



# Contribution of different sectors to developed countries' fulfillment of GHG emission reduction targets under the first commitment period of the Kyoto Protocol



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## ABSTRACT

Greenhouse gas (GHG) data submitted in April 2014 on land use, land use change and forestry (LULUCF), energy, industrial processes, solvents and other product use, agriculture, and waste for 37 developed countries was analyzed to estimate the relative contributions of different sectors to GHG emission reductions. This GHG data from the first commitment period of the Kyoto Protocol included 35 parties to Annex B of the Kyoto Protocol, the United States and Canada. Results show that the contribution of each sector was, in order: energy (36.9%), industrial processes (12.4%), agriculture (9.9%), LULUCF (7.7%), waste (3.4%), and solvents and other product use (0.1%). The average proportion of base year emissions reduced in each sector by countries in Annex B was, in order: energy (7.4%), agriculture (2.7%), LULUCF (1.9%), industrial processes (1.2%), waste (0.5%), and solvents and other product use (0.1%). Overall, the energy sector contributed the highest GHG emission reductions, while the agriculture and LULUCF sectors also made contributions. Most countries achieved limited absolute GHG reductions from their chosen LULUCF activities, but the relative contribution of GHG emission reductions from LULUCF was significant but small. This suggests that, unless there are substantial changes to accounting rules, future emission reductions will mainly result from mitigation actions targeting fossil fuel consumption, while the agriculture and LULUCF sectors will continue to play auxiliary roles.

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## 1. Introduction

The Kyoto Protocol (hereafter referred to as 'the Protocol'), adopted in 1997 under the United Nations Framework Convention on Climate Change (UNFCCC) negotiations, includes commitments ('Kyoto targets') by Annex B parties, which includes most developed countries, to achieve emission reductions against base year emission levels. These reductions were to be achieved by the end of the Kyoto commitment period in 2012, which began in 2008 (IPCC, 2000a,b, 2001, 2003; UNFCCC, 2005). Annex A of the Protocol lists five sectors/source categories, including energy,

industrial processes, agriculture, waste, and solvent and other product use, which are used to calculate the carbon dioxide (CO<sub>2</sub>) equivalence of anthropogenic emissions by sources and removals by sinks of greenhouse gases (GHG) for developed countries from 2008 to 2012. The Protocol allows these countries to use the net changes in GHG emissions by sources and removals by sinks resulting from direct human-induced land use, land use change and forestry (LULUCF) activities to fulfill emission reduction and limitation targets subject to specific accounting rules during the commitment period (UNFCCC, 2005; Hohne et al., 2007; Grassi et al., 2012). In this context, the comparability of efforts between different countries is one of the most important issues in ongoing discussions (den Elzen et al., 2010).

LULUCF activities can reduce GHG emissions and remove atmospheric GHGs by changing management practices in forests,

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cropland and grazing lands. Activities in this sector have been seen as the most cost effective way to stabilize global atmospheric CO<sub>2</sub> concentrations and slow down global warming (IPCC, 2014). Therefore, LULUCF has become a key focus of negotiations in relation to the Protocol. However, LULUCF accounting rules<sup>1</sup> are more complicated than accounting rules in the other five sectors, and there have been many disputes over the accounting rules for LULUCF.

Studies have assessed the advantages and disadvantages of the LULUCF accounting system from the perspective of the scope, content, and rules for accounting, using either case study methods or interpretation of accounting rules (Ellison et al., 2013; Benndorf et al., 2007; Monni et al., 2007; Schlamdinger et al., 2007; Blujdea et al., 2010; Zhang, 2011; Liu et al., 2011). Their conclusions mostly focused on whether or not the LULUCF accounting system could encourage parties to take more positive and effective measures to reduce GHG emissions by implementing LULUCF activities, and how the rules could impact the scale of the contribution of the LULUCF sector to parties' fulfillment of emission reduction targets. However, most studies have been based on country reported data for the first 2 or 3 years of the commitment period only.

The aim of this paper is to analyze the contribution of the five sectors listed in Annex A and LULUCF to developed countries' emission reductions during the first commitment period using complete data for the first commitment period. On this basis, we identify the relative contribution of each sector to emission reductions by developed countries.

