Comparison of uncertainty in different emission trading schemes

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Abstract

Emission trading in the EU will begin in 2005, covering the least uncertain emission sources of greenhouse gas emission inventories (CO_2 from combustion and from selected industrial processes in large installations). If the Kyoto Protocol enters into force, the emission trading covering all gases (CO_2, CH_4, N_2O, HFCs, PFCs and SF_6) and sectors (energy, industry, agriculture, waste, land use, land-use change and forestry (LULUCF)) will begin in 2008. Various other choices for emission trading schemes have also been proposed. Uncertainty in emissions to be traded may be significant, and vary largely between different emission trading schemes. In this paper, we estimate the uncertainties in different emission trading schemes based on uncertainties in corresponding inventories. According to the results, uncertainty in emissions included in the EU emission trading scheme (2005-2007) from EU-15 and EU-25 is $\pm 3\%$ (at 95% confidence interval relative to the mean value). If the trading were extended to CH_4 and N_2O in addition to CO_2, then tradable amount of emissions would increase only by 2%, but the uncertainty in the emissions would range from -4 to +7%. Finally, uncertainty in emissions included in the emission trading under the Kyoto Protocol was estimated to vary from -6 to +21%. Inclusion of removals from LULUCF activities under the Kyoto Protocol did not affect total uncertainty. The results including the LULUCF estimates should be considered only as indicative.

1 Introduction

In the Kyoto Protocol, which aims at reducing greenhouse gas emissions from industrial countries by 5% below 1990 level in the commitment period 2008-2012, several mechanisms are implemented for the accomplishment of the emission reduction target. All the Kyoto mechanisms (emission trading, joint implementation and clean development mechanism) aim at cost-effectiveness in emission reduction.

EU has decided to begin CO_2 emission trading to both improve cost-efficiency in emission reductions, and to give experience to member states on emission trading. This emission trading scheme, to be carried out between 2005 and 2007, covers CO_2 emissions from combustion and from selected industrial processes. A majority of emissions included are derived from combustion, but a part of emissions is due to use of raw materials. Most member states of EU-15 and also some of the new member states have already published their national allocation plans (NAP). Altogether, emission trading in the EU-25 will cover around 2000 Tg CO_2 emissions annually, corresponding close to 50% of CO_2 equivalent emissions from the EU-15 in 2002 [1,2]. The new member states of the European Union participating emission trading are expected to be mainly vendors of emission allowances during the first phase.

Because emission trading covers high monetary values, there is need for good verification of emissions to ensure equitable trading. Therefore the Guidelines for the Monitoring for EU emission trading scheme [3] gives also advice on uncertainties that are acceptable in plants that participate in emission trading within the EU emission trading scheme.

Emission trading under the Kyoto Protocol will begin in 2008, if the protocol enters into force. Emission trading under the Kyoto Protocol will cover all gases of the Kyoto Protocol (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6) as well as all sectors (energy, industrial processes, waste, agriculture, and LULUCF for activities defined in Articles 3.3 and 3.4 of the Protocol). The rules for emission trading under the Kyoto Protocol have been agreed and defined in the Marrakesh Accords [4]. Emissions are traded between parties, not between companies. Parties can enable companies to trade under domestic and multilateral schemes, such as the EU emission trading scheme. Parties of the Convention are liable to estimate and report uncertainties in their emission estimates to the UNFCCC, but the Marrakesh Accords does not include any bounds for uncertainty in tradable emissions.

In this paper, we estimate the uncertainties in emissions under the EU emission trading scheme for EU-15 and EU-25. In addition, we present uncertainty estimates for a hypothetical scheme extended to cover also CH_4 and N_2O for the source categories included in the EU emission trading scheme, and Kyoto emission trading scheme both with and without LULUCF. All uncertainty estimates are based on uncertainties in national inventories.

