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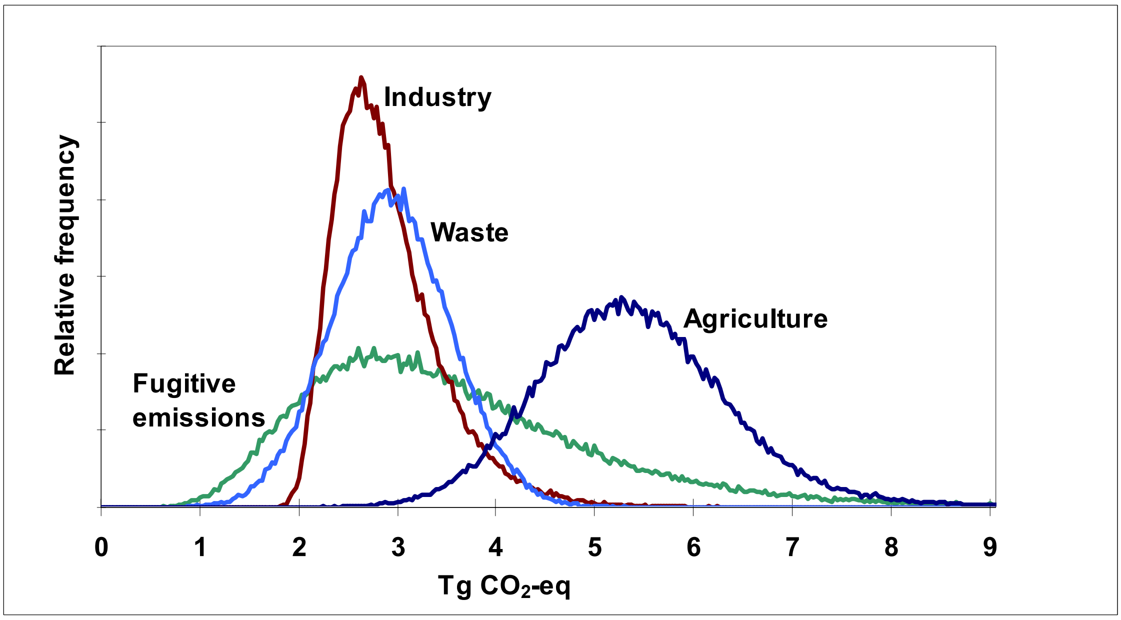

Uncertainties in the Finnish 2002 Greenhouse Gas Emission Inventory

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Abstract

This report is a part of Finland's greenhouse gas inventory work to the United Nations Framework Convention on Climate Change. A detailed uncertainty estimate, based on Monte Carlo simulation, was performed first time for the 2001 inventory. This report presents the changes in uncertainty estimates related to the previous inventory, as well as the uncertainties in the 2002 inventory. In this study, some input parameter uncertainty estimates were revised, and the uncertainty calculation method was changed for the Energy sector. The uncertainty calculation model was also developed further during the project. In 2002, the total uncertainty in the inventory was –5 to +6%. In absolute terms, the emissions (covered by this uncertainty estimate) in 2002 were 76 to 85 Tg (CO_2 equivalents) with 80 Tg as the most likely value. The trend uncertainty was ±5%-points. This means that the increase in emissions from 1990 to 2002 was between 3 and 10 Tg (CO_2 equivalents) with 6 Tg as the most likely value. When compared with the previous uncertainty estimate, the aggregated relative uncertainties have not been changed. The most important sources affecting the uncertainty in 2002 were CO_2 emissions from peat lands and N_2O emissions from agricultural soils. The uncertainty estimate does not cover land use, land-use change and forestry.

Keywords
uncertainty, Monte Carlo simulation, greenhouse gases, emission inventory, Kyoto protocol, UNFCCC

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Preface

This study is a part of Finland's greenhouse gas inventory work to the United Nations Framework Convention on Climate Change. Uncertainty in the 2002 greenhouse gas emission inventory and that of trend is presented, as well as the most important sources affecting the uncertainty.

This work was performed at VTT Processes, where Prof Ilkka Savolainen and Dr Sanna Syri gave important contribution to the work. The study was partly funded by the Ministry of Trade and Industry, and partly by Statistics Finland. The supervising group was chaired by Mirja Kosonen from Statistics Finland. Other members of the supervising group were Jaakko Ojala (Ministry of the Environment), Kristina Saarinen (Finnish Environment Institute), Timo Alanko (Statistics Finland), Martti Esala (MTT Agrifood Research Finland) and Juha Rajala (Ministry of Trade and Industry). In addition to the supervising group, the author also wants to thank other compilers of the greenhouse gas inventory who have lent their expertise to this work (Kari Grönfors from Statistics Finland, Kari Mäkelä from VTT Building and Transport, Paula Perälä and Kristiina Regina from MTT and Jouko Petäjä from the Finnish Environment Institute). Teemu Oinonen from the Finnish Environment Institute gave important contribution to the work both by giving valuable comments and by writing an appendix to the report as an example of Tier 2 quality control procedure. Trainee Sami Niemelä, who worked for VTT during the summer 2003, has also contributed to the work, especially in the development of the calculation model in energy sector.

Contents

1. Introduction

This report is a part of Finland's Greenhouse Gas Emission Inventory work to the United Nations Framework Convention on Climate Change (UNFCCC). Reliable uncertainty estimates are required by the UNFCCC, and they also function as a tool for increasing the quality of national emission inventories.

The uncertainty in the Finnish greenhouse gas emission inventory was estimated first time using Monte Carlo simulation for the 2001 inventory. The uncertainty estimates of input parameters, as well as the calculation model, are presented in detail in the project report (Monni & Syri, 2003).

Since the previous uncertainty estimate, additional information was obtained on some emission sources, leading to changes in uncertainty estimates. The uncertainty calculation model was also developed further during this project. The most important changes were the revised calculation of uncertainties in fuel combustion, and automatization of reporting tables.

This report presents the revisions of uncertainty calculation since the 2001 uncertainty estimate. The changes cover most of the subjects that were identified as areas for further research in (Monni & Syri, 2003). Uncertainty estimate and key source identification for the 2002 inventory are also reported in this document, as well as recommendations for further research. The calculations were based on greenhouse gas inventory submitted to European Commission in December 2003. Therefore, some minor differences related to the submission to UNFCCC in 2004 occur, but these changes do not affect the results notably. In Appendix A, detailed tables submitted to the UNFCCC are presented. Appendix B (written by Teemu Oinonen) gives an example of Tier 2 quality control procedure.

2. Changes Related to the 2001 Uncertainty Estimate

2.1 Development of the Calculation Model

The calculation model that was firstly prepared for the uncertainty assessment of the 2001 inventory was developed further in this study. The most important changes are related to user-friendliness (automated reporting tables, development of an instruction manual in Finnish) and calculation of base year uncertainties (base year uncertainties can now be reported similarly as inventory year uncertainties, and in trend calculation, also the base year emissions in denominator is taken as a simulated value).

The Finnish uncertainty calculation model contains three parts: emission models of landfills and agriculture, which are modified to be used in uncertainty assessment, and the total calculation model containing also key source identification and reporting tables according to the IPCC Good Practice Guidance (Penman et al., 2000). All calculation models are MS Excel workbooks that can be used with Crystal Ball simulation tool (Decisioneering, 2000). The use of calculation model is documented in Finnish as a user manual, in which detailed guidance for the use of model is given in addition to exact references to CRF tables.

2.2 Changes in Uncertainty Distributions

In the IPCC Good Practice Guidance (Penman et al., 2000) it is stated, that "the criteria of comparability, consistency and transparency in emission inventories are best met when the minimum number of probability distribution is used, and when these probability distributions are well based". The default distributions include normal, lognormal, uniform and triangular distribution. It is recommended, that other distributions are used only, if there are compelling reasons from empirical observations, or from expert judgement backed up by theoretical arguments (Penman et al., 2000).

To follow the IPCC guidance more precisely, some changes for the uncertainty distributions are made in relation to the 2001 uncertainty estimate (Monni & Syri, 2003). These changes are presented in Table 1. The uncertainty distributions were changed if:

- In the 2001 uncertainty estimate, the used distribution was not one of the default distributions
- The distribution used in 2001 was based on expert judgement
- The distribution can be changed without changing the upper (97.5) percentile

Other changes are related to negatively skewed distributions. For example, some gamma distributions are changed to beta to ensure smoother behaviour in simulation. In many cases, however, the use of other distributions than the default distributions is still reasonable, due to country-specific knowledge on, e.g., suitability of emission factors to Finnish conditions.

Changes in uncertainty distributions presented in Table 1 are not likely to affect results much. However, some changes are important in practice, because e.g. lognormal distribution behaves more smoothly in simulation than gamma distribution, and therefore the number of trials needed, to reach a specified precision, decreases.

Table 1. Changes in input parameter distributions related to the previous uncertainty estimate (Monni & Syri, 2003). Uncertainties are presented as upper and lower bounds of the 95% confidence interval and expressed as percent relative to the mean value.

Emission source	type of parameter[1]	previous estimate[2]	current estimate
Enteric fermentation of reindeer (4A)	EF	gamma -26...+250%	lognormal -85...+250%
Manure management N_2O (liquid/slurry)	EF	lognormal -50...+100%	lognormal -57...+100%
Direct N_2O from cultivated organic soils	EF	gamma -75...+87.5%	normal ±87.5%
Indirect N_2O from atmospheric deposition of NH_4 and NO_x	EF	gamma -80...+100%	lognormal -57...+100%
Indirect N_2O from agricultural soils	$Frac_{LEACH}$	gamma -66...+166%	lognormal -73...+166%
N_2O from leaching/runoff in agriculture (4D) and from wastewaters (6B)	EF	gamma/weibull -92...+380%	lognormal -94...+380%
CH_4 from wastewaters (6B)	MCF	-50...+100% Weibull	-57...+100% lognormal
k-values (slow and default) (6A)	k	Weibull -40...+300%	lognormal -89...+300%
Oxidation factor (6A)	OX	gamma -50...+10	beta -50...+10
Municipal sludge (6A)	A	-50...+100% gamma	-57...+100% lognormal

[1]A=activity data, EF=emission factor
[2](Monni & Syri, 2003)

2.3 Energy

Energy sector releases CO_2, CH_4 and N_2O. The sector covers stationary combustion, transportation and fugitive emissions from fuels. Most uncertainty estimates are the same as in the 2001 uncertainty estimate (Monni & Syri, 2003). Changes are reported below.

In Finland, total usage of imported fossil fuels is known accurately (Monni & Syri, 2003). The reporting of emissions, however, is required at a more disaggregated level, and dissaggregation tends to increase uncertainty due to lack of knowledge of sectoral shares. The uncertainty estimates for the 2001 inventory (Monni & Syri, 2003) were performed at the reporting level. To obtain a more reliable uncertainty estimate, activity data in combustion was, in this 2002 uncertainty estimate, simulated in a manner that allows the usage of the data of uncertainty in total fuel use. This change affected both calculation of CO_2 emissions from fuel combustion and uncertainty assessment of activity data for liquid and gaseous fuels.

Since the previous uncertainty estimate, additional information is obtained on CO_2 emissions from peat combustion and N_2O emissions from road transportation. This information is taken at use in uncertainty estimates. Indirect N_2O from fuel combustion is excluded from the Finnish greenhouse gas emission inventory, and is therefore also excluded from uncertainty assessment.

2.3.1 Activity Data for Fuel Combustion

In energy statistics, differences between top-down and bottom-up approaches usually reflect systematic errors (Penman et al., 2000). On the contrary, random error is relatively unimportant in energy statistics (EIA, 1997). Therefore, uncertainty estimate of total fuel consumption can be based on differences between different statistics (this approach is used, e.g., in uncertainty estimates of the USA (EIA, 1997), Austria (Winiwarter & Rypdal, 2001), Norway (Rypdal & Zhang, 2000) and the UK (Charles et al., 1998)).

In Finland's National Inventory Report (NIR) sent to the UNFCCC in 2004, the differences between energy balance (in TJ) and figures reported in CRF tables were as follows: 2% for solid fuels, 1.7% for liquid fuels and 0.9% for gaseous fuels (Ministry of the Environment, 2004).

