On the Design of the International Climate Policy Regime

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I will be failing if I do not thank my family - and my parents in particular - for making this thesis possible. It is the result of their continuous support and their understanding for whatever I plan to do - for already thirty years now.

Abstract

As a consequence of the increasing awareness of anthropogenic climate change and its impacts, the international community agreed to take action to mitigate greenhouse gas emissions. This action is organised through the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol. Though a number of implementation rules as for example the Marrakech Accords exist, there are still a lot of open questions that need to be answered. Against this background this dissertation thesis focuses on selected issues which all involve the concept of emissions trading.

Regarding projects under the so-called Clean Development Mechanism (CDM) it is analysed how the required baseline should be set and how the investment additionality concept must be applied in order not to provide undesirable incentives for renewable energy project developers to invest at unattractive sites. Such an investment behaviour would result in an inefficient climate policy regime from the macro-economic perspective. It is proposed to calculate emission reductions on the basis of physical electricity grids, regardless of their geographical extension, and not on the basis of any national emission data. Furthermore, a fuzzy investment additionality threshold is introduced which can weaken the undesirable incentives mentioned above.

These CDM-projects can be undertaken in developing countries, which, unlike industrialised countries, do not have a binding emission target. However, in order to meet the long-term target of a stabilisation of the atmospheric greenhouse gas concentration as defined in Art. 2 of the UNFCCC, sooner or later all countries must accept such a target. This is why a global burden sharing rule regarding the allocation of greenhouse gas emission (GHG) entitlements is proposed that combines the two justice principles *responsibility* and *equity of rights*. The new approach also allows for flexibility regarding the timing of accepting an absolute emission target. Such flexibility may help to increase the acceptance of a global burden sharing scheme by Parties which are currently hesitant with respect to the

ratification of a global climate agreement. As burden sharing is not only an issue between developing and industrialised countries, different rules and their implications are studied for the member states of the enlarged European Union, too. It turns out that, with regard to the four different options studied, much is at stake single member, especially for Eastern European countries. This may complicate the negotiations on the burden sharing after 2012 in Brussels. As GHG emissions from international maritime transportation are currently also uncapped, options for limiting emissions from this sector are also studied. A "wet-CDM" is proposed as an initial step to cost-efficiently curb these emissions.

Finally, the implications of different methods of allocating emission entitlements free of charge in multi-period emissions trading schemes are analysed. The electricity sector, which is a major source of GHG emissions, is studied as an example. It turns out that the implications strongly depend on the fuel used and the price of emission allowances on the market.

The results of this study are of interest for different stakeholders involved in climate policy such as policy makers, environmental NGOs and industry which is often direct subject of environmental legislation.

Contents

List of Abbreviations

AA	Assigned Amount
AAU	Assigned Amount Unit
AGBM	Ad Hoc Group of the Berlin Mandate
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CGE	Computable General Equilibrium
CoP	Conference of Parties
EEC	Equal Emissions per Capita
EECT	Equal Emissions per Capita over Time
EPC	Emissions per Capita
EU	European Union
FCCC	Framework Convention on Climate Change
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GNI	Gross National Income
GWP	Global Warming Potential
IA	Investment Additionality
IMO	International Maritime Organisation
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
KRK	Klimarahmenkonvention
LULUCF	Land-Use Land-Use-Change Forestry
MEPC	Marine Environment Protection Committee
MS	Member State
NGO	Non Governmental Organisation
ODA	Official Development Aid
RE	Renewable Energies
UK	United Kingdom
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
US	United States

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Chapter 1

Climate Change and the International Climate Policy Regime

Sven Bode

Contents

1. Introduction

1.1 Motivation

The subject "climate change" has become more and more important in recent years in both natural and social science, as well as in policy. The term itself, however, is somewhat misleading. Climate has been changing since the formation of the Earth's atmosphere and will continue to do so in future (Berner and Streif 2000, Glaser 2001). However, for the first time in the Earth's history, human activities influence global climate. Emissions of greenhouse gases (GHG) through for example burning of fossil fuels and deforestation enhance the natural greenhouse effect (Met Office 2003, IPCC 2001a). Thus, the growth in global energy use and in industrial production has to a multiple increase in GHG emissions during the 20th century.

Climate change itself can be measured by a number of different parameters, but global mean near surface air temperature is generally considered as a good proxy (WGBU 2003). Climate change or more specifically an increase of global mean near surface air temperature is likely to lead to an overall sea level rise and to more and more extreme weather events like storms, floods and droughts. At the same time snow and ice cover decrease continuously. The concrete effects are likely to differ from region to region (IPCC 2001b).