2 Uncertainties in different emission trading schemes

All emission estimates contain uncertainty. Uncertainties arise due to, e.g., errors in models or measurement instruments, poor knowledge on the emission generating process or unsuitability of emission factors used. The countries that have performed uncertainty analyses have usually ended up with uncertainty of $\pm$5-20% in annual greenhouse gas emission inventories without LULUCF [5,6,7]. It is important to differentiate between uncertainties of emission estimates of single point sources (e.g. power plants) and emission inventories. Random errors in uncorrelated emission estimates of different sources partly cancel each other, but possible systematic errors may cumulate in the national inventory.

CO_2 from fuel combustion, included also in the EU emission trading scheme (2005-2007) is the most accurately known emission source in greenhouse gas emission inventories. For commercially traded fuels, uncertainties in emission estimates of plants are usually around $\pm$2.5-5% for large plants and $\pm$5-10% for small plants [3]. Uncertainties in, e.g. waste combustion, may be much higher, up to ±50% [8], but in the Guidelines for Monitoring for EU emission trading [3], uncertainty in plant specific emissions from waste combustion is estimated much lower, i.e. ±5-12.5%.

Industrial processes covered in the EU emission trading scheme are also among the best known emission sources (e.g. limestone and dolomite used in cement and lime manufacture), though their uncertainty is typically larger than that of fuel combustion, from ±5-10% [3,8], up to ±20-40% depending on the emission estimation method [8].

In the examination of a hypothetical extended EU emission trading scheme, we included also CH_4 and N_2O from the emission sources covered by the EU emission trading scheme. CH_4 and N_2O emissions from combustion are largely dependent on process conditions (e.g. temperature in the boiler), combustion technology and fuel quality. Uncertainty in CH_4 emissions from stationary combustion is estimated to vary between ±50-150% [5,8] and that in N_2O ±20-200% [6]. IPCC [8] estimates that uncertainty in N_2O from combustion may be even an order of magnitude. Plant-specific uncertainty estimates based on measurements would be much smaller.

In the Kyoto emission trading scheme, there are some industrial sources not included in the extended EU emission trading scheme, e.g. nitric acid and adipic acid production which can be rather accurately estimated using, e.g. continuous measurement (e.g. ±7% [5]), but whose uncertainty may be very large if emission estimation is based on calculation (up to 230% [5]). Kyoto emission trading scheme covers also transportation and combustion in small installations, which are somewhat more uncertain than emissions covered by the extended EU emission trading scheme. Uncertainties in HFCs, PFCs and SF6 from different industrial processes vary from ±5 to 100% [5,6,9].

CO_2, CH_4 and N_2O emissions from other than industrial sources (e.g. agriculture and waste management) are often very uncertain. Uncertainties in these emissions vary from, e.g. ±30-50% for CH_4 from landfills to ±75-1000% for N_2O from agricultural soils [5,8,10].

Land use, land-use change and forestry is also a very uncertain emission category. Changes in carbon stocks of trees is estimated to contain an uncertainty of around ±30-35% [9,11] and emissions from liming an uncertainty of ±20% [10]. Emissions from soils are estimated to be more uncertain (e.g. ±60% [11]). In addition, uncertainties in emissions or removals from land use change are estimated large. However, according to the Kyoto Protocol, only a part of the sink can be subtracted from national emissions. Uncertainties in carbon stock changes from activities under Article 3.3 (afforestation, reforestation, reforestation) and Article 3.4 (forest management, revegetation, cropland management and grazing land management) of the Kyoto Protocol is estimated to vary between ±50-100% for some activities. Uncertainties in N_2O emissions from forest soils are in the same order as those from agricultural soils [12].

3 Methods

In this study, we present an uncertainty estimate of various emission trading schemes for the EU area. The examination covers uncertainty in EU emission trading scheme (2005-2007) for both EU-15 and EU-25, a hypothetical EU emission trading scheme extended to cover also CH_4 and N_2O, and emission trading under the Kyoto Protocol both with and without LULUCF. Estimates of non-CO_2 gases are based on emissions in 2002, and estimates of emissions under EU emission trading scheme on average projected emissions between 2005 and 2007.