The estimated uncertainties (expressed as 95% confidence interval) in this study were ±2% for liquid and ±1% for gaseous fuels. Uncertainty in solid fuels was obtained as a result of simulation, and was ±1.5%. These uncertainties are in good agreement with the above numbers published in NIR.

The uncertainty in the use of peat fuel can not be estimated using the method described above. Peat is entirely domestic fuel, and therefore there is not any import figure, with which the fuel use could be compared. In addition, in the reporting, peat fuel is reported in class "other fuels" which includes also, e.g., combustion of municipal waste.

In fuel combustion, CO_2 emission factor mainly depends on the carbon content of the fuel instead of combustion technology. Therefore, in this uncertainty estimate, the uncertainty in CO_2 emissions is calculated at a rather aggregated level, i.e. by fuel type rather than by sector. For liquid and gaseous fuels uncertainty in total fuel consumption is estimated based on differences between different statistics. For solid fuels, the uncertainty in total consumption is calculated from the uncertainty information of activity data of different subcategories, as in the previous uncertainty estimate.

2.3.2 Simulation Approach for Liquid and Gaseous Fuels

The sectoral shares of fuel use are usually less well known than the total fuel consumption. Uncertainty in total fuel consumption can be estimated based on differences between different statistics (see above). This uncertainty sets bounds to the uncertainty in the sum of sectoral shares. When uncertainty in sum and most individual subcategories is estimated, activity data in one sector can be defined as the residual when all the other activity data is subtracted from the sum. This information is taken advantage of in the new simulation method. For both liquid and gaseous fuels, the subcategory with the largest absolute uncertainty (in 2001 inventory) was chosen to be calculated as the residual. In the case of liquid fuels this means that activity data for subcategory 1A4 (including residential, commercial, institutional, agriculture, forestry, fisheries) is calculated as the residual and for gaseous fuels subcategory 1A5 (residue of fuel sold and military use) represents the residual. This approach is not applied for solid and other fuels. Other fuels comprise mainly peat which is domestic fuel. Therefore the statistics for total fuel use are not notably more accurate than the sectoral shares. Solid fuels, instead, are used significant amounts only in energy production and industry, for which activity data is almost as well known as the total activity data.

Positive correlation between the sum and its elements has to be introduced in the model, because otherwise the residual will not correspond well to reality. The reason is that, obviously, if one element of the sum is relatively high the sum also has to be high. The correlation coefficient between the sums and their elements was set to 0.8.

Negative correlation between liquid fuel use in Other Sectors, Other Navigation and Other Transportation (Monni and Syri, 2003) was removed from the model, because the positive correlation presented above replaces this approach.

Using the approach described above, simulated uncertainties in subsectors were significantly lower than estimated in the previous uncertainty estimate. To keep the results comparable, we calculated uncertainty in the new method using fuel use in 2001. Simulated uncertainty in liquid fuel use in 1A4 was ±4%, whereas it was estimated at

±30% in the previous uncertainty estimate. Respective numbers for gaseous fuels in 1A5 are ±13% and ±20%. This result supports the considerations made in the sensitivity analysis of the 2001 inventory (Chapter 11 in Monni & Syri, 2003).

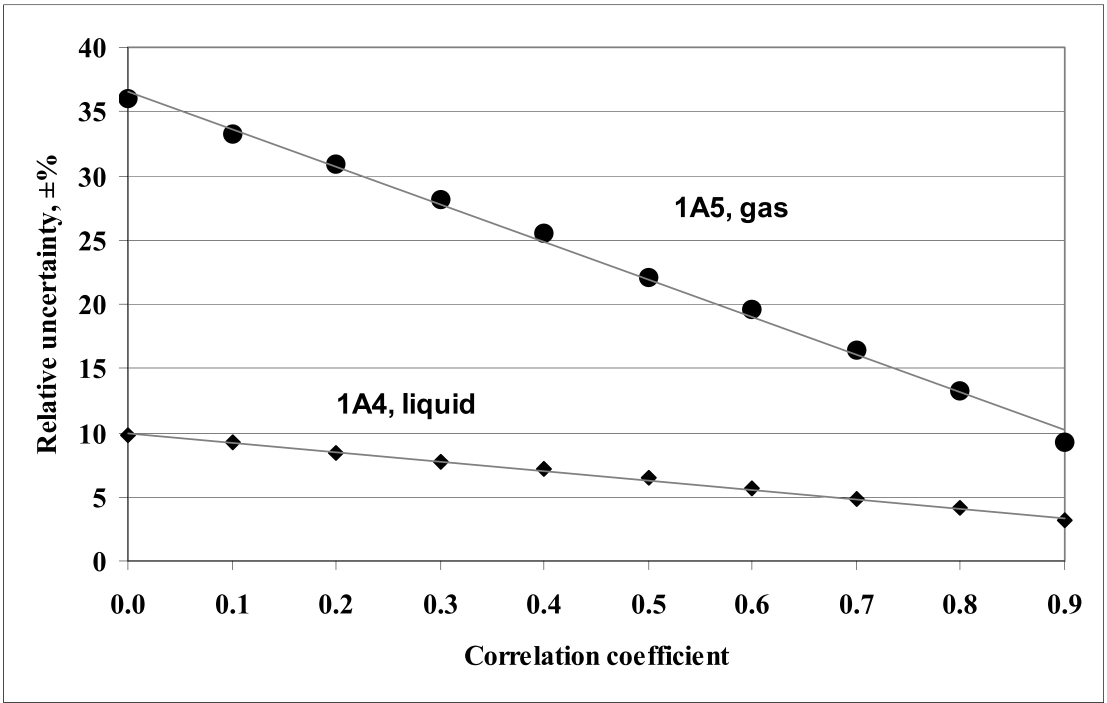

Figure 1. The dependency of correlation coefficient and the relative uncertainty. The relative uncertainty represents upper and lower bounds of 95% confidence interval expressed as percent relative to the mean value. Simulated values are denoted with black markers, and grey lines are trend lines fitted to the data. Numbers in this figure are calculated using fuel use in 2001.

The correlation coefficient was here chosen based on expert judgement, and needs therefore further consideration. If a large value of the sum corresponds to a large value of some sector (high correlation) the difference remains more constant than if the values are random (low correlation). Therefore, in this case, lower correlation means higher uncertainty. Correlation between the sum and its terms must evidently be positive. Figure 1 presents the uncertainty with different values of correlation. All simulations were performed with the same random numbers for each assumption to obtain comparable results. Correlations stronger than 0.9 are not likely to occur in this case, so these values set a lower bound to the uncertainty. In addition, the sum and its terms are evidently correlate at least to some extent, so the correlation of zero gives an upper bound to the uncertainties. According to calculations, the uncertainty in activity data in liquid fuel use in small-scale combustion (residential, commercial, institutional, agriculture, forestry, fisheries) is ±3-10% according to the strength of the correlation, and in military gas use and residue of gas sold it is ±9-36%. Though the correlation coefficient has a large effect on uncertainty, it is shown that the previous uncertainty estimate of liquid fuel activity data in 1A4 that was identified also as a key source was an overestimate. The effect of the choice of correlation coefficient on total inventory uncertainty is negligible.

The share of fuel use in each category in each year has an effect on the relative uncertainty, and therefore the figures may be slightly different in each year. Corresponding calculations as presented above were performed for the 2002 inventory. The results that are used in the current uncertainty estimate, are presented in Table 2.

2.3.3 CO_2 Emission Factor for Peat Combustion

In the 2001 uncertainty estimate, the uncertainty in CO_2 emission factor of peat combustion (other fuels) was estimated at ±5% in Energy Industries (1A1) and Manufacturing Industries and Construction (1A2), based on expert judgement. In 2003, a study was performed in VTT Processes, where CO_2 emission factor for peat combustion was measured from five different power plants. Selected power plants were located in different sites in Finland. Therefore the peat they use represents rather well the variation in peat quality in geographically different locations in Finland. According to measurements, the emission factor was 105.9 g CO_2/MJ, and the range of variation was 101-112 g CO_2/MJ (Vesterinen, 2003). The mean value is equal to that used in the inventory. We fitted a distribution to the monthly CO_2 emission factors for each power plant presented in the report. The resulting distribution was a logistic distribution with a 95% confidence interval of ±4%. These results support the use of the same uncertainty estimate as in the previous inventory.

2.3.4 N_2O from Road Transportation

In the 2001 uncertainty estimate, key sources identified in transportation sector were N_2O from civil aviation, N_2O from gasoline fuelled cars with and without catalytic converters, and diesel fuelled cars. The uncertainty estimates of road transportation were based on variation of emission factors found in literature. Uncertainty in emission for cars with catalytic converters was estimated at -70 to +150% (Pringent & De Soete 1989; Potter 1990; Becker et al. 1999; Perby 1990; Egebäck & Bertilson 1983), for cars without catalytic converters -80 to +180% (Perby 1990; Pringent & De Soete 1989; Egebäck & Bertilson 1983) and for cars with diesel engines -80 to +200% (Pringent & De Soete 1989; Sjöberg et al. 1989; Becker et al. 1999). For the purposes of this study, we used some additional and more recent literature to adjust the previous uncertainty estimate, in which the number of data points used was rather low.

The literature used presents measurements performed for various vehicles and driving conditions. Odaka et al. (2000) compared different studies of N_2O emissions from cars with different emission controls, different fuel types and under various driving modes. Especially the emissions from cars with three-way catalysts showed large variation. Jimenez et al. (2000) made totally 1361 N_2O emission measurements for cars and light trucks, 99% of which had a catalytic converter. Authors compared their results with various other studies. Lipman and Delucchi (2002) considered methane and nitrous oxide emissions from passenger cars, light-duty trucks and heavy-duty vehicles. They reviewed various studies to obtain an emission factor. Oonk et al. (2002) measured nitrous oxide emissions from 32 passenger cars of different ages and in different driving conditions. Behrentz (2003) measured N_2O emissions in different driving cycles from passenger cars, sport utility vehicles and light-duty trucks. Totally 300 vehicles were measured, all equipped with a catalytic converter.

The method used to obtain an uncertainty estimate using different studies was the same as used in the previous uncertainty estimate (Monni & Syri, 2003). All data obtained from the studies mentioned above, including measurement data and data reviewed from other studies was used, in addition to the data used in the previous uncertainty estimate. For cars with catalytic converters the resulting distribution was lognormal with a mean value of 42 mg/km, (the value used in the inventory is 50 mg/km) with a 95% confidence interval of -90% to +380% In the case of cars without catalytic converters, we obtained a lognormal distribution with a confidence interval of -90 to +260%. In diesel vehicles, the best-fitting distribution was triangular distribution (-100 to +160%) with a mean value of 21 mg/km. The values used in the Finnish inventory are 10 mg/km for passenger cars, 20 mg/km for trucks and 30 mg/km for semi trucks and busses. These ranges are used in the 2002 uncertainty estimate.

It can clearly be seen that the uncertainty ranges presented here are larger than those in the previous uncertainty estimate in other cases than diesel vehicles. It does not, however, indicate an increased uncertainty in inventory, but an increased accuracy in the uncertainty estimate.

2.3.5 Indirect N_2O from Fuel Combustion

Indirect N_2O emissions from fuel combustion that was a key source in 2001, is excluded from the Finnish inventory due to recommendations of an Expert Review Team (UNFCCC Secretariat, 2003). This source is correspondingly excluded also from the uncertainty assessment.

2.4 Industry

In the industrial sector, uncertainty estimates of CO_2, CH_4 and N_2O were not changed, because no additional information was available. The uncertainty estimates of f-gases were again entirely performed in the Finnish Environment institute (Oinonen, 2004). Due to a somewhat different approach in estimating and expressing uncertainty, small differences occurred in uncertainty estimates in this study, when compared with the study of Oinonen (2004). The used uncertainty ranges are presented in Table 2.

2.5 Agriculture

Agriculture releases CH_4, N_2O and CO_2, of which CO_2 emissions are not covered in this uncertainty estimate. The development of agricultural greenhouse gas inventory is under preparation in MTT Agrifood Research Finland. Some changes will probably be made to the calculation parameters in the future, which will also cause needs to revise uncertainty estimates. There were currently no changes in calculation when compared with the 2001 inventory, and therefore also the uncertainty estimates were kept unchanged.

Uncertainties in N_2O emissions from agricultural soils were studied in a rather detailed level. No basis for changes was found, as described below.