The changing weather patterns result in adverse impacts on the majority of natural and human systems: Due to altering precipitation, water resources may become scarce in some regions while floods occur in others. Agriculture and food security is affected by changing precipitation as well as by draughts and higher wind speed. Again, effects may differ locally. Sea level rise may threaten freshwater resources and infrastructure in vulnerable areas. Impacts on human health may be positive in some cases, however, in the most part they would be negative (IPCC 2001b). It goes without saying that, apart from the direct consequences on (human) life, there are economic consequences too. Costs due to catastrophic weather events, for example, have increased rapidly over the last decades: "Yearly economic losses from large events increased 10.3-fold from US$4 billion yr^{-1} in the 1950s to US$30 billion yr^{-1} in the 1990s." (IPCC 2001b, p. 43). Recently, the risk of abrupt climate change, like the breakdown of the North-Atlantic thermohaline circulation and the possible corresponding impacts even entered the US national security policy due to a report by the Department of Defence (Stipp 2004).

Climate change as such slowly entered the international political agenda in 1970 when the possibility of a 'catastrophic warming effect' was mentioned in the environment report by the Secretary General of the UN. As a consequence of some alarming studies, the first World Climate Conference was held in 1979. After several conferences, the Intergovernmental Panel on Climate Change (IPCC) was established in 1988 in order to provide authoritative assessment to governments of states of current knowledge concerning climate change. The IPCC produced its first report in 1990, which concluded inter alia that GHG emissions are rising due to human activities and that this rise would cause climate change with impacts as mentioned above. Against this background the negotiations on global agreement on a climate change began in 1991 (Grubb 1999, pp. 3-6). The resulting United Nations Convention on Climate Change (UNFCCC) was adopted in 1992 at the Earth Summit in Rio. The ultimate objective of the Convention is defined in Art. 2 (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.*

Already by December 1993 had the Convention been ratified by 50 states, the required number to enter into force. As of February 26, 2004, it has been ratified by 188 states.

A *Conference of Parties*, the supreme body of the Convention, was established which “shall make (…) the decisions necessary to promote the effective implementation of the Convention.” (Art. 7). At its third session in Kyoto in 1997, the Conference of Parties adopted the so-called Kyoto Protocol which inter alia specifies several points of the Convention.

An important aspect of the Kyoto-Protocol is the determination of concrete absolute emission targets for the so-called Annex-B countries.[1] This was necessary as the original target defined in Art. 4.2[2] of the Convention was found to be already inadequate at the first Conference of Parties in 1995. Another important aspect was the introduction of the so-called flexible mechanisms which allow the Annex-B countries to meet their obligations by both domestic emission reductions and by the purchase of emission rights on the market. Such rights are offered for sale by those Parties which, due to low abatement costs, over comply with their targets. Another option to create emission rights is the implementation of emission reduction projects in countries which are not listed in Annex-B. Since then, GHG emissions trading slowly has become a cornerstone of national climate policy in many states.

Though the Protocol already contains many articles specifying the international climate policy regime and though there are many implementation rules, as for example the Marrakech Accords decided in 2001, many issues are not settled yet. The present study deals with some of these open questions which mostly focus on limiting GHG emissions into the atmosphere and thus refer to the ultimate objective of the Convention. The study focuses, among other things, on the following five aspects:

1. How must the rules for the determination of emission reductions by renewable energies (RE) in developing countries be set in order to avoid

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1 Annex-B comprises 38 industrialised countries and countries in transition. The targets must be fulfilled during the first commitment period from 2008 to 2012.

2 According to Art. 4.2 of the Convention the target for developed country Parties was to “return individually or jointly to their 1990 levels.”

the crediting of non-additional emissions reductions and in order to avoid adverse incentives regarding the cost efficiency of the international climate policy regime?

2. How can the burden of limiting GHG emissions be shared among states in such a way that the two justice principles *responsibility* (for climate change) and *equity of rights* are combined, while at the same time offering flexibility regarding the time of fulfilling the resulting obligation for each Party?
3. How can the European Union, the leader in international climate policy, continue its burden sharing after 2012 and what are the consequences of different approaches regarding the costs and the negotiation process among member states?
4. How can emissions from international maritime transport, which are currently not part of any Party's GHG emission inventory, be addressed by and integrated into the international climate regime?
5. What are the implications for the participants of different approaches to allocate GHG emission entitlements in multi-period emissions trading?