<sup>1</sup> The main LULUCF accounting rules in the first commitment period include: Article 3.3 regulates afforestation, reforestation and deforestation (ARD) since 1990 as mandatory activities. During the first commitment period, ARD used gross-net accounting that considers carbon stock changes resulting from the difference between emissions and removals in the commitment period without considering the base year, so that a debit occurs when emissions are larger than removals on a unit of land, and a credit occurs if there are net removals within the commitment period. Under Article 3.4, a country may choose to account for anthropogenic GHG emission by sources and removal by sinks resulting from forest management, revegetation, and cropland management and grazing land management. Net-net accounting (i.e. emissions and removals compared to emissions and removals in the base year) was applied for the latter three voluntary activities, so that a credit applies when a net carbon sink can be quantified between the two periods, while for forest management gross-net accounting was applied. In addition, a credit cap was applied to forest management to limit the effects of natural factors. Accountable anthropogenic GHG emission by sources and removal by sinks resulting from cropland management, grazing land management and revegetation under Article 3.4 shall be equal to anthropogenic GHG emission by sources and removal by sinks in the commitment period less five times the anthropogenic GHG emission by sources and removal by sinks resulting from these eligible activities in the base year of that country. A country that incurs a net source of emission under the provisions of Article 3.3 may account for anthropogenic GHG emission by sources and removal by sinks in areas under forest management under Article 3.4, up to a level that is equal to the net source of emission under the provisions of Article 3.3, but not greater than 9.0 megatonnes of carbon times five, if the total anthropogenic GHG emission by sources and removal by sinks in the managed forest since 1990 is equal to, or larger than, the net source of emission incurred under Article 3.3. For the first commitment period, the total removal for each country by sinks under Article 3.4 and Joint Implementation projects shall not exceed 5 times the GHG source/sink limit of each country listed in Appendix 5 of Decision 16/CMP.1. Article 3.7 of the Protocol provides that, if in 1990 the LULUCF activity of a country was a net GHG emission source, the emission of GHGs produced by land use change (deforestation) in that year shall be included in the total emission of anthropogenic GHG in the base year, which affected 3 parties (Australia, Netherlands and Portugal) The Protocol also established 3 mechanisms that contribute to the fulfillment of emission reduction targets of Annex B parties, but these GHG emission reductions were very small, and are not considered in this paper.

## 2. Methods

### 2.1. Data source

The data used in this paper are from the GHG reports of 37 developed countries (excluding Monaco due to incomplete data) to the Protocol in the first commitment period (2008–2012). The data, including total GHG emissions in the base year for different countries (UNFCCC, 2010a,b)<sup>2</sup>; GHG emissions in the base year of every sector for different countries; and annual GHG emissions/removals from 2008 to 2012 (UNFCCC, 2013, 2012, 2011; UNFCCC GHG Data, 2013) verified by the expert review team (ERT) and published on the website of UNFCCC.<sup>3</sup>

### 2.2. Calculation method

Firstly, we calculated the average annual change in GHG emissions and final credits in fulfillment of the targets of different eligible LULUCF activities of different countries according to the accounting rules for the first commitment period. Then, we compared the emission reductions and the relative contribution of GHG emission reductions in these 6 sectors between different developed countries.<sup>4</sup> The calculation formulas used were as follows.

$$\Delta E_{1,ij} = E_{1,ij} - E_{B,ij} (i = 1, \dots, 37, j = 1, \dots, 6) \quad (1)$$

In Formula (1),  $\Delta E_{1,ij}$  represents the average annual GHG emission reduction/increase in sector  $j$  for country  $i$  in the first commitment period, measured in Gg CO<sub>2</sub> equivalent (CO<sub>2</sub>-eq).  $E_{1,ij}$  represents average annual GHG emissions in sector  $j$  for country  $i$  in the first commitment period (Gg CO<sub>2</sub>-eq).  $E_{B,ij}$  represents average annual GHG emissions in the base year in sector  $j$  for country  $i$  in the first commitment period (Gg CO<sub>2</sub>-eq).  $i$  refers to each of the 37 countries to the Protocol analyzed in this paper and  $j$  refers to the 6 sectors defined in the Protocol, which are energy, industrial processes, solvents and other product use, agriculture, waste and LULUCF. A negative value indicates GHG emission reductions, while a positive value indicates a GHG emission increase.

$$C_j = \frac{\sum_{i=1}^{37} \Delta E_{1,ij}}{\sum_{i=1}^{37} \sum_{j=1}^6 \Delta E_{1,ij}} \times 100\% (i = 1, \dots, 37, j = 1, \dots, 6) \quad (2)$$

In Formula (2),  $C_j$  represents the relative emission reduction contribution in sector  $j$  for all countries in the commitment period,

<sup>2</sup> GHG emissions in the base year refers to total GHG emissions (including non-CO<sub>2</sub> gases) in the base year. The Protocol allowed some flexibility in choosing the base year. According to Article 3.5, the Protocol allowed some parties, which were undergoing the process of transition to a market economy, to choose a base year other than 1990 as their base year. Four parties adopted a base year other than 1990: Bulgaria (1998), Hungary (the mean value from 1985–1987), Poland (1988), and Romania (1989).

<sup>3</sup> UNFCCC regulated that the Annex B parties had to report their annual GHG emissions/removals for the first commitment period to the secretary in their national communications. The ERT reviews these data, and calculates annual GHG emission reductions in 6 sectors for each country, and if any problems were identified the ERT requests the country to explain or address through revisions. Although the U.S. and Canada did not join the first commitment period of the Protocol, they account for a large percentage of global GHG emissions in different sectors. Thus, in order to arrive at a more comprehensive analysis, we include data from reports by these two countries' to the UNFCCC on their GHG emissions in 1990, and from 2008 to 2012.

<sup>4</sup> Relative contribution refers to the percentage change in net GHG emissions/removals compared to the base year GHG emissions for each country or sector. It can take two forms: relative emission reduction contribution (i.e. Decrease in GHG emissions compared with GHG emissions in the base year) and relative emission increase contribution (i.e. GHG emission increase compared with GHG emissions in the base year).

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