2.5.1 N_2O Emissions from Agricultural Soils

The 2001 uncertainty estimate of N_2O from agricultural soils was based on the ranges of possible values given in the Revised 1996 IPCC Guidelines (IPCC, 1996). According to the IPCC Good Practice Guidance (Penman et al., 2000) uncertainty ranges may be much wider. Some other countries (e.g. Norway, UK and Austria) have also estimated very large uncertainty ranges - up to one or two orders of magnitude. We decided to study the uncertainty ranges more to find out if we have underestimated the uncertainty in Finland. The examination described below was performed in co-operation with Kristiina Regina and Paula Perälä from MTT.

Data from national field measurements of N_2O was available from four fields on mineral soils and five fields on organic soils where the measurements had been going on for 1-3 years. The emissions were measured gas chromatographically using the closed chamber method 1-4 times per month. The results and descriptions of the methods can be found in the original papers (Nykänen et al., 1995; Maljanen et al., 2003; Maljanen et al., submitted; Regina et al., in press; Syväsalo et al., submitted; Syväsalo et al., manuscripts a and b). The uncertainty in emission factors was calculated using the variation in annual emission rates of each measurement point or in some cases the mean of several points. Both direct and indirect emissions were included in these estimates because in the field measurements these two can not be separated. The Finnish measurements of N_2O emissions show, that the yearly variation in N_2O emission factor is relatively small (-104 to +171%), and even the daily variation (up to 550%) is lower than the uncertainty estimates of some other countries. Because emission inventories are performed annually, the yearly variation is a good basis for uncertainty estimates.

The study revealed that the Finnish assessment of uncertainty in N_2O emission factor is not an underestimate. The magnitude of uncertainty was very similar in both IPCC (1996) estimates and national measurements, though the national ranges are slightly higher. Because results from national measurements have not yet been taken at use in emission estimates, we have still used the IPCC (1996) values for uncertainty ranges.

2.6 Waste

Waste sector releases CH_4 and N_2O. Most uncertainty estimates have not been changed since the previous uncertainty estimate (Monni & Syri, 2003). The changes, which all were related to methane emissions, are described below.

2.6.1 Fraction of Methane in Landfill Gas

In the Finnish 2001 uncertainty estimate, the uncertainty in fraction of methane in landfill gas (F) was estimated at ±22% based on variation in measurement data. However, according to National Expert Riitta Pipatti, the uncertainty in measurements may be larger than the uncertainty in fraction of methane. In addition, in (Frøiland & Pipatti, 2002) the estimated range of F is 0.4-0.6 with a mean value of 0.5. This gives an uncertainty range of ±20%, which is used in this study.

2.6.2 Methane from Wastewaters

In this study, CH_4 emissions from wastewaters is divided into two subcategories, i.e. densely and sparsely populated areas (as is already done in the case of N_2O in 2001), because these two subcategories are calculated using different methods. The uncertainty estimates of 2001 inventory are used in the case of densely populated areas.

For sparsely populated areas, the IPCC check method is used in inventory calculations. The activity data uncertainty for sparsely populated areas is estimated at ±15%. This uncertainty estimate is larger than that of densely populated areas, because in densely populated areas activity is based on measurement data and in sparsely populated areas on population. The emission factor uncertainty, however, is estimated rather low in the check-method used for sparsely populated areas, i.e. -30 to +20%. The uncertainty distribution is negatively skewed, because the emission factor of the check method is likely to overestimate emissions. These estimates are based on expert judgement of Jouko Petäjä, who is responsible for the greenhouse gas emission inventory of waste management in Finland.

2.7 Summary of Changes

Table 2 presents the changes made related to the previous uncertainty estimate.

Table 2.Changes in input parameter uncertainty estimates related to the previous uncertainty estimate (Monni & Syri, 2003). Uncertainties are presented as upper and lower bounds of 95% confidence interval and expressed as percent relative to the mean value. When the shape of distribution is not mentioned, it is normal.

Emission source	type of parameter[1]	previous estimate[2]	current estimate	basis for change
Fuel combustion (1A), solid fuels	A	±2%	±1.5%[3]	change in aggregation (See Chapter 2.3.1)
Fuel combustion (1A), other fuels	A	±5%	±4%[3]	change in aggregation (See Chapter 2.3.1)
Stationary Combustion, Other Sectors (1A4), liquid fuels	A	±30%	±3%[3]	methodological change (see Chapter 2.3.2)
Stationary combustion, Other (1A5), gaseous fuels	A	±20%	±12%[3]	methodological change (see Chapter 2.3.2)
Cars with catalytic converters (1A3)	N_2O EF	-70..+150% lognormal	-94%...+378% lognormal	Odaka et al., 2000; Jimenez et al., 2000; Lipman & Delucchi, 2002; Oonk et al., 2002; Behrentz, 2003
Cars without catalytic converters (1A3)	N_2O EF	-82...+179% gamma	-86...+259% lognormal	Odaka et al., 2000; Lipman & Delucchi, 2002
Cars with diesel engines	N_2O EF	-80...+200% lognormal	-99...+158% triangular	Lipman & Delucchi, 2002
Indirect N_2O from fuel combustion (1A)	E	-79...+100%	not estimated	excluded from the inventory
Refrigeration and Air Conditioning Equipment (2F1)	E	-73...+44% neg Gumbel	-8...+24% pareto	Oinonen, 2004
Foam Blowing (2F2)	E	±26%	±27%	Oinonen, 2004
Aerosols and one component foam (2F4)	E	±4%	±2%	Oinonen, 2004
Electrical Equipment (2F7)	E	-7...+12% gumbel	-8...+14% gumbel	Oinonen, 2004
Other (grouped data, 2F)	E	±39%	±36%	Oinonen, 2004
Fraction of methane in landfill gas (6A)		±22%	±20%	expert judgement; Frøiland & Pipatti, 2002
CH_4 from domestic and commercial wastewaters, sparsely populated areas (6B2)	A	-	±15% normal	Change in disaggregation
CH_4 from domestic and commercial wastewaters, sparsely populated areas (6B2)	EF	-	-32...+20% gumbel	Change in disaggregation

[1]A=activity data, EF=emission factor, E=emissions
[2](Monni & Syri, 2003)
[3]Result of simulation

3. Results

This chapter presents the results of the 2002 uncertainty estimate. The calculations were based on greenhouse gas inventory submitted to European Commission in December 2003 (Ministry of the Environment, 2003). Therefore, some minor differences related to the submission to UNFCCC in 2004 occur, but these changes do not affect the results notably. The results are presented both by gas and by fuel, and also for inventory totals. Detailed tables used for reporting of uncertainties to the UNFCCC are presented in Appendix A. The tables contain both uncertainties estimated with Tier 1 and Tier 2 method, and also the identification of key sources.

3.1 Fuel Combustion

Fuel combustion releases CO_2, CH_4 and N_2O, and covers 80% of the emissions concerned in this uncertainty estimate. The uncertainty in this sector is low when compared with other sectors: the uncertainty in 2002 emissions is -2 to +3%. Finland has no fossil fuel production – all fossil fuels are imported, and these statistics are very accurate. The allocation of total fuel use into sectoral shares is more uncertain. The most important factor affecting the uncertainty in fuel combustion in 2002 is N_2O emission factor for cars with catalytic converters.

The uncertainty in CO_2 emissions from fuel combustion was ±2% in 2002. This is one percentage point lower uncertainty than in the 2001 estimate. The new simulation approach in fuel consumption (see Chapter 2.3.2), which represents uncertainties in a more realistic manner than the previous one, has reduced the effect of activity data uncertainty. Uncertainties in CH_4 and N_2O in fuel combustion are presented in sector-specific level in Table 3.

Table 3. Uncertainties in CH_4 and N_2O emissions from fuel combustion sector in 2002.Uncertainties are presented as upper and lower bounds of the 95% confidence interval and expressed as percent relative to the mean value.

Sector	IPCC Category	CH_4	N_2O
Energy Industries	1.A.1	±30%	-40...+70%
Manufacturing Industries and Construction	1.A.2.	±30%	±40%
Transportation	1.A.3.	-30...+35%	-70...+240%
Other Sectors	1.A.4.	-70...+140%	-60...+40%
Other	1.A.5.	-60...+150%	-60...+20%
Total fuel combustion	1.A.	-50...+100%	-30...+80%

3.2 Fugitive Emissions from Fuels

The uncertainty in fugitive emissions from fuels is high, -60...+110%, dominated by the uncertainties in emissions related to production of peat fuel (CO_2 emissions from peat production areas and arable peatlands).

3.3 Industry

Industrial processes release all greenhouse gases of the Kyoto protocol. The most important industrial non-combustion greenhouse gas source is nitric acid production that is also the most uncertain industrial source category with an uncertainty of -60...+100% in 2002. The uncertainty is mainly due to variability of emissions according to process conditions. The total uncertainty in industrial processes is -30...+50%. Source-specific uncertainties in industrial sector are presented in Table A - 1 in Appendix A. The uncertainties in F-gas emissions are presented in detail by Oinonen (2004).

3.4 Agriculture

The agriculture sector releases methane and nitrous oxide. Agriculture also releases carbon dioxide, but these emissions were beyond the scope of this work. Total uncertainty in agriculture sector is -30...+40%. The most uncertain emission source in agriculture is N_2O emissions from agricultural soils. The most important parameters in terms of uncertainty are N_2O emission factor for direct emissions, N_2O emission factor for cultivated organic soils and emission factor for indirect emissions from leaching/runoff.

3.5 Waste

In solid waste disposal on land, the uncertainty in emissions from landfills was simulated separately from other uncertainties, using the dynamic waste degradation model. The uncertainty in 2002 emissions was ±40%. The most important parameters affecting the total uncertainty were fraction of methane in landfill gas, waste degradation coefficients (slow and default) and fraction of degradable organic carbon dissimilated. The uncertainty estimate is larger than in the previous estimate due to changes in uncertainty estimate (e.g. changes in input distributions). It is important to notice that the increased uncertainty range does not mean real increase in uncertainty in emissions when compared with the previous inventory. Emission calculation methods are the same, and equally accurate, as in the previous inventory, but the uncertainty estimation has been changed and is now more accurate than before.

The uncertainty in wastewater treatment is now much smaller than in the previous uncertainty estimate (-40 to +50% vs. -60 to 190%). This is due to the changes in allocation of uncertainty in methane emissions: the uncertainty estimate was divided into sparsely and densely populated areas in this uncertainty estimate. In the previous uncertainty estimate, the uncertainty in emissions from densely populated areas was used for the whole emission category. Because uncertainty in sparsely populated areas is lower than in densely populates areas, and the emissions are estimated larger, the total uncertainty decreases.

3.6 Overall inventory uncertainty in 1990, 2002 and uncertainty in trend

In 2002, the total uncertainty in the Finnish greenhouse gas emission inventory was –5 to +6%. When the uncertainty estimate was performed using the Tier 1 method, the corresponding uncertainty was ±7%. When compared with the previous uncertainty estimate, these uncertainties have not been changed. Figure 2 presents uncertainty distribution of fuel combustion, distribution of other emissions than fuel combustion and that of all greenhouse gas emissions concerned in this study. In can be seen that uncertainty distribution for other sources than fuel combustion is much wider than that of fuel combustion. Figure 3 presents uncertainty distributions of other emissions than those from combustion in more detail.