Apart from the pure academic gain of knowledge, the aspects mentioned above are of relevance for a number of stakeholders involved in climate policy. On the one hand policy makers who are involved in both international negotiations and national legislation are concerned. They may find new answers to open questions in this study. On the other hand emitters who are generally subject to environmental legislation on the national level may get an idea on how some of the open questions may be addressed. Based on this, they may (re)define their lobbying strategy.

1.2 Place in Literature

The body of literature on climate policy is growing rapidly. With regard to the existing international climate policy regime two major lines of literature can be distinguished. The one accepts the Kyoto-Protocol as the basis for the further development of the international regime and the other one opposes the Protocol. The present study is explicitly part of the former group. With regard to the second line, it would be out of the scope of this introduction to review the relevant literature. An overview on 13 alternatives is provided by Aldy et al. (2003). More specific publications are referred to in Chapter 3.

Within the economic "pro Kyoto" literature, two general major methodological approaches must be mentioned in the context of this study. The first is based on computable general equilibrium models. These models sometimes form the economic component of the so-called integrated assessment models which also include physical characteristics as for example the atmospheric composition (Springer 2003, p. 529). Within the CGE models, mitigation costs are generally calculated from a macro-economic perspective, i.e. in terms of losses in income or GDP (Algas 1996). They offer useful insights in implications of different policy approaches on the macro-economic level, as for example the inclusion of certain Parties into an international GHG emissions trading scheme. Springer (2003) provides an overview on different kinds of models and the respective assumptions made during their applications. Though Ellermann et al. (1998) who apply the MIT-EPPA model conclude that "…any emissions trading, no matter how constrained or imperfect it is, is better than none at all", one should not refrain from trying to design the scheme as perfect as possible.

However, the CGE models have been criticised for different reasons of which the most important may be the assumption of perfect markets which are assumed to be in equilibrium prior to and after policy changes (Springer 2003, p. 530).

The second line of economic literature uses partial models, which are applicable for more detailed analyses of specific research issues. Partial models may be applied on a sector level, as for example the energy sector, on a sub-sector level, as for example the electricity sector or even on a single investor's level. The present study uses such partial models in order to answer the questions raised above. Different levels, as mentioned above, are investigated depending on what was judged to be the most appropriate in the context of the concrete question. As the questions addressed in this study are very specific, it would be of no use to review the relevant literature at this point. This is rather done in each of the following chapters.

1.3 Structure

The present chapter provides an introduction into the study and the scientific basis of climate change. Chapter 2 to 6 take up the 5 questions raised above. It proposed to read these chapters in order. However, due to the topic-specific introduction at the beginning of each chapter, each can also be read on its own.

Chapter 7 summarises the results and discusses the limitations of the study as well as aspects for future research. Additional data used during the analyses in Chapter 3 and 4 is provided in Chapter 8.

The second section of this chapter provides a short introduction into the science of climate change. This is to help non-climatologists to better understand the reasons why anthropogenic climate change is a global challenge and why climate policy needs to be approached by the international community as a whole.

2. The Basis of Climate Change

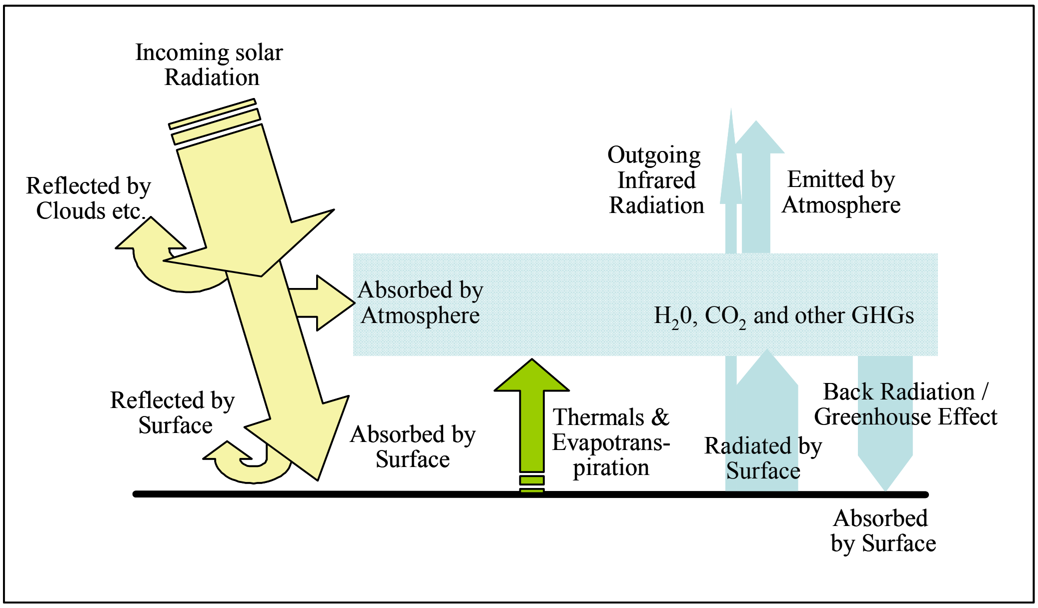
The greenhouse effect itself has been known since 1827 when French scientist Fourier suggested that the earth's atmosphere warms the surface by letting through high-energy solar radiation but trapping part of the longer-wave heat radiation being reflected from the surface. Among several responsible gases, carbon dioxide and water vapour are of crucial importance (Grubb 1999, p. 3).[3] This is still accepted as a major aspect of the greenhouse effect which is depicted in Figure 1.1. It goes without saying that the knowledge on the atmosphere's composition and the role of its components has improved much since these days. For example, the role of indirect GHG is better understood (IPCC 2001a, p. 241) and aerosols which generally have negative radiative forcing, i.e. a cooling effect, have been integrated into climate models (IPCC 2001a, p. 48-49).

