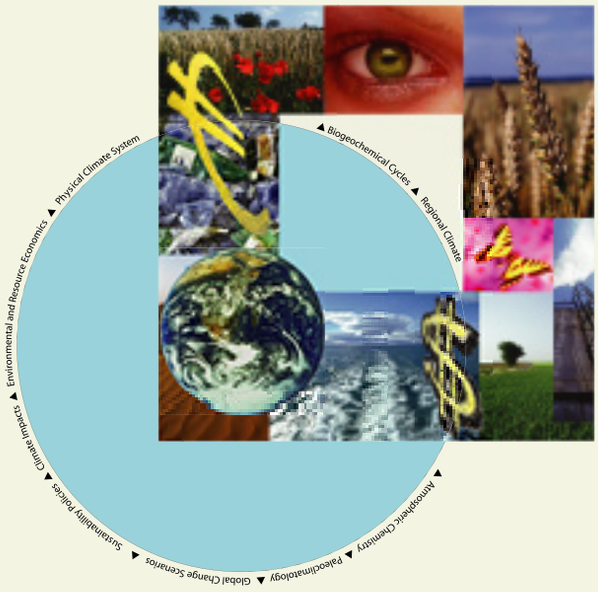
International Max Planck Research School on
EARTH SYSTEM MODELLING

"Carbon sequestration options in the international climate regime"

Martina Jung

PhD Thesis prepared within the
International Max Planck Research School on
Earth System Modelling



1. Introduction

1.1. Climate change – the scientific basis

Since the end of the 20th century, the relation of humans to the climate has changed considerably. While climate was long perceived as something given, nowadays the perception of climate is focused on issues related to the human influence on the climate (Cubasch and Kasang 2000).

The greenhouse effect was described as early as 1827 by the French scientist Fourier. He found that trace gases (e.g. water vapor, carbon dioxide, methane, nitrous oxide) let the sunlight pass freely to the Earth´s surface, but absorb and trap the sunlight which is reflected back towards space as infrared radiation (heat). Therefore, these trace gases are also called greenhouse gases. At Fourier´s time, the greenhouse effect was discussed mainly with view on its role for maintaining a life-sustaining environment on the earth. At the end of the nineteenth century, however, the Swedish scientist Arrhenius was the first to point out that the growing volume of carbon dioxide emissions due to the Industrial Revolution was changing the concentration of greenhouse gases in the atmosphere and was leading to an increase in the Earth´s surface temperature (Grubb 1999). It took until 1957 - the International Geophysical Year – for the international research community to address this question more seriously. The First World Climate Conference in 1979 was one of the first major international meetings on the issue of climate change (UNFCCC 2003a). A result of this conference was the increased support of research on the scientific basis of climate change which finally led to the establishment of the Intergovernmental Panel on Climate Change (IPCC) in 1988. The findings of the First and Second Assessment Report of the IPCC published in 1990 and 1996 concluded that the concentration of greenhouse gases in the atmosphere was rising due to human activities and that this would lead to rising temperatures and a human-induced climate change[1] (Grubb 1999). The Third Assessment Report of the IPCC published in 2001 reinforced the conclusions of the earlier reports, stating that the global average surface temperature has increased over the 20th century by about 0.6° C, and, that there is evidence that most of the warming observed over the last 50 years is caused by anthropogenic activities. (IPCC 2001)

1.2. The international climate policy regime

Against the background of the results of the First Assessment Report of the IPCC, the Second World Climate Conference held in 1990 called for the creation of a global treaty

[1] A certain degree of climate change due to natural reasons has existed since the formation of the earth.

and initiated negotiations on a convention on climate change by establishing the Intergovernmental Negotiation Committee (INC). In 1992, the INC adopted the United Nations Framework Convention on Climate Change (UNFCCC) which was subsequently opened for signature at the United Nations Conference on Environment and Development in the same year. The UNFCCC entered into force on 21 March 1994 (UNFCCC 2003a). Article 2 addresses the objective of the convention (UNFCCC 1992):

> *"The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."*

Ever since 1995, Parties have met annually at the Conferences of the Parties (COP). The COP is the ultimate decision-making body of the UNFCCC responsible for the implementation of the Convention as well as its further development. However, soon Parties noticed that the relatively general provisions of the UNFCCC would not be enough to achieve the goal of stabilizing the greenhouse gas concentration in the atmosphere. Therefore, at the first conference of the Parties (COP 1) in Berlin, the negotiation of more detailed and binding commitments were initiated (Oberthür and Ott 1999). A framework sketching basic rules and including legally binding commitments for a set of industrialized countries and countries with economies in transition (Annex B countries[2]) - now known as the Kyoto Protocol - was adopted at COP 3 in Kyoto, Japan in December 1997. In the Kyoto Protocol, so called Annex B countries have agreed to reduce their overall greenhouse gas[3] emissions by at least 5% below 1990 levels in the first commitment period (2008-2012). However, implementation details are not addressed by the Protocol. In 1998, COP 4 decided the Buenos Aires Plan of Action which laid out a work program for the negotiation on open implementation issues. After a deadlock at COP 6 in La Hague, the Buenos Aires Plan of Action could be finalized in 2001 at COP 7 in Marrakech. The resulting decisions - also labeled the Marrakech Accords - were a milestone in the negotiations on the rules and

[2] The terms Annex B and Annex I country are often used interchangeably. This is, however, not exact. Annex I refers to the UNFCCC. Parties with emission reduction targets are listed in Annex B of the Kyoto Protocol, therefore labelled Annex B countries. Only two countries (Turkey and Belarus) are Annex I countries without being listed in Annex B of the Kyoto Protocol.