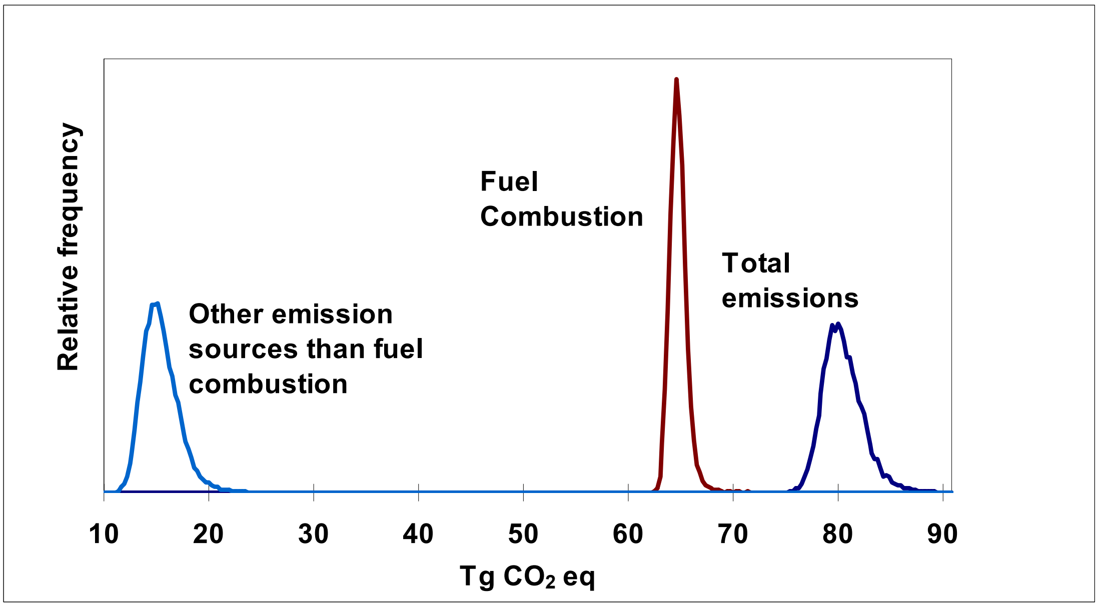

Figure 2. Uncertainty distribution of all greenhouse gas emissions in 2002, distribution of emissions from fuel combustion and emissions from other sources than fuel combustion.

The uncertainty in base year emissions is slightly higher than in 2002, -6 to +7%. The accuracy of emission estimates has increased since 1990, which leads to lower uncertainty in 2002. In addition, the share of the most important source category (in terms of uncertainty), N_2O from agricultural soils, has decreased since 1990. On the contrary, the share of N_2O from cars with catalytic converters, which also is a very uncertain source category, has increased.

The uncertainties by gas in 2002 were as follows: -4 to +6% for CO_2, ±30% for CH_4, -30 to +50% for N_2O and -10 to +20% for HFCs, PFCs and SF_6 together. Gas-specific uncertainties have changed slightly since 2001, mainly due to differences in uncertainty estimation. The larges change in uncertainty occurred in f-gas emissions Oinonen (2004).

The absolute uncertainty in trend (i.e. change in emissions 1990-2002) was ±5%-points (or -4% to +6%-points depending on rounding). In other words, the increase in emissions (in the sectors included in this study) was from 74 Tg (CO_2-eq) to 80 Tg (CO_2-eq), i.e. 6 Tg corresponding to 8% of 1990 emissions. The 95% confidence interval of this change was from 3 Tg to 10 Tg (4 to 14 %).

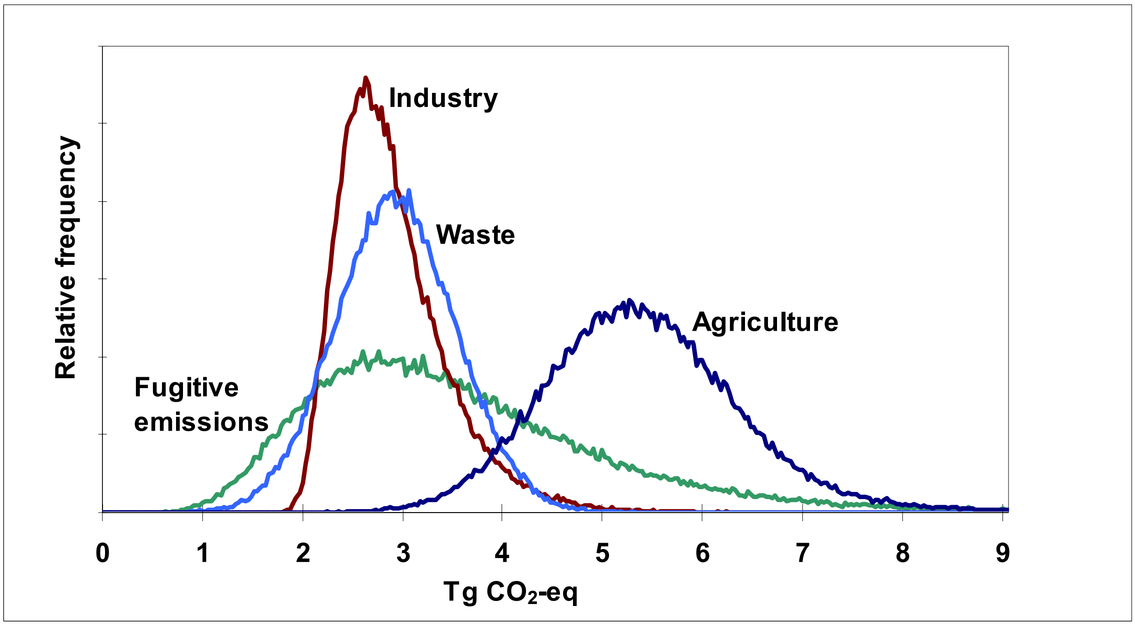

Figure 3. Uncertainty distributions of fugitive emissions, industry, waste and agriculture sectors. The best-known sector, fuel combustion, is not presented in this figure.

3.7 Key Source Identification and Sensitivity Analysis

Key sources are the emission sources, which have a significant influence on the total inventory in terms of the absolute level of emissions (2002), trend of emissions (change between 1990 and 2002) or both. There are two alternative methods for identifying key sources: Tier 1 and Tier 2. In the Tier 1 method, the emission sources are sorted according to their contribution to emission level or trend. In the Tier 2 method also the relative uncertainties of source categories are taken into account. Key sources are the categories which represent together 90% of the inventory uncertainty.

In Finland, key sources are identified using the Tier 2 method. Key sources by level in 1990 and 2002, and by trend are presented in Tables 4, 5 and 6. The number of key sources identified in 1990 and 2002 was 16 and according to trend analysis the number of key sources was 18. The number of key categories decreased when compared with the previous inventory. This is mainly due to the change in aggregation level: CO_2 from combustion is aggregated by fuel type in this key source analysis, and therefore some of the key source categories are very large. Therefore the threshold of 90% is obtained with a smaller number of source categories than in the previous inventory. Key source category summary is also presented in Appendix A.

Table 4. Key sources in 1990 (Tier 2). Emission estimates in column C are presented in Gg CO_2 equivalents.

A	B	C	E	F
IPCC Source Category	**Gas**	**Base Year Estimate**	**Level Assessment with uncertainty**	**Cumulative Total of Column E**
1.B.1 Solid Fuels: Arable peatlands	CO_2	2500	0.17	0.17
4.D. Agricultural soils: indirect emissions	N_2O	764	0.14	0.31
4.D. Agricultural soils: direct emissions, animal production and sludge spreading	N_2O	3506	0.11	0.42
1.B.1 Solid Fuels: Peat production areas	CO_2	1000	0.11	0.52
2.B.2 Nitric Acid Production	N_2O	1594	0.08	0.61
6.A. Solid Waste Disposal on Land	CH_4	3679	0.08	0.69
1.A. Fuel Combustion: Liquid fuels	CO_2	27386	0.04	0.73
4.A. Enteric fermentation	CH_4	1868	0.03	0.76
1.A. Fuel Combustion: Solid fuels	CO_2	15746	0.03	0.78
4.B. Manure management	N_2O	554	0.02	0.81
1.A.4. Other Sectors: Biomass	CH_4	245	0.02	0.83
1.A. Fuel Combustion: Other fuels	CO_2	5674	0.02	0.85
7. Other - non-energy use of fuels	CO_2	640	0.02	0.86
6.B.2 Domestic and Commercial Wastewater: densely populated areas	N_2O	84	0.02	0.88
1.A.1 Energy Industries: Other fuels	N_2O	141	0.01	0.89
1.A.3. Transport: b. Road Transportation Cars without Catalytic Converters	N_2O	67	<0.01	0.90

Table 5. Key sources in 2002 (Tier 2).Emission estimates in column D are presented in Gg CO_2 equivalents.

A	B	D	E	F
IPCC Source Category	**Gas**	**Current Year Estimate**	**Level Assessment with uncertainty**	**Cumulative Total of Column E**
1.B.1 Solid Fuels: Arable peatlands	CO_2	2500	0.18	0.18
1.B.1 Solid Fuels: Peat production areas	CO_2	1000	0.11	0.29
4.D. Agricultural soils: indirect emissions	N_2O	557	0.10	0.39
4.D. Agricultural soils: direct emissions, animal production and sludge spreading	N_2O	2720	0.08	0.47
1.A.3.b Road Transportation: Cars with Catalytic Converters	N_2O	380	0.08	0.55
2.B.2 Nitric Acid Production	N_2O	1311	0.07	0.62
6.A. Solid Waste Disposal on Land	CH_4	2684	0.06	0.68

1.A. Fuel Combustion: Liquid Fuels	CO_2	26747	0.04	0.72
1.A. Fuel Combustion: Other fuels	CO_2	9388	0.03	0.75
1.A. Fuel Combustion: Solid fuels	CO_2	17273	0.03	0.78
1.A.4. Other Sectors: Biomass	CH_4	311	0.02	0.81
4.A. Enteric fermentation	CH_4	1562	0.02	0.83
7. Other - non-energy use of fuels	CO_2	720	0.02	0.85
4.B. Manure management	N_2O	378	0.02	0.87
1.A.1 Energy Industries: Other Fuels	N_2O	207	0.02	0.89
6.B.2 Domestic and Commercial Wastewater: densely populated areas	N_2O	65	0.01	0.90

Table 6. Key source categories by trend (Tier 2). Emission estimates in columns C and D are presented in Gg CO_2 equivalents.

A	B	C	D	E	F
IPCC Source Category	**Gas**	**Base Year Estimate**	**Current Year Estimate**	**Trend Assessment with uncertainty**	**Cumulative Total of Column E**
1.A.3.b Road Transportation: Cars with Catalytic Converters	N_2O	35	380	0.21	0.21
4.D. Agricultural soils: indirect emissions	N_2O	764	557	0.15	0.36
4.D. Agricultural soils: direct emissions, animal production and sludge spreading	N_2O	3506	2720	0.10	0.46
6.A. Solid Waste Disposal on Land	CH_4	3679	2684	0.09	0.55
2.B.2 Nitric Acid Production	N_2O	1594	1311	0.07	0.62
1.B.1 Solid Fuels: Arable peatlands	CO_2	2500	2500	0.04	0.66
1.A. Fuel Combustion: Other fuels	CO_2	5674	9388	0.03	0.70
4.B. Manure management	N_2O	554	378	0.03	0.73
1.B.1 Solid Fuels: Peat production areas	CO_2	1000	1000	0.03	0.75
1.A.3.b Road Transportation: Cars without Catalytic Converters	N_2O	67	20	0.02	0.78
4.A. Enteric fermentation	CH_4	1868	1562	0.02	0.80
1.A.1 Energy Industries: Biomass	N_2O	10	83	0.02	0.82
6.B.2 Domestic and Commercial Wastewater: densely populated areas	N_2O	84	65	0.02	0.83
2.F.1. Refrigeration and Air Conditioning Equipment	HFCs, PFCs	0.01	385	0.02	0.85
1.A.3.a. Civil Aviation	N_2O	57	4	0.01	0.86
1.A. Fuel Combustion: Liquid Fuels	CO_2	27386	26747	0.01	0.88
1.A.1 Energy Industries: Other Fuels	N_2O	141	207	0.01	0.89
1.A.4. Other Sectors: Biomass	CH_4	245	311	0.01	0.90

Key sources are also identified using sensitivity analysis for the level assessment (2002). In this method, rank correlation coefficients are computed between all input parameters and total emissions in 2002 (with a simulation tool Crystal Ball). The advantage of this method is that the sources of uncertainties are identified at a disaggregated level, which is useful when planning inventory improvements. The results of this method are presented in Figure 4. It can be seen from the figure that area of arable peatlands is the most important factor affecting the total uncertainty. Even the largest rank correlation coefficients in the figure are, however, small, which indicates that none of the factors alone can well explain the uncertainty in the inventory.