As can be seen on the right hand side in Figure 1.1, some of the infra-red radiation is absorbed and re-emitted by greenhouse gases. As a consequence, the surface loses less heat than it would without greenhouse gases. Any changes in the radiation received from the sun or lost to space will affect the climate (IPCC 1992, p. 7). Thus, to a certain degree GHGs in the atmosphere are a necessary condition for life to be possible on earth. However, rapid excessive release of GHGs[4] alters the climate in such a way that adequate adaptation may not be possible.

3 At the end of the same century, Swedish scientist Arrhenius was the first to propose that the growing volume of carbon dioxide from factories would change the atmosphere's composition and thus cause the surface temperature to rise (Grubb 1999, pp. 3-4).

4 The atmospheric carbon dioxide concentrations, for example, have increased by more than 30 % since pre-industrial times and continue to rise at an unprecedented rate of an average of 0.4% per year (IPCC 2001, pp. 38-39).

Figure 1.1
Schematic depiction of the greenhouse effect



Based on IPCC 2001a, p. 90 and Schotterer et al. 1990, p. 48.

Greenhouse gases are generally considered as globally mixed throughout the atmosphere, although some short living gases have heterogeneous local concentrations (IPCC 2001a, p. 38). Thus, it is unimportant where GHG are emitted or, in the context of mitigation, where they are *not* emitted. From an economic perspective, any reduction should thus be undertaken where it is cheapest.

On the other hand, the even distribution of GHGs throughout the atmosphere involves the problem of incentive compatibility. Each state has an incentive to sit and wait for the others to start to reduce emissions. These free-riders would benefit from mitigated climate change while only those states reducing emissions would bear the costs from such actions. Consequently, an international agreement on each state's contribution seems necessary if real cuts in emissions, as called for by climatologists, are to be realised. Flexible mechanisms as agreed upon in the Kyoto-Protocol may than help to meet these reductions targets cost-efficiently as, at least according to theory, emissions are reduced where it is cheapest.

Another concept which is worthwhile to be mentioned here, is the so-called *Global Warming Potential* (GWP). So far, the term greenhouse gases has been used in plural. Indeed, there are different greenhouse gases which have different life times, i.e. they remain for different times in the atmosphere until they decay or until they are absorbed.[5] As a consequence, the emission of the same quantity of different gases has a different effect on global warming. For comparison of the overall effect of each gas, it is put into relation to the effect the same quantity of carbon dioxide would have over a period of 100 years.[6] Table 1.1 provides an overview on certain characteristics of the basket of the six GHGs agreed upon in the Kyoto-Protocol. As can be seen some GHG have very long lifetimes which implies that any emission of these gases "…is a quasi-irreversible commitment to sustained radiative forcing over decades, centuries, or millennia before natural processes can remove the quantity." (IPCC 2001a, p. 38).

Table 1.1
Lifetime and global warming potential of different GHGs[*)]

Gas	Lifetime (years)	Global Warming Potential as agreed upon politically
Carbon dioxide	variable	1
Methane	12	21
Nitrous oxide	114	310
HFCs	1.5 – 264	140 - 11,700
PFCs	2,600 – 50,000	6,500 – 9,200
SF_6	3,200	23,900

Source: IPCC 1996, p. 22.