[3] The greenhouse gases included in the Kyoto Protocol are carbon dioxide (CO_2), methane, nitrous oxide, HFCs, PFCs as well as SF_6.

modalities for the Kyoto Protocol. With the Russian ratification of the Kyoto Protocol, it entered into force on 16 February 2005.

The three flexible mechanisms of the Kyoto Protocol – Joint Implementation (JI), the Clean Development Mechanism (CDM) and emissions trading are supposed to lead to an efficient compliance with the Kyoto commitments. The first two allow Parties with emission targets to conduct emission reduction or sink enhancement projects in other countries and use the resulting emission credits for compliance with their commitments. Emission trading creates an international market on which emission allowances and credits can be traded. Further details on these mechanisms, especially the CDM, will be dealt with in later chapters of this study.

1.3. Carbon sequestration as a climate mitigation option

Mitigation options for limiting the increase of the greenhouse gas concentration in the atmosphere comprise either emission reduction (avoiding emissions at the source) or removal and storage of greenhouse gases. Article 3.1 - in stating the goal of the Kyoto Protocol - uses the expression 'reducing the overall emissions'. However, national emission inventories include emission reduction as well as removal of greenhouse gases through certain sequestration activities.

Carbon sequestration activities have in common that they do not avoid the production of CO_2, but lock carbon (dioxide) away from the atmosphere for a certain period of time. This long-term storage of carbon can take place either in the terrestrial biosphere, underground or in the oceans. Carbon sequestration in the terrestrial biosphere refers to activities leading to an increase in carbon stocks in the terrestrial biomass as for example through afforestation. Such carbon sequestration activities have entered the Kyoto Protocol as the 'Land use, Land-use change and Forestry (LULUCF)' issue. Often LULUCF has simply been referred to as the 'sinks issue'[4]. As the rules and modalities for accounting for LULUCF significantly affected the already agreed Kyoto targets, negotiations on this issue were one of the most contentious issues in the climate negotiations. A sequestration option, which has only recently entered the climate policy arena, is the one of carbon dioxide capture and storage (CCS). This refers to activities which capture carbon dioxide at large point sources like power plants and store it subsequently in reservoirs.

The literature on LULUCF and CCS has so far evolved rather independently from each other. The literature on carbon sequestration in the terrestrial biosphere is extensive,

[4] It has to be mentioned, though, that this term is not really exact since LULUCF comprises human-induced emissions as well as removals (sinks) of greenhouse gases in the land-use sector.

covering natural as well as social sciences. The economic part has mainly focused on costs of different options as well as policy aspects regarding the temporary nature of carbon sequestration in biomass. This body of literature has, to a great extent, developed parallel to the discussion on the integration of LULUCF into the international climate regime. Most of the literature on carbon capture and storage deals with technical aspects of capturing, transporting and storing carbon, and costs associated with this. While the early literature on carbon dioxide capture and storage was mainly based on the idea of ocean sequestration, it is now focusing on storage of CO_2 in geological reservoirs. Some recent studies address different aspects of seepages of CO_2 from reservoirs. However, only very few studies examine issues related to the integration of carbon dioxide capture and storage into the international climate regime.

The present study deals with some of the policy-related issues of carbon sequestration which so far have not been considered sufficiently in the literature.

These issues are:

1. The negotiation process on the integration of LULUCF into the Kyoto Protocol, including the respective negotiating positions of Parties to the UNFCCC as well as their main driving forces.
2. Market effects of the inclusion of forestry projects in the CDM, including consequences for the price of emission permits in the international market and the redistribution of benefits and losses between countries and regions.
3. Factors determining CDM host country attractiveness, including implications for the geographical distribution of CDM projects.
4. Inventorying and accounting of CCS under the Kyoto Protocol considering different cross-border cases and non-permanence of storage, including economic implications of possible releases of CO_2 from storage reservoirs.

In the following section, the structure of the thesis is described briefly.

1.4. Structure

Chapter 2 includes an analysis of the negotiation process on LULUCF in the context of the UNFCCC. Contrary to most of the studies on the negotiation process, it is not restricted to a qualitative analysis, but applies quantitative methods for investigating negotiating positions of Parties. Factors influencing the positions of countries are identified using a multinomial regression model. Furthermore, a zero-inflated Poisson model is applied to analyze the participation of countries in the submission process on LULUCF.

The economic consequences of decisions taken in the negotiations on LULUCF are examined in Chapter 3. Its focus lies on forestry options in the CDM. As most of the economic models of the international market for emission permits are neglecting carbon sequestration options in the climate regime, marginal sequestration cost curves reflecting different LULUCF policy scenarios are developed and integrated into a partial equilibrium model of the international market for emission permits. The results shed light on the effect of different policy scenarios on the market price of emission permits as well as the distribution of benefits and losses between countries and regions.

While marginal cost curves, as used for the analysis in Chapter 3, are purely based on the potentials and costs of mitigation options, other factors are likely to influence investment into CDM projects as well. Therefore, Chapter 4 investigates the attractiveness of host countries for CDM investments taking into account that not only the mitigation potential, but also the institutional CDM capacity and the general investment climate are relevant factors. A cluster analysis is conducted to classify 114 CDM host countries regarding their attractiveness for CDM investments. The results can give an indication of what a future geographical distribution of CDM projects might look like.

While a whole set of rules and modalities has been elaborated for integrating LULUCF into the climate regime, the debate on whether and how to account for CCS under the Kyoto Protocol is rather new. Therefore, Chapter 5 deals with the implementation of CCS into the international climate regime. It is one of the first studies investigating implications for inventorying and accounting of CCS, considering the possibility of cross-border cases and non-permanence of storage. Furthermore, economic implications of the non-permanence of storage are examined under varying assumptions on seepage and discount rates as well as crediting periods.

Chapter 6 summarizes the main results of the previous chapters, concludes and highlights some policy implications.