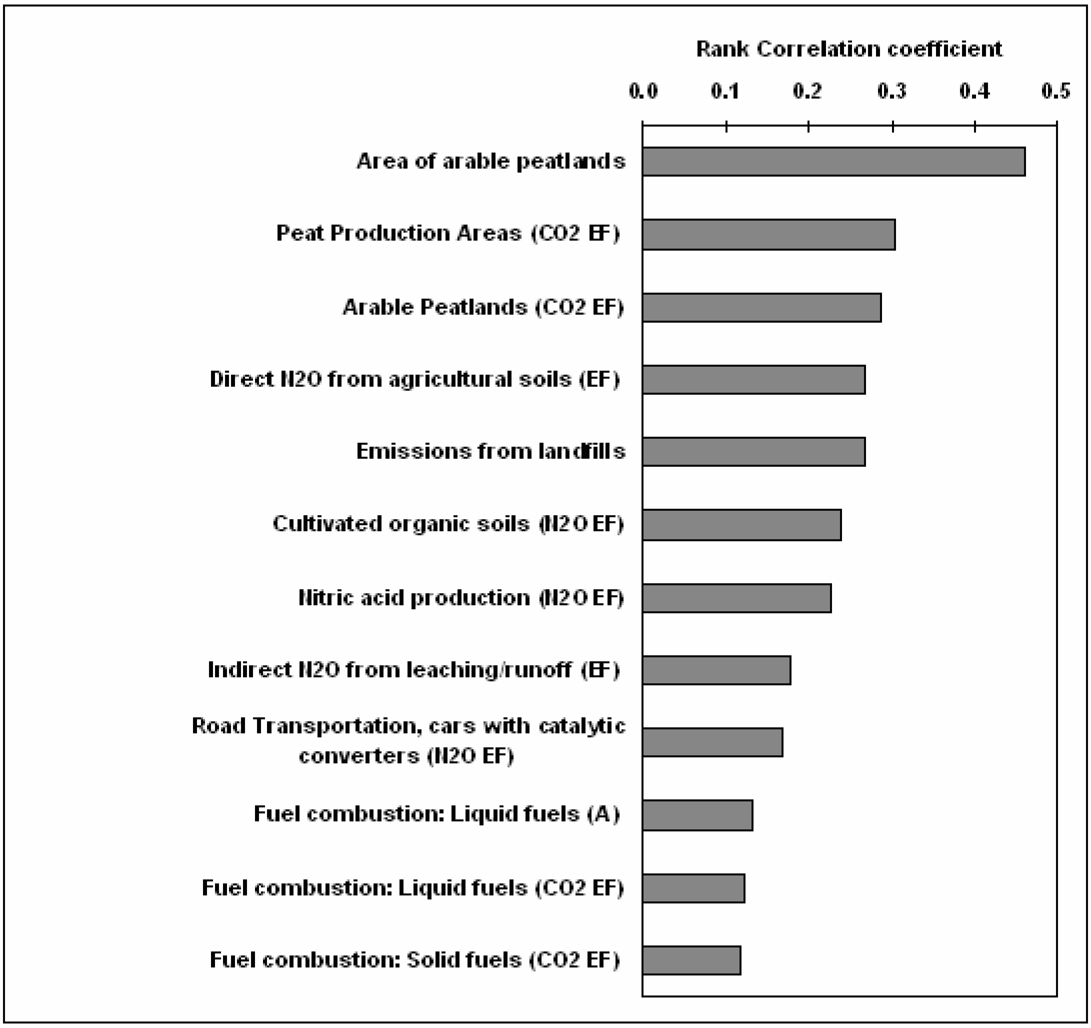

Figure 4. Key sources of the Finnish 2002 emission inventory identified using sensitivity analysis. In this method, rank correlation coefficients are calculated between calculation parameters and total emissions in 2002. In the figure, the parameters whose rank correlation coefficient is >0.1 are presented. EF denotes emission factor and A activity data.

4. Recommendations for Further Research

Uncertainty estimates in Finland cover currently most anthropogenic greenhouse gas emission sources (that are annually reported to the UNFCCC) in a sufficient level of detail. Some needs for changes in uncertainty estimates may arise, if inventory methods or data quality change. For example switching to higher tiers should in principle lead to lower uncertainties. In addition, further research, e.g. all greenhouse gas emission measurements are potential sources for more accurate data for uncertainty estimates.

There are still some emission sources that are not covered in the current uncertainty assessment, but are reported annually to the UNFCCC. All these are related to LULUCF (land use, land use change and forestry) sector. These include, e.g., carbon balance of forests and CO_2 from agricultural soils. The uncertainty in forest carbon balance will be covered in an ongoing research project between Finnish Forest Research Institute (Metla), European Forest Institute (EFI) and VTT. Preliminary estimates of uncertainties in CO_2 from agricultural soils and peat production have already been performed. These estimates need revision, and the guidance given in IPCC Good Practice Guidance for LULUCF may give additional information for these estimates (IPCC, 2003). In peat production, an ongoing research programme on emissions from peat soils will probably also give data for uncertainty estimates.

5. Discussion and Conclusions

This study covers the uncertainty estimate of the Finnish 2002 greenhouse gas emission inventory. This report updates the more detailed report (Monni & Syri, 2003) that documents the first Tier 2 (Monte Carlo simulation) uncertainty estimate of the Finnish greenhouse gas emission inventory. When compared with the previous uncertainty estimate, total uncertainty in national inventory has not been changed, though some estimates have been revised.

In this study, some individual uncertainty estimates have been revised (e.g. N_2O emission factor for road transportation). There were not any significant changes in emission estimation methods since the previous inventory, and therefore the changes presented in this document were merely due to changes in uncertainty estimates rather than to changes in real uncertainties of the inventory (except f-gases, see Oinonen, 2004). In addition, we have revised the simulation approach to some extent.

The total uncertainty in the Finnish 2002 greenhouse gas emission inventory was -5% to +6%, when presented as a 95% confidence interval, and expressed as percent relative to the mean value. In absolute terms, the emissions (covered by this uncertainty estimate) in 2002 were 76 to 85 Tg (CO_2 equivalents) with 80 Tg as the most likely value.

The trend uncertainty was ±5%-points. This means that the increase in emissions from 1990 to 2002 was something between 3 and 10 Tg (CO_2 equivalents) with 6 Tg as the most likely value.

The most important emission sources in terms of uncertainty are, according to key source analysis, CO_2 emissions from peat lands (arable peatlands and peat production areas) and N_2O emissions from agricultural soils (both direct and indirect emissions). If emissions are considered by trend, emissions from cars with catalytic converters become the most important key source, partly due to large uncertainties and partly due to strongly increasing trend. According to the sensitivity analysis, however, none of the factors alone can well explain the total uncertainty.

This uncertainty estimate covers all anthropogenic greenhouse gas emission sources that Finland reports to the UNFCCC excluding Land-use, land use change and forestry. The inclusion of this emission category in uncertainty estimates is the most important area for further research. Some parts of this work have already begun in Finland, and results are expected in 2005.

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Appendix A: Uncertainty and key source reporting tables

Table A - 1. Tier 2 uncertainty reporting.

A	B	C	D	E	F	G	H	I	J
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Gas	Base year (1990) emissions	Year t (2002) emissions	Uncertainty in year 2002 emissions as % of emissions in the category		uncertainty introduced on national total in year 2002	% change in emissions between year t and base year	range of likely % change between year t and base year	
		Gg CO2 equivalent	Gg CO2 equivalent	% below (2.5 percentile)	% above (97.5 percentile)	%	%	Lower % (2.5 percentile)	Upper % (97.5 percentile)
1.A. Fuel Combustion									
Liquid Fuels	CO2	27 386	26 747	3	3	0.96	-2	-5	1
Solid fuels	CO2	15 746	17 273	3	3	0.73	10	7	12
Gaseous fuels	CO2	5 087	8 573	1	1	0.15	69	66	71
Other fuels	CO2	5 674	9 388	6	7	0.77	65	56	75
1.A.1 Energy Industries									
Liquid Fuels	CH4	6	7	75	12	0.01	18	-23	78
	N2O	26	29	75	12	0.03	13	-26	71
Solid Fuels	CH4	9	11	75	12	0.01	33	-13	110
	N2O	85	122	50	50	0.08	45	17	78
Gaseous Fuels	CH4	4	7	75	11	0.01	98	28	216
	N2O	18	36	50	50	0.02	104	65	151
Biomass	CH4	2	27	51	56	0.02	1 186	798	1 749
	N2O	10	83	71	153	0.16	761	429	1 305
Other Fuels	CH4	5	6	50	50	0.00	12	-11	40
	N2O	141	207	70	148	0.39	47	-4	123
1.A.2. Manufacturing Industries and Construction									
Liquid Fuels	CH4	8	7	74	12	0.01	-10	-45	47
	N2O	83	152	75	12	0.14	84	10	197
Solid Fuels	CH4	4	3	76	12	0.00	-36	-62	6
	N2O	108	89	50	50	0.06	-17	-35	4
Gaseous Fuels	CH4	5	6	75	11	0.01	35	-19	132
	N2O	17	20	50	50	0.01	16	-8	48
Biomass	CH4	20	19	51	54	0.01	-5	-31	32
	N2O	111	83	71	151	0.16	-26	-55	23
Other Fuels	CH4	4	3	51	51	0.00	-29	-45	-8
	N2O	56	25	70	149	0.05	-56	-73	-29
1.A.3. Transport									

a. Civil Aviation	CH4	11	0.3	57	100	0.00	-98	-98	-97
	N2O	57	4	70	149	0.01	-93	-96	-89
b. Road Transportation									
Gasoline	CH4	44	43	50	50	0.03	-2	-25	26
Cars with Catalytic Converters	N2O	35	380	94	378	1.80	974	291	2 805
Cars without Catalytic Converters	N2O	67	20	86	258	0.06	-70	-88	-28
Diesel	CH4	15	6	50	50	0.00	-61	-70	-50
	N2O	80	81	99	158	0.16	2	-87	249
Natural gas	CH4	0	1	50	50	0.00	*	*	*
	N2O	0	0.04	70	149	0.00	*	*	*
c. Railways	CH4	0.1	0.1	60	109	0.00	40	-5	106
	N2O	25	17	70	150	0.03	-33	-60	11
d. Navigation									
Residual Oil & Gas/Diesel Oil	CH4	0.1	0.5	57	101	0.00	300	171	493
	N2O	29	25	70	151	0.05	-15	-50	45
Gasoline	CH4	0	9	59	104	0.01	*	*	*
	N2O	0	0	71	150	0.00	*	*	*
e. Other Transportation									
Liquid fuels	CH4	0.3	7	54	64	0.01	2 227	1 289	3 840
Gasoline	N2O	1	0.7	72	158	0.00	-18	-59	63
Diesel	N2O	75	61	90	71	0.07	-18	-77	73
1.A.4. Other Sectors									
Liquid Fuels	CH4	19	16	75	13	0.02	-17	-56	53
	N2O	201	183	74	13	0.17	-9	-51	73
Solid Fuels	CH4	0.1	0.6	74	20	0.00	460	204	960
	N2O	0.3	0.3	50	52	0.00	0	-27	37
Gaseous Fuels	CH4	0.1	0.3	75	15	0.00	100	8	281
	N2O	1	1	50	50	0.00	100	47	172
Biomass	CH4	245	311	70	149	0.58	27	-30	129
	N2O	24	61	71	152	0.12	151	38	354
Other Fuels	CH4	5	1	53	60	0.00	-76	-85	-62
	N2O	1	1	71	154	0.00	0	-49	94
1.A.5. Other									
Liquid Fuels	CH4	2	2	76	17	0.00	-13	-55	71
	N2O	6	11	75	17	0.01	85	-6	269
Gaseous Fuels	CH4	0.3	0.4	75	22	0.00	43	-27	186
	N2O	1	2	51	53	0.00	75	23	149
1.B. Fugitive Emissions from Fuels									
1.B.1 Solid Fuels									
Arable peatlands	CO2	2 500	2 500	69	131	4.12	0	0	0
Peat production areas	CO2	1 000	1 000	80	205	2.58	0	0	0

