use	CO_2	316	128	25%	10%	27%	00%	00%	00%
2E	HFC-23 emissions from HCFC-22 manufacture	HFC	5759	243	10%	10%	14%	00%	-02%	00%
5D2	Land converted to Wetlands	CO_2	40	55	25%	50%	56%	00%	00%	00%
1A1b	Stationary combustion : Petroleum Refining: gases	CO_2	1042	2596	1%	1%	1%	00%	00%	00%
1A3	Mobile combustion: road vehicles	CH_4	157	45	3%	60%	60%	00%	00%	00%
5B2	Land converted to Cropland	CO_2	35	48	25%	50%	56%	00%	00%	00%
2C3	CO_2 from aluminium production	CO_2	395	431	2%	5%	5%	00%	00%	00%
6D	OTHER CH_4	CH_4	1	67	20%	25%	32%	00%	00%	00%
1A3	Mobile combustion: aircraft	CO_2	41	41	50%	1%	50%	00%	00%	00%
2C3	PFC from aluminium production	PFC	1901	101	2%	20%	20%	00%	-02%	00%
5G	Other (liming of soils)	CO_2	183	71	25%	1%	25%	00%	00%	00%
4B	Emissions from manure management : other	CH_4	11	15	10%	100%	100%	00%	00%	00%
5F2	Land converted to Other Land	CO_2	18	25	25%	50%	56%	00%	00%	00%
2E	HFC by-product emissions from HFC manufacture	HFC	12	24	10%	20%	22%	00%	00%	00%
1A3	Mobile combustion: other (railways)	CO_2	91	97	5%	0%	5%	00%	00%	00%
2G	Other industrial: N_2O	N_2O	3	6	50%	50%	71%	00%	00%	00%
1A3	Mobile combustion: other (non-road)	N_2O	1	2	50%	100%	112%	00%	00%	00%
1A3	Mobile combustion: ther (non-road)	CH_4	1	1	50%	100%	112%	00%	00%	00%
1A1c	Stationary combustion : Manuf of Solid Fuels and Other En Ind: liquids	CO_2	2	1	20%	2%	20%	00%	00%	00%
	TOTAL	GHG	220983	215527	-2%			41%		

Emissions (Gg) and uncertainty estimates for the subcategories of Sector 5 LULUCF, as used in the Tier 1 Uncertainty analysis **Table A5.3**

IPCC	Category	Gas	CO_2-eq 1990	CO_2-eq 2005	AD uncert	EF uncert	EM uncertainty estimate
5A1	Forest Land remaining Forest Land	CO_2	-2505	-2289	25.0%	61.8%	67%
5A2	Land converted to Forest Land	CO_2	-13	-220	25.0%	57.9%	63%
5B2	Land converted to Cropland	CO_2	-36	-36	25.0%	50.0%	56%
5C1	Grassland remaining Grassland	CO_2	4246	4246	25.0%	50.0%	56%
5C2	Land converted to Grassland	CO_2	194	194	25.0%	61.2%	66%
5E2	Land converted to Settlements	CO_2	-152	-152	25.0%	50.0%	56%
5F2	Land converted to Other Land	CO_2	750	750	25.0%	50.0%	56%
5G	Other (liming of soils)	CO_2	183	81	25.0%	1.0%	25%
5A1	Forest Land remaining Forest Land	N_2O	0	0	25.0%	20.0%	32%

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Reports and other information on uncertainty estimates available:

- Two workshop reports (Van Amstel et al., 2000a,b).
- Factsheets compiled by RIVM (RIVM, 1999)
- NIRs
- Four spreadsheets (Olivier, pers. comm.)
- IVM Tier 2 report (Olsthoorn and Pielaat, 2003)
- TNO report on uncertainty in CO_2 emisions from industrial fuel combustion (and other similar reports)
- Brandes, Olivier and Vreuls (Poland 2004 and Utrecht 2005) (and other similar papers)
- Papers on the Netherlands presented at NCGG-3 and NCGG-4
- ROB reports (Novem)
- CO_2 NEU reports by UU (Patel/Neelis)
- CBS report on CO_2 emissions from fossil-fuel combustion (Huurman, 2005)
- Uncertainty assessment of NO_x and NH_3 (Van Gijlswijk et al., 2001)
- University Utrecht Tier 2 report (Ramírez et al., 2006, 2008)
- Protocols for GHG emission sources describing the methodology and data sources used, and their quality http://www.greenhousegases.nl/

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Colophon

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This research has been performed by order and for the account of the Directorate-General for Environmental Protection, Sources and Emissions Division, of the Netherlands Ministry of Spatial Planning, Housing and the Environment, within the framework of PBL project 500080, 'The Netherlands Pollutant Release & Transfer Register'

IPCC Tier-1: suitable method for greenhouse gas emission uncertainty estimates

The Netherlands signed the United Nations Framework Convention on Climate Change (UNFCCC), and, therefore, is bound to report its greenhouse gas emissions, annually in a National Inventory Report (NIR). Within the framework of this NIR, an annual uncertainty assessment is made for both national total annual emissions and the trend, from the base year 1990 (1995 for F-gases) to the current year. The present report documents uncertainty estimates in the assessment performed for the NIR 2006 and (minor) updates made in the later submissions (2007 and 2008).

Uncertainty estimates were made using the simplified IPCC Tier 1 uncertainty analysis following the Intergovernmental Panel on Climate Change (IPCC) Good practice Guidance. In addition, assumptions and results of two more comprehensive analyses are presented in this report, based on IPCC Tier 2 Monte Carlo assessments. These Tier 1 and Tier 2 assessments were used for identifying areas for improvement within the emissions inventory. Both studies showed that Tier 2 and Tier 1 uncertainty analyses, using similar underlying uncertainty data, resulted in similar magnitudes of overall uncertainty calculations, both for level and trend uncertainty. Therefore, using Tier 1 as the main method for uncertainty analysis in the NIR is justified, also because it is unlikely that the uncertainties will change quickly over the years.

Netherlands Environmental Assessment Agency, August 2009