Emissions used in the calculation (Table 1) are based on Inventory Report of the EU [1] and new EU member states [13] and available National Allocation Plans [2]. For the purposes of this study, emissions included in the EU emission trading scheme have been divided to following sub-groups: Stationary combustion (including e.g. combustion in energy, oil refineries, pulp and paper, metal and mineral industry) production of cement and lime (emissions from raw materials) and metal production (process emissions, e.g. use of reducing agents). The allocation of emissions to different sectors is done rather roughly. Process emissions from production of cement and lime reported to the UNFCCC (IPCC code 2A) are used to estimate process emissions from mineral industry, because other emissions are mainly due to combustion processes. Emissions reported as emissions of metal production (2C) are used to estimate process emissions from metal production.

IPCC category[1]	Emission source	gas	Emissions (Tg CO_2 eq)	uncertainty[2]
Sources included in EU emission trading scheme (EU-15)				
1A	Stationary combustion included in EU emission trading[3]	CO_2	1370	±3%
2A	Production of cement and lime	CO_2	110	±7%
2C	Metal industry	CO_2	20	± 6%
Sources included in EU emission trading scheme (New EU member states)				
1A	Stationary combustion included in EU emission trading[3]	CO_2	480	±7%
2A	Production of cement and lime	CO_2	20	±10%
2C	Metal industry	CO_2	4	±8%
Sources included in extended EU emission trading scheme in addition to EU emission trading (EU-15)				
1A	Stationary combustion (including the same sources as above)	CH_4	5	±50%
1A	Stationary combustion (including the same sources as above)	N_2O	14	-100 to +550%
Sources included in Kyoto emission trading scheme, in addition to extended EU emission trading scheme (EU-15)				
1A	Stationary combustion not included above	CO_2	930	±7%
1A	Stationary combustion not included above	CH_4	4	±50%

1A	Stationary combustion not included above	N_2O	10	-100 to +550%
1A3	Transportation	CO_2	840	±5%
1A3	Transportation	CH_4	3	±50%
1A3	Transportation	N_2O	30	-100 to +550%
1B	Fugitive emissions from fuels	CO_2, CH_4	70	±30%
2B	Chemical products	CO_2	10	±20%
2B	Chemical products (e.g. adipic acid and nitric acid production)	N_2O	40	±15%
2	HFC emissions	HFCs	50	±40%
2	PFC emissions	PFCs	5	±40%
2	SF6 emissions	SF_6	9	±30%
3	Solvent and other product use	CO_2, N_2O	8	±30%
4A	Enteric fermentation	CH_4	140	±40%
4B	Manure management	CH_4	70	±40%
4B	Manure management	N_2O	20	-70 to +150%
4C	Rice cultivation	CH_4	2	-80 to +200%
4D	Agricultural soils	N_2O	190	-100 to +1000%
6A	Solid waste disposal on land	CH_4	80	±45%
6B	Wastewater management	CH_4	70	±50
6B	Wastewater management	N_2O	7	-70 to +150%
6C	Waste incineration	CO_2	9	±20%
5	LULUCF (Kyoto Protocol)[4]	CO_2	-30	±90%

[1]Definitions of the categories are not exactly the same due to division between categories included and excluded from EU emission trading scheme
[2]Lower and upper bounds of 95% confidence interval expressed as percent relative to the mean value. Symmetrical uncertainties are assumed normally distributed and asymmetrical ones lognormally distributed except N_2O from agricultural soils, which is assumed gamma distributed due to high asymmetry.
[3]Emission estimates are based on the situation in summer 2004, and have to be considered preliminary due to unavailability of NAPs of some member states.
[4]Based on estimates of maximum annual potential for carbon sequestration of forests under the first commitment period 2008-2012 including ARD (afforestation, reforestation, deforestation) activities and forest menagement [14, p. 50] The IPCC Good Practice Guidance on Land Use, Land-Use Change and Forestry [12] was finalised in 2003. Parties of the UNFCCC will be using the methodologies in this guidance in preparing their national greenhouse gas inventories from the year 2005 onwards, and highly likely in Kyoto Protocol reporting (decision is expected at COP10 in December 2004). The guidance is expected to improve and make the reporting on the LULUCF sector more comprehensive. The estimates in the table should therefore be considered only as indicative. In addition, not all emissions/removals from the LULUCF sector are included in emission trading.