	CH4	21	21	80	208	0.05	0	0	0
1.B.2. Oil and Natural Gas	CO2	42	23	22	23	0.01	-46	-55	-35
	CH4	4	8	22	23	0.00	111	76	153
2. Industrial Processes									
2.A.1 Cement Production	CO2	777	565	7	7	0.05	-27	-33	-22
2.A.2 Lime Production	CO2	398	425	11	11	0.06	7	-8	23
2.B.2 Nitric Acid Production	N2O	1 594	1 311	57	100	1.65	-18	-47	28
2.B.5 Other	CH4	4	5	21	21	0.00	21	6	39
2.C Iron and Steel production	CH4	5	10	20	20	0.00	87	65	113
2.F.1. Refrigeration and Air Conditioning Equipment	HFCs, PFCs	0	385	8	24	0.12	*	*	*
2.F.2 Foam Blowing	HFCs	0	23	29	28	0.01	*	*	*
2.F.4 Aerosols	HFCs	0	67	2	2	0.00	*	*	*
2.F.7 Electrical Equipment	SF6	87	33	8	13	0.01	-61	-75	-22
2.F Other (grouped data)	HFCs, PFCs, SF6	8	19	36	36	0.01	139	31	408
3. Total Solvent and Other Product Use	N2O	62	44	34	38	0.02	-30	-55	11
4. Agriculture									
4.A. Enteric fermentation	CH4	1 868	1 562	29	30	0.58	-16	-31	1
4.B. Manure management	CH4	199	202	17	17	0.04	2	-9	14
4.B. Manure management	N2O	554	378	82	33	0.39	-32	-74	85
4.D. Agricultural soils: direct emissions, animal production and sludge spreading	N2O	3 506	2 720	56	56	1.90	-22	-52	25
4.D. Agricultural soils: indirect emissions	N2O	764	557	82	340	2.38	-27	-77	138
6. Waste									
6.A. Solid Waste Disposal on Land	CH4	3 679	2 684	43	43	1.46	-27	-62	32
6.B.1 Industrial Wastewater	CH4	22	19	61	110	0.03	-16	-33	7
6.B.2 Domestic and Commercial Wastewater									
sparsely pop areas	CH4	118	96	34	27	0.04	-19	-49	31
densely pop areas	CH4	12	13	60	108	0.02	6	-11	26
sparsely pop areas	N2O	21	18	94	381	0.08	-16	-35	5
densely pop areas	N2O	84	65	94	383	0.31	-23	-40	-2
6.B.3. N input from Fish Farming	N2O	8	4	94	375	0.02	-58	-69	-42
6.B.3. N input from industrial wastewater	N2O	28	17	94	374	0.08	-38	-55	-16
7.Other - non-energy use of fuels	CO2	640	720	50	50	0.45	12	-49	151
Total		73 564	79 662	5	6	6	8	4	13

*Trend not calculated, when base year emissions ≈ 0.

Table A - 2. Tier 1 uncertainty reporting, columns A-M.

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC Greenhouse Gas Source and Sink Categories	Direct Green house Gas	Base Year emissions, 1990	Current Year emissions, 2002	Activity data uncertainty	Emission factor uncertainty[1]	Combined uncertainty	Combined uc as part of total national emissions in 2002	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
1.A. Fuel Combustion Activities												
Liquid Fuels	CO2	27 386	26 747	2 %	2 %	2.83 %	0.95 %	-0.0394	0.3636	-0.08 %	1.03 %	1.03 %
Solid fuels	CO2	15 746	17 273	2 %	3 %	3.35 %	0.73 %	0.0030	0.2348	0.01 %	0.50 %	0.50 %
Gaseous fuels	CO2	5 087	8 573	1 %	1 %	1.41 %	0.15 %	0.0416	0.1165	0.04 %	0.16 %	0.17 %
Other fuels	CO2	5 674	9 388	4 %	5 %	6.40 %	0.75 %	0.0440	0.1276	0.22 %	0.72 %	0.75 %
1.A.1 Energy Industries												
Liquid Fuels	CH4	6	7	2 %	75 %	75 %	0.01 %	0.0000	0.0001	0.00 %	0.00 %	0.00 %
	N2O	26	29	2 %	75 %	75 %	0.03 %	0.0000	0.0004	0.00 %	0.00 %	0.00 %
Solid fuels	CH4	9	11	2 %	75 %	75 %	0.01 %	0.0000	0.0002	0.00 %	0.00 %	0.00 %
	N2O	85	122	2 %	50 %	50 %	0.08 %	0.0004	0.0017	0.02 %	0.00 %	0.02 %
Gaseous fuels	CH4	4	7	1 %	75 %	75 %	0.01 %	0.0000	0.0001	0.00 %	0.00 %	0.00 %
	N2O	18	36	1 %	50 %	50 %	0.02 %	0.0002	0.0005	0.01 %	0.00 %	0.01 %
Biomass	CH4	2	27	20 %	50 %	54 %	0.02 %	0.0003	0.0004	0.02 %	0.01 %	0.02 %
	N2O	10	83	20 %	150 %	151 %	0.16 %	0.0010	0.0011	0.15 %	0.03 %	0.15 %
Other fuels	CH4	5	6	5 %	50 %	50 %	0.00 %	0.0000	0.0001	0.00 %	0.00 %	0.00 %
	N2O	141	207	5 %	150 %	150 %	0.39 %	0.0007	0.0028	0.11 %	0.02 %	0.11 %
1.A.2. Manufacturing Industries and Construction												
Liquid Fuels	CH4	8	7	2 %	75 %	75 %	0.01 %	0.0000	0.0001	0.00 %	0.00 %	0.00 %
	N2O	83	152	2 %	75 %	75 %	0.14 %	0.0008	0.0021	0.06 %	0.01 %	0.06 %
Solid fuels	CH4	4	3	2 %	75 %	75 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %
	N2O	108	89	2 %	50 %	50 %	0.06 %	-0.0004	0.0012	-0.02 %	0.00 %	0.02 %
Gaseous fuels	CH4	5	6	1 %	75 %	75 %	0.01 %	0.0000	0.0001	0.00 %	0.00 %	0.00 %
	N2O	17	20	1 %	50 %	50 %	0.01 %	0.0000	0.0003	0.00 %	0.00 %	0.00 %
Biomass	CH4	20	19	15 %	50 %	52 %	0.01 %	0.0000	0.0003	0.00 %	0.01 %	0.01 %
	N2O	111	83	15 %	150 %	151 %	0.16 %	-0.0005	0.0011	-0.08 %	0.02 %	0.08 %
Other fuels	CH4	4	3	5 %	50 %	50 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %
	N2O	56	25	5 %	150 %	150 %	0.05 %	-0.0005	0.0003	-0.07 %	0.00 %	0.07 %
1.A.3. Transport												

a. Civil Aviation	CH4	11	0	5 %	100 %	100 %	0.00 %	-0.0002	0.0000	-0.02 %	0.00 %	0.02 %
	N2O	57	4	5 %	150 %	150 %	0.01 %	-0.0008	0.0001	-0.12 %	0.00 %	0.12 %
b. Road Transportation												
Gasoline	CH4	44	43	1 %	50 %	50 %	0.03 %	-0.0001	0.0006	0.00 %	0.00 %	0.00 %
Cars with Catalytic Converters	N2O	35	380	1 %	378 %	378 %	1.80 %	0.0046	0.0052	1.75 %	0.01 %	1.75 %
Cars without Catalytic Converters	N2O	67	20	1 %	259 %	259 %	0.06 %	-0.0007	0.0003	-0.19 %	0.00 %	0.19 %
Diesel	CH4	15	6	1 %	50 %	50 %	0.00 %	-0.0001	0.0001	-0.01 %	0.00 %	0.01 %
	N2O	80	81	1 %	158 %	158 %	0.16 %	-0.0001	0.0011	-0.01 %	0.00 %	0.01 %
Natural gas	CH4	0	1	1 %	50 %	50 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %
	N2O	0	0	1 %	150 %	150 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %
c. Railways	CH4	0.1	0.1	5 %	110 %	110 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %
	N2O	25	17	5 %	150 %	150 %	0.03 %	-0.0001	0.0002	-0.02 %	0.00 %	0.02 %
d. Navigation												
Residual Oil & Gas/Diesel Oil	CH4	0.1	1	10 %	100 %	100 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %
	N2O	29	25	10 %	150 %	150 %	0.05 %	-0.0001	0.0003	-0.01 %	0.00 %	0.01 %
Gasoline	CH4	0	9	20 %	100 %	102 %	0.01 %	0.0001	0.0001	0.01 %	0.00 %	0.01 %
	N2O	0	0	20 %	150 %	151 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %
e. Other Transportation												
Gasoline&Diesel	CH4	0.3	7	30 %	50 %	58 %	0.01 %	0.0001	0.0001	0.00 %	0.00 %	0.01 %
Gasoline	N2O	1	1	30 %	150 %	153 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %
Diesel	N2O	75	61	30 %	90 %	95 %	0.07 %	-0.0003	0.0008	-0.02 %	0.04 %	0.04 %
1.A.4. Other Sectors												
Liquid Fuels	CH4	19	16	3 %	75 %	75 %	0.02 %	-0.0001	0.0002	0.00 %	0.00 %	0.01 %
	N2O	201	183	3 %	75 %	75 %	0.17 %	-0.0005	0.0025	-0.03 %	0.01 %	0.04 %
Solid fuels	CH4	0.1	1	10 %	75 %	76 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %
	N2O	0.3	0.3	10 %	50 %	51 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %
Gaseous fuels	CH4	0.1	0.3	5 %	75 %	75 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %
	N2O	1	1	5 %	50 %	50 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %
Biomass	CH4	245	311	15 %	150 %	151 %	0.59 %	0.0006	0.0042	0.09 %	0.09 %	0.13 %
	N2O	24	61	15 %	150 %	151 %	0.12 %	0.0005	0.0008	0.07 %	0.02 %	0.07 %
Other fuels	CH4	5	1	25 %	50 %	56 %	0.00 %	-0.0001	0.0000	0.00 %	0.00 %	0.00 %
	N2O	1	1	25 %	150 %	152 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %
1.A.5. Other												
Liquid Fuels	CH4	2	2	7 %	75 %	75 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %
	N2O	6	11	7 %	75 %	75 %	0.01 %	0.0001	0.0002	0.00 %	0.00 %	0.01 %
Gaseous fuels	CH4	0.3	0.4	12 %	75 %	76 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %
	N2O	1	2	12 %	50 %	51 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %

1.B. Fugitive Emissions from Fuels												
1.B.1 Solid Fuels												
arable peatlands	CO2	2 500	2 500	109 %	50 %	120 %	3.77 %	-0.0028	0.0340	-0.14 %	-0.31 %	0.34 %
peat production areas	CO2	1 000	1 000	10 %	208 %	208 %	2.61 %	-0.0011	0.0136	-0.23 %	-0.01 %	0.23 %
	CH4	21	21	10 %	208 %	208 %	0.05 %	0.0000	0.0003	0.00 %	0.00 %	0.00 %
1.B.2. Oil and Natural Gas	CO2	42	23	10 %	20 %	22 %	0.01 %	-0.0003	0.0003	-0.01 %	0.00 %	0.01 %
	CH4	4	8	10 %	20 %	22 %	0.00 %	0.0000	0.0001	0.00 %	0.00 %	0.00 %
2. Industrial Processes												
2.A.1 Cement Production	CO2	777	565	5 %	5 %	7 %	0.05 %	-0.0038	0.0077	-0.02 %	0.05 %	0.06 %
2.A.2 Lime Production	CO2	398	425	10 %	5 %	11 %	0.06 %	-0.0001	0.0058	0.00 %	0.08 %	0.08 %
2.B.2 Nitric Acid Production	N2O	1 594	1 311	5 %	100 %	100 %	1.65 %	-0.0056	0.0178	-0.56 %	0.13 %	0.58 %
2.B.5 Other	CH4	4	5	5 %	20 %	21 %	0.00 %	0.0000	0.0001	0.00 %	0.00 %	0.00 %
2.C Iron and Steel production	CH4	5	10	3 %	20 %	20 %	0.00 %	0.0001	0.0001	0.00 %	0.00 %	0.00 %
2.F.1. Refrigeration and Air Conditioning Equipment	HFC	0	385	24 %	0 %	24 %	0.12 %	0.0052	0.0052	0.00 %	0.18 %	0.18 %
2.F.2 Foam Blowing	HFC	0	23	29 %	0 %	29 %	0.01 %	0.0003	0.0003	0.00 %	0.01 %	0.01 %
2.F.4 Aerosols	HFC	0	67	2 %	0 %	2 %	0.00 %	0.0009	0.0009	0.00 %	0.00 %	0.00 %
2.F.7 Electrical Equipment	SF6	87	33	14 %	0 %	14 %	0.01 %	-0.0008	0.0005	0.00 %	0.01 %	0.01 %
2.F Other (grouped data)	HFC PFC SF6	8	19	36 %	0 %	36 %	0.01 %	0.0001	0.0003	0.00 %	0.01 %	0.01 %
3. Total Solvent and Other Product Use	N2O	62	44	30 %	20 %	36 %	0.02 %	-0.0003	0.0006	-0.01 %	0.03 %	0.03 %
4. Agriculture												
4.A.Enteric fermentation	CH4	1 868	1 562	29.58 %	0.00 %	30 %	0.58 %	-0.0063	0.0212	0.00 %	0.89 %	0.89 %
4.B.Manure management	CH4	199	202	17.07 %	0.00 %	17 %	0.04 %	-0.0002	0.0027	0.00 %	0.07 %	0.07 %
4.B.Manure management	N2O	554	378	82.34 %	0.00 %	82 %	0.39 %	-0.0030	0.0051	0.00 %	0.60 %	0.60 %
4.D.Agricultural soils: direct emissions, animal production and sludge spreading	N2O	3 506	2 720	55.75 %	0.00 %	56 %	1.90 %	-0.0146	0.0370	0.00 %	2.91 %	2.91 %
4.D.Agricultural soils: indirect emissions	N2O	764	557	339.86 %	0.00 %	341 %	2.38 %	-0.0037	0.0076	0.00 %	3.65 %	3.65 %
6. Waste												
6.A. Solid Waste disposal on Land	CH4	3 679	2 684	43 %	0 %	43 %	1.45 %	-0.0177	0.0365	0.00 %	2.22 %	2.22 %
6.B.1 Industrial Wastewater	CH4	22	19	10 %	104 %	105 %	0.02 %	-0.0001	0.0003	-0.01 %	0.00 %	0.01 %
6.B.2 Domestic and Commercial Wastewater												
sparcely populated areas	CH4	118	96	15 %	32 %	35 %	0.04 %	-0.0004	0.0013	-0.01 %	0.03 %	0.03 %
densely populated areas	CH4	12	13	5 %	104 %	105 %	0.02 %	0.0000	0.0002	0.00 %	0.00 %	0.00 %
sparcely populated areas	N2O	21	18	10 %	380 %	380 %	0.08 %	-0.0001	0.0002	-0.03 %	0.00 %	0.03 %
densely populated areas	N2O	84	65	5 %	380 %	380 %	0.31 %	-0.0004	0.0009	-0.14 %	0.01 %	0.14 %
6.B.3. N input from Fish Farming	N2O	8	4	10 %	380 %	380 %	0.02 %	-0.0001	0.0000	-0.03 %	0.00 %	0.03 %

6.B.3. N input from industrial wastewater	N2O	28	17	5 %	380 %	380 %	0.08 %	-0.0002	0.0002	-0.07 %	0.00 %	0.07 %
7.Other - non-energy use of fuels	CO2	640	720	50 %	5 %	50 %	0.45 %	0.0004	0.0098	0.00 %	0.69 %	0.69 %
Total		73 564	79 662				6.5 %					5.84 %

[1]When uncertainties are calculated with a separate model, resulting uncertainty in emissions is reported in column E, thus resulting in 0% in column F.

Table A - 3. Tier 1 uncertainty reporting, columns A-B and N-Q.

A	B	N	O	P	Q
IPCC Greenhouse Gas Source and Sink Categories	Direct Greenhouse Gas	Emission factor quality indicator	Activity data quality indicator	Expert judgement reference numbers[1]	Footnote Reference numbers[1]
1.A. Fuel Combustion					
Liquid fuels	CO2	R	R	E1	
Solid fuels	CO2	R	R	E1	
Gaseous fuels	CO2	R	R	E1	
Other fuels	CO2	R	R	E1	M4
1.A.1 Energy Industries					
Liquid Fuels	CH4	R	R	E1	M2
	N2O	R	R	E1	M2
Solid fuels	CH4	R	R	E1	M2
	N2O	R	R	E1	
Gaseous fuels	CH4	R	R	E1	M2
	N2O	R	R	E1	
Biomass	CH4	R	R	E1	
	N2O	R	R	E1	
Other fuels	CH4	R	R	E1	
	N2O	R	R	E1	
1.A.2. Manufacturing Industries and Construction					
Liquid Fuels	CH4	R	R	E1	M2
	N2O	R	R	E1	M2
Solid fuels	CH4	R	R	E1	M2
	N2O	R	R	E1	
Gaseous fuels	CH4	R	R	E1	
	N2O	R	R	E1	
Biomass	CH4	R	R	E1	
	N2O	R	R	E1	
Other fuels	CH4	R	R	E1	
	N2O	R	R	E1	
1.A.3. Transport					
a. Civil Aviation	CH4	D	R		L4
	N2O	R	R		
b. Road Transportation					
Gasoline	CH4	M	R		L5
Cars with Catalytic Converters	N2O	M	R		L6,L7,L8,L9,L10,L19,L20, L21,L22,L23
Cars without Catalytic Converters	N2O	M	R		L6, L9, L10, L19, L21
Diesel	CH4	M	R		L5
	N2O	M	R		L6, L8, L11, L21
Natural gas	CH4	M	R		L5
	N2O	R	R		
c. Railways	CH4	M	R		M3
	N2O	R	R		M3
d. Navigation					
Residual Oil & Gas/Diesel Oil	CH4	D	R		L4
	N2O	R	R		
Gasoline	CH4	R	R		L4
	N2O	R	R		

e. Other Transportation					
Gasoline&Diesel	CH4	R	R		
Gasoline	N2O	R	R		
Diesel	N2O	R	R		
1.A.4. Other Sectors					
Liquid Fuels	CH4	R	R	E1	M2
	N2O	R	R	E1	M2
Solid fuels	CH4	R	R	E1	M2
	N2O	R	R	E1	
Gaseous fuels	CH4	R	R	E1	M2
	N2O	R	R	E1	
Biomass	CH4	R	R	E1	
	N2O	R	R	E1	
Other fuels	CH4	R	R	E1	
	N2O	R	R	E1	
1.A.5. Other					
Liquid Fuels	CH4	R	R	E1	M2
	N2O	R	R	E1	M2
Gaseous fuels	CH4	R	R	E1	M2
	N2O	R	R	E1	
1.B. Fugitive Emissions from Fuels					
1.B.1 Solid Fuels					
arable peatlands	CO2	R	R		L3
peat production areas	CO2	R	R		
	CH4	R	R		
1.B.2. Oil and Natural Gas	CO2	R	R	E1	
	CH4	R	R	E1	
2. Industrial Processes					
2.A.1 Cement Production	CO2	R	R	E1	
2.A.2 Lime Production	CO2	R	R	E1	
2.B.2 Nitric Acid Production	N2O	R	R		M1
2.B.5 Other	CH4	R	R	E1	
2.C Iron and Steel production	CH4	R	R	E1	
2.F.1. Refrigeration and Air Conditioning Equipment	HFCs	R	R		L24
2.F.2 Foam Blowing	HFCs	R	R		L24
2.F.4 Aerosols	HFCs	R	R		L24
2.F.7 Electrical Equipment	SF6	R	R		L24
2.F Other (grouped data)	HFCs. PFCs. SF6	R	R		L24
3. Total Solvent and Other Product Use	N2O	R	R	E1	
4. Agriculture					
4.A.Enteric fermentation	CH4	D/R	R		L4, L13
4.B.Manure management	CH4	R	R		
4.B.Manure management	N2O	R	R		L12, L14, L15, L16, L17, L4
4.D.Agricultural soils: direct emissions, animal production and sludge spreading	N2O	D/R	R		L2, L18
4.D.Agricultural soils: indirect emissions	N2O	D/R	R		L2, L18
6. Waste					
6.A. Solid Waste disposal on Land	CH4	R	R	E2	L4
6.B.1 Industrial Wastewater	CH4	R	R	E2	L4
6.B.2 Domestic and Commercial Wastewater					

sparcely populated areas	CH4	R	R	E3	
densely populated areas	CH4	R	R	E2	L4
sparcely populated areas	N2O	R	R	E2	L2
densely populated areas	N2O	R	R	E2	L2
6.B.3. N input from Fish Farming	N2O	R	R	E2	L2
6.B.3. N input from industrial wastewater	N2O	R	R	E2	L2
7.Other - non-energy use of fuels	CO2	R	R	E1	

[1] See Table A-4.

Table A - 4. References of Table A-3.

Expert Elicitations	
E1	Kari Grönfors and Mikko Äikäs, Statistics Finland, 27 August 2002
E2	Jouko Petäjä (Finnish Environment Institute) 21 November 2002
E3	Jouko Petäjä (Finnish Environment Institute) 15 January 2004
Measurement data	
M1	Confidential measurement data from nitric acid production plants
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Table A - 5. Source Category Analysis Summary for 2002

Quantitative Method Used: Tier 2			
A	**B**	**C**	**D**
IPCC Source Categories	**Direct Greenhouse Gas**	**Key Source Category**	**Cirteria of identification**[1]
1.A. Fuel Combustion			
Liquid fuels	CO2	YES	L, T
Solid fuels	CO2	YES	L
Gaseous fuels	CO2	NO	
Other fuels	CO2	YES	L, T
1.A.1 Energy Industries			
Liquid fuels	CH4	NO	
	N2O	NO	
Solid fuels	CH4	NO	
	N2O	NO	
Gaseous fuels	CH4	NO	
	N2O	NO	
Biomass	CH4	NO	
	N2O	YES	T
Other fuels	CH4	NO	
	N2O	YES	L, T

1.A.2. Manufacturing Industries and Construction			
Liquid fuels	CH_4	NO	
	N_2O	NO	
Solid fuels	CH_4	NO	
	N_2O	NO	
Gaseous fuels	CH_4	NO	
	N_2O	NO	
Biomass	CH_4	NO	
	N_2O	NO	
Other fuels	CH_4	NO	
	N_2O	NO	
1.A.3. Transport			
a. Civil Aviation	CH_4	NO	
	N_2O	YES	T
b. Road Transportation			
Gasoline	CH_4	NO	
Cars with Catalytic Converters	N_2O	YES	L, T
Cars without Catalytic Converters	N_2O	YES	T
Diesel	CH_4	NO	
	N_2O	NO	
Natural gas	CH_4	NO	
	N_2O	NO	
c. Railways	CH_4	NO	
	N_2O	NO	
d. Navigation			
Residual Oil & Gas/Diesel Oil	CH_4	NO	
	N_2O	NO	
Gasoline	CH_4	NO	
	N_2O	NO	
e. Other Transportation			
Liquid fuels	CH_4	NO	
Gasoline	N_2O	NO	
Diesel	N_2O	NO	
1.A.4. Other Sectors			
Liquid fuels	CH_4	NO	
	N_2O	NO	
Solid fuels	CH_4	NO	
	N_2O	NO	
Gaseous fuels	CH_4	NO	
	N_2O	NO	
Biomass	CH_4	YES	L, T
	N_2O	NO	
Other fuels	CH_4	NO	
	N_2O	NO	
1.A.5. Other			
Liquid fuels	CH_4	NO	
	N_2O	NO	
Gaseous fuels	CH_4	NO	
	N_2O	NO	
1.B. Fugitive Emissions from Fuels			

1.B.1 Solid Fuels			
Arable peatlands	CO2	YES	L, T
Peat production areas	CO2	YES	L, T
	CH4	NO	
1.B.2. Oil and Natural Gas	CO2	NO	
	CH4	NO	
2. Industrial Processes			
2.A.1 Cement Production	CO2	NO	
2.A.2 Lime Production	CO2	NO	
2.B.2 Nitric Acid Production	N2O	YES	L, T
2.B.5 Other	CH4	NO	
2.C Iron and Steel production	CH4	NO	
2.F.1. Refrigeration and Air Conditioning Equipment	HFCs, PFCs	YES	T
2.F.2 Foam Blowing	HFCs	NO	
2.F.4 Aerosols	HFCs	NO	
2.F.7 Electrical Equipment	SF6	NO	
2.F Other (grouped data)	HFCs, PFCs, SF6	NO	
3. Total Solvent and Other Product Use	N2O	NO	
4. Agriculture			
4.A. Enteric fermentation	CH4	YES	L, T
4.B. Manure management	CH4	NO	
4.B. Manure management	N2O	YES	L, T
4.D. Agricultural soils: direct emissions, animal production and sludge spreading	N2O	YES	L, T
4.D. Agricultural soils: indirect emissions	N2O	YES	L, T
6. Waste			
6.A. Solid Waste Disposal on Land	CH4	YES	L, T
6.B.1 Industrial Wastewater	CH4	NO	
6.B.2 Domestic and Commercial Wastewater			
sparsely populated areas	CH4	NO	
densely populated areas	CH4	NO	
sparsely populated areas	N2O	NO	
densely populated areas	N2O	YES	L, T
6.B.3. N input from Fish Farming	N2O	NO	
6.B.3. N input from industrial wastewater	N2O	NO	
7.Other - non-energy use of fuels	CO2	YES	L

[1] L=level, T=trend

Table A - 6. Source category analysis for the base year.