Table 1: Estimated emissions and corresponding uncertainties for different emission trading schemes used in the study as the basis for the comparisons.

National allocation plans are made by plant or by activity, and therefore it is not possible to differentiate between emissions from combustion and processes. Emissions deriving from use of raw materials in other industries (pulp and paper, glass, ceramic) is minor. Not all members of the EU-25 have provided an Inventory Report or National Allocation Plan. In these cases we estimated the share of emissions included in emission trading using average shares of other countries. Therefore the amount of tradable emissions used in this study has to be considered preliminary.

The uncertainty estimates presented in Table 1 are based on IPCC default uncertainties [8], estimates of member states of the EU [5,7,10,11,15], and in the case of EU emission trading scheme, the Guidelines for monitoring [3]. For the estimation of activity data uncertainty in new EU countries we have used the study of Suutari et al. [16], and for the LULUCF, estimates of the IPCC [12]. All uncertainties are addressed to EU-15 as a whole. If it is assumed that every country in EU-15 had the same relative uncertainty for a single emission category used here, then this approach would give an upper bound to the uncertainty.

We have excluded emission sources whose contribution to EU inventory in 2002 was <0.05%. These are typically emission sources reported by a single country only. These emission sources represent together around 0.1% of CO_2 equivalent emissions from the EU and therefore their effect on uncertainty can be assessed minor.

Uncertainties in different sectors were combined using Monte Carlo simulation. In Monte Carlo simulation, random numbers are taken from all input distributions thousands of times, and as a result, a probability distribution of total emissions is obtained.

4 Results

The results of the different emission trading schemes are presented in Table 2.

Emission trading scheme	Area	Gases	Emissions included[1] (Tg CO_2 eq)	uncertainty[2]
EU emission trading scheme	EU-15	CO_2	1500	±3%
EU emission trading scheme	EU-25	CO_2	2000	±3%
Extended EU emission trading scheme	EU-15	CO_2, CH_4, N_2O	1530	-4 to +7%
Kyoto Emission trading without LULUCF	EU-15	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6	4110	-6 to +21%
Kyoto Emission trading with LULUCF	EU-15	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6	4080[3]	-6 to +21%

[1]Totals may not exactly correspond with Table 2 due to rounding.
[2]Uncertainties are expressed as upper and lower bounds of the 95% confidence interval and presented as percent relative to the mean value
[3]Net emissions including LULUCF are smaller than excluding LULUCF, but in reality the amount of tradable permits increases when allowances related to both emissions are removals are traded.

Table 2: Amount of tradable emissions and related uncertainties in different emission trading schemes.

5 Discussion and Conclusions

The results of this study show that differences between uncertainties in different emission trading schemes can be significant. These results can be utilised when planning future emission trading schemes and potential verification procedures. Differences between uncertainties in emissions under different emission trading schemes (including EU emission trading scheme for EU-15 and EU-25, a hypothetical EU emission trading scheme extended to cover CH_4 and N_2O gases, and Kyoto emission trading scheme both with and without LULUCF) were estimated based on uncertainties in national greenhouse gas inventories. The estimated uncertainties in the emissions under the different schemes ranged from ±3% for the EU emission trading scheme to (-6 to +21%) for Kyoto emission trading scheme including LULUCF. Participation of the new EU countries in the emission trading of the EU-15 will not increase uncertainties in emissions under the scheme notably.

If CH_4 and N_2O in addition to CO_2 were included in EU emission trading scheme (sectors would be kept the same), the market volume of emission trading would not increase much, but the uncertainties would be increased significantly. The uncertainties could possibly be reduced with plant-specific data but this would increase the costs of monitoring and verification. On the other hand, the CH_4 and N_2O gases can be significant for specific processes and the costs for reducing these emissions are sometimes lower than those for reducing the CO_2 emissions. Careful consideration of the pros and cons for the whole scheme would be needed to assess the benefits of including these gases under the scheme. This hypothetical EU emission trading scheme is only one possibility to extend EU emission trading. Other choices include e.g. inclusion of CO_2 emissions from transportation to the current emission trading scheme.

Finally, uncertainty in emissions included in the emission trading under the Kyoto Protocol was estimated, both with and without LULUCF and was found to be from -6 to +21%. The inclusion of the other sectors (especially the Agriculture sector) and non-CO_2 gases introduces much additional uncertainty into the system. Inclusion of LULUCF sector does not increase these uncertainties notably, as the uncertainties in LULUCF sector are of the same order of magnitude as for the emissions in the Agriculture and Waste sectors. In addition, the estimated removals from LULUCF sector are relatively low during the first commitment period 2008-2012, and therefore the inclusion of this source did not affect the estimated uncertainties much. Not all categories included in the IPCC Good Practice Guidance for LULUCF are included in the estimates above, e.g. the carbon stock changes in the dead organic matter pools or N_2O emissions from forest soils are not considered. Inclusion of all sources may increase the uncertainties. Emissions or removals from land use change and forestry contain some poorly understood processes with large natural variability, and it is very difficult to make the difference between natural and human-induced fluxes. Therefore, the result from the inclusion of the LULUCF sector should be considered only as indicative.

In this study, we estimated the uncertainties in plants included in EU emission trading (2005-2007) smaller than for plants not included in emission trading. This is true for current inventories, where emissions in larger plants are often more accurately known than those in smaller plants due to more tight reporting requirements for large installations in national environmental regulations. In addition, in the current Guidelines for Monitoring [3], more accurate estimates of activity data are required for large plants than for smaller plants. Probably, if small-scale installations (<20 MW) will also be included in emission trading, they may obtain as tight emission estimation requirements as large plants, and in this case there will be not any difference between uncertainties.

In the case of emission trading covering all the gases, results are highly sensitive to the assumptions of uncertainty in N_2O emissions from combustion and agricultural soils. Sensitivity of uncertainty of inventories for uncertainty estimate for N_2O from agricultural soils is discussed, e.g., by Rypdal & Winiwarter [5]. In addition, under the Kyoto Protocol, only a particular share of emissions can be subjected to emission trading which is not taken into account in this study.

In this study, comparison between different emission trading schemes was made based on uncertainties in corresponding emission inventories. In emission trading, uncertainties arise from emission reductions of single actors (companies, countries etc) and the trading of emissions is dealt with emission allowances which are exactly defined. Therefore, in practice, the uncertainties are related to annual emission estimates of companies and to verification of the emissions. However, this approach gives a good picture of differences between different emission trading schemes.

In the future, emission trading may cover a wider range of countries than at the moment. Currently, uncertainties in emission estimates of developing countries are larger than those of industrial countries. But, if the same rules of accepted uncertainty in emission eligible for trading are applied for all the countries, participation of developing countries will not necessarily increase uncertainty. Uncertainty in emission inventories increases usually when the CO_2 fraction decreases. This fraction is typically lower for developing countries than for industrial countries. If maximum number of countries participate emission trading, the emission reductions will become most cost-efficient. But, if uncertainties in less developed countries remain large, real emission reduction benefits from emission trading may be difficult to assess.

Similar quality of data between vendors and purchasers of emissions is important. For example OECD [17] suggested that tradable emissions could be discounted according to uncertainty. In this scheme, emissions with larger uncertainty could have a smaller value in emission trading. Another option would be to divide emission trading to parts in which uncertainties are similar. For example, emission allowances originating from increasing the carbon stock of forests could be used in the purchasing country to decrease carbon stock of forests but not to increase fossil fuel combustion [17]. Another possibility would be to include some kind of limit for uncertainty in emissions included in emission trading.

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