Quantitative Method Used: Tier 2			
A	**B**	**C**	**D**
IPCC Source Categories	**Direct Greenhouse Gas**	**Key Source Category**	**Cirteria of identification**
1.A. Fuel Combustion			
Liquid fuels	CO2	YES	L
Solid fuels	CO2	YES	L
Gaseous fuels	CO2	NO	

Other fuels	CO_2	YES	L
1.A.1 Energy Industries			
Liquid fuels	CH_4	NO	
	N_2O	NO	
Solid fuels	CH_4	NO	
	N_2O	NO	
Gaseous fuels	CH_4	NO	
	N_2O	NO	
Biomass	CH_4	NO	
	N_2O	NO	
Other fuels	CH_4	NO	
	N_2O	YES	L
1.A.2. Manufacturing Industries and Construction			
Liquid fuels	CH_4	NO	
	N_2O	NO	
Solid fuels	CH_4	NO	
	N_2O	NO	
Gaseous fuels	CH_4	NO	
	N_2O	NO	
Biomass	CH_4	NO	
	N_2O	NO	
Other fuels	CH_4	NO	
	N_2O	NO	
1.A.3. Transport			
a. Civil Aviation	CH_4	NO	
	N_2O	NO	
b. Road Transportation			
Gasoline	CH_4	NO	
Cars with Catalytic Converters	N_2O	NO	
Cars without Catalytic Converters	N_2O	YES	L
Diesel	CH_4	NO	
	N_2O	NO	
Natural gas	CH_4	NO	
	N_2O	NO	
c. Railways	CH_4	NO	
	N_2O	NO	
d. Navigation			
Residual Oil & Gas/Diesel Oil	CH_4	NO	
	N_2O	NO	
Gasoline	CH_4	NO	
	N_2O	NO	
e. Other Transportation			
Liquid fuels	CH_4	NO	
Gasoline	N_2O	NO	
Diesel	N_2O	NO	
1.A.4. Other Sectors			
Liquid fuels	CH_4	NO	
	N_2O	NO	
Solid fuels	CH_4	NO	
	N_2O	NO	

Gaseous fuels	CH4	NO	
	N2O	NO	
Biomass	CH4	YES	L
	N2O	NO	
Other fuels	CH4	NO	
	N2O	NO	
1.A.5. Other			
Liquid fuels	CH4	NO	
	N2O	NO	
Gaseous fuels	CH4	NO	
	N2O	NO	
1.B. Fugitive Emissions from Fuels			
1.B.1 Solid Fuels			
Arable peatlands	CO2	YES	L
Peat production areas	CO2	YES	L
	CH4	NO	
1.B.2. Oil and Natural Gas	CO2	NO	
	CH4	NO	
2. Industrial Processes			
2.A.1 Cement Production	CO2	NO	
2.A.2 Lime Production	CO2	NO	
2.B.2 Nitric Acid Production	N2O	YES	L
2.B.5 Other	CH4	NO	
2.C Iron and Steel production	CH4	NO	
2.F.1. Refrigeration and Air Conditioning Equipment	HFCs, PFCs	NO	
2.F.2 Foam Blowing	HFCs	NO	
2.F.4 Aerosols	HFCs	NO	
2.F.7 Electrical Equipment	SF6	NO	
2.F Other (grouped data)	HFCs, PFCs, SF6	NO	
3. Total Solvent and Other Product Use	N2O	NO	
4. Agriculture			
4.A. Enteric fermentation	CH4	YES	L
4.B. Manure management	CH4	NO	
4.B. Manure management	N2O	YES	L
4.D. Agricultural soils: direct emissions, animal production and sludge spreading	N2O	YES	L
4.D. Agricultural soils: indirect emissions	N2O	YES	L
6. Waste			
6.A. Solid Waste Disposal on Land	CH4	YES	L
6.B.1 Industrial Wastewater	CH4	NO	
6.B.2 Domestic and Commercial Wastewater			
sparsely populated areas	CH4	NO	
densely populated areas	CH4	NO	
sparsely populated areas	N2O	NO	
densely populated areas	N2O	YES	L
6.B.3. N input from Fish Farming	N2O	NO	
6.B.3. N input from industrial wastewater	N2O	NO	
7.Other - non-energy use of fuels	CO2	YES	L

[1] L=level, T=trend

Appendix B: A case study: Tier 2 QC of the trend uncertainty estimate presented in this report

Teemu Oinonen

At the time of publication of this report, Statistics Finland is formulating quality management procedures for the Finnish inventory of greenhouse gases. I have the pleasure to participate in a working group developing these procedures. As one part of the efforts of the working group, I undertook an analysis attempting to duplicate the trend uncertainty estimate presented in the current report. Such analyses are part of the Tier 2 QC procedures described in the IPCC Good Practice Guidance. According to the Guidance it "is *good practice* for QC procedures to be applied to the uncertainty estimations to confirm that calculations are correct and that there is sufficient documentation to duplicate them" (Penman et al. 2000, p. 8.15).

The approach selected was to use emission level and their uncertainty estimates calculated by Suvi Monni using Monte Carlo simulation, but to use different mathematical techniques to quantify the uncertainty. The techniques selected were the total differential, and two variants of the first order Taylor series expansion: Gaussian approximation and the full first order expansion.[1]

The variables and their values needed in the analysis are:

Base year (1990) emission level	A = 73.564 Tg CO_2-eq.
Current year (2002) emissions level	B = 79.662 Tg CO_2-eq.
Standard deviation of A	$\sigma_A = 0.065 \times A/2$ Tg CO_2-eq.
Standard deviation of B	$\sigma_B = 0.055 \times B/2$ Tg CO_2-eq.
Error in A	$\Delta A = 0.065 \times A$ Tg CO_2-eq.
Error in B	$\Delta B = 0.055 \times A$ Tg CO_2-eq.
The trend	$X = (B - A)/A \times 100\%$
Correlation between A and B	*r (unknown)*

Emission levels were taken from the draft report. Values 0.065 and 0.055 are averages of the reported uncertainties (section 3.6) calculated for the purposes of the analysis.

The trend of emissions between 1990 and 2002 is $X = (79.662 - 73.564)/73.564 \times 100\% \approx 8.289\%$.

[1] For the total differential, see any standard text book on calculus. Taylor series expansion and its application in uncertainty propagation is described, for instance, in Morgan & Henrion (1990).

The solution to the total differential of X is

$$|\Delta X| \le \left| -\frac{B}{A^2}\Delta A \right| + \left| \frac{1}{A}\Delta B \right|.$$

Typing in the values, and carrying out the calculations, it evaluates to

$$|\Delta X| \le \left| -\frac{79.662}{73.564^2}\times 4.782 \right| + \left| \frac{1}{73.564}\times 4.381 \right| \approx 0.1299.$$

The trend of Finnish emissions between 1990 and 2002 is thus (8±13)%. The uncertainty is much higher than that calculated using Monte Carlo analysis: (8±5)%. This can be expected since the total differential gives an upper bound of uncertainty (note the use of absolute values in the formula).

The next model of uncertainty to try was the Gaussian approximation:

$$U_G = 2\left[\left(-\frac{B}{A^2}\right)^2 \sigma_A^2 + \left(\frac{1}{A}\right)^2 \sigma_B^2\right]^{\frac{1}{2}} \times 100\%$$

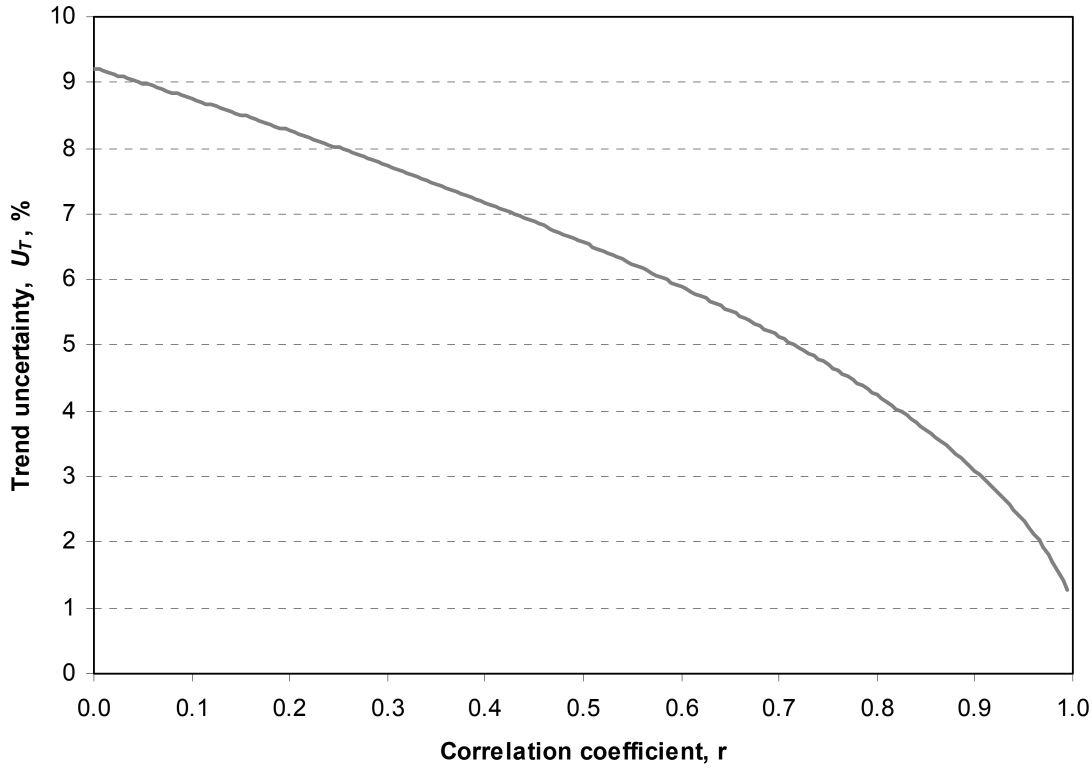
$$U_G = 2\left[\left(-\frac{79.662}{73.564^2}\right)^2 (0.065\times 73.564/2)^2 + \left(\frac{1}{73.564}\right)^2 (0.055\times 79.662/2)^2\right]^{\frac{1}{2}} \times 100\% \approx 9.221\%.$$

Compared to the total differential, it yields lower trend uncertainty of ±9%. Since it was still considerably higher that the value calculated in the report, the next model to try was the full first order expansion, which incorporates the covariance of A and B. The idea was to try whether some degree of correlation between the level uncertainties could account for the difference. The solution to the expansion is

$$U_T = 2\left[\left(-\frac{B}{A^2}\right)^2 \sigma_A^2 + \left(\frac{1}{A}\right)^2 \sigma_B^2 + 2\sigma_A\sigma_B\left(-\frac{B}{A^2}\right)\left(\frac{1}{A}\right) r\right]^{\frac{1}{2}} \times 100\%.$$

A short computer code was written to evaluate the above model for $r = 0.000, 0.005, 0.010, \ldots, 1.000$. The results, U_T as a function of r, were then plotted on a graph (see below).

The result verifies the estimate obtained by Monte Carlo –simulation. An *r* value of approximately 0.7 is needed for the 5% trend uncertainty. The graph also shows that the assumption regarding correlation has a large effect on trend uncertainty. For the variable values specific to the Finnish 2002 inventory, the trend uncertainty can vary between 1 and 9 percent, depending on the degree of correlation assumed[2].



[2]According to Monni & Syri (2003), in the Finnish uncertainty estimate, emission factors are assumed fully correlated between years and activity data are assumed independent. This approach is also recommended by the Good Practice Guidance (Penman et al., 2000)

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