*) Note that scientists have revised GWPs and that new greenhouse gases have been found (compare IPCC 2001a, pp. 388-390 and IPCC 1996, p. 22). However, these facts have not entered the political agenda yet.

5 Furthermore, the gases differ regarding their radiative forcing. However, in the interest of brevity this aspect is not discussed any further at this point. For more information see IPCC (2001a, pp. 349-416).

6 Both the reference gas carbon dioxide and the reference period of 100 years have been agreed upon politically during the negotiations of the Kyoto Protocol. There is no scientific justification for this choice. Other options exist (see for example IPCC 2001a, pp. 388–390).

With the help of the GWPs, greenhouse gas emissions and their reductions become comparable. This is a prerequisite for a uniform market of emissions entitlements to be able to develop. This unit is generally referred to as one tonne of carbon dioxide equivalent or $CO_{2\text{-}eq}$.

Chapter 2

Avoiding Perverse Effects of Baseline and Investment Additionality Determination in the Case of Renewable Energy Projects

Sven Bode, Axel Michaelowa

Contents

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Abstract

Within the international climate negotiations, there is a lot of discussion about the methodologies for quantifying the emission reductions of greenhouse gas reduction projects, also known as the baseline discussion, and about granting emission reduction credits exclusively to projects that are additional, referred to as the investment additionality concept. So far this discussion has been fairly general and has not systematically analysed the impacts on investor decisions. We analyse these impacts for the case of renewable energies and show that the approaches under discussion can all give negative incentives to invest at unfavourable sites. Thus, higher CO_2 abatement costs compared to a scenario without any crediting system may be realised what in turn results in an inefficient climate policy. To overcome this problem we introduce a new investment additionality concept and propose to have only one emission reduction factor for each electricity grid.

1. Introduction

Among the variety of possibilities to reduce greenhouse gas (GHG) emissions into the atmosphere, the use of renewable energies (RE)[7] is generally considered as a promising option and many studies have been undertaken to assess abatement costs and reduction potential of CO_2 (FME 2000, IEA Greenhouse Gas R&D Programme 2000). These studies only focus on the macro-economic level. However, the quantification of emission reductions achieved by a single project becomes more and more important as additional revenues from the sale of emission reduction credits become more and more relevant in the individual investor's decision making process. This is why micro-economic aspects must also be analysed. Project based calculation which is strongly dependent on the criteria used, is necessary for different reasons:

- According to Article 6 and 12 of the Kyoto Protocol, it is possible for Annex B countries to invest in Joint Implementation (JI) and Clean Development Mechanism (CDM) projects in order to create emission reductions that may help to reduce costs for achieving compliance with the emission targets (UNFCCC 1997a).

- Interest in the acquisition of emission reductions for other reasons: for example voluntary emission targets, as for example companies organised in the partnership for climate action, or in order to meet legal national requirements (Climate Trust 2001).

In order to quantify project based emission reductions it is necessary to determine a business as usual scenario in order to be able to answer the following question: "What would have happened in the absence of the project?" This issue is also referred to as baseline setting. Apart from the question how much emissions are reduced by a project, one can ask if these "reductions in emissions are additional

7 In the following the term renewable energies refers to zero GHG emission technologies as for example wind, solar or wave power, i.e. technologies where the yield is dependent on the site of installation. Consequently, biomass is not considered in this context.

to any that would occur in the absence of the certified project activity" (Art. 12.5 of the Kyoto Protocol). This issue is referred to as investment additionality (IA) and aims at ensuring environmental integrity when using flexible mechanisms as part of an efficient climate policy.

In the following sections we describe these two aspects in greater detail before discussing the relationship between the individual investor's decision making and macro-economic CO_2 abatement costs. We show theoretically how the different approaches for baseline setting and investment additionality influence the aforementioned relationship between micro- and macro-economic aspects. We then continue by examining the theoretical findings in a simulation of realistic projects and discuss our findings. Finally, we come up with new proposals for setting baselines for renewable energies (RE) and investment additionality.

2. CO_2 Emission Reductions

When discussing about quantification of CO_2 emission reductions one has to distinguish between the reduced quantity calculated by whatever baseline methodology used, and the real empirical reductions. These two figures do not need to be equal. In fact, they are even likely to be unequal since the exact quantification is desirable but transaction costs may be too high to justify precise measurement.

2.1 Baseline Determination

To answer the question "What quantity of GHGs was abated by the project?" requires the following (Baumert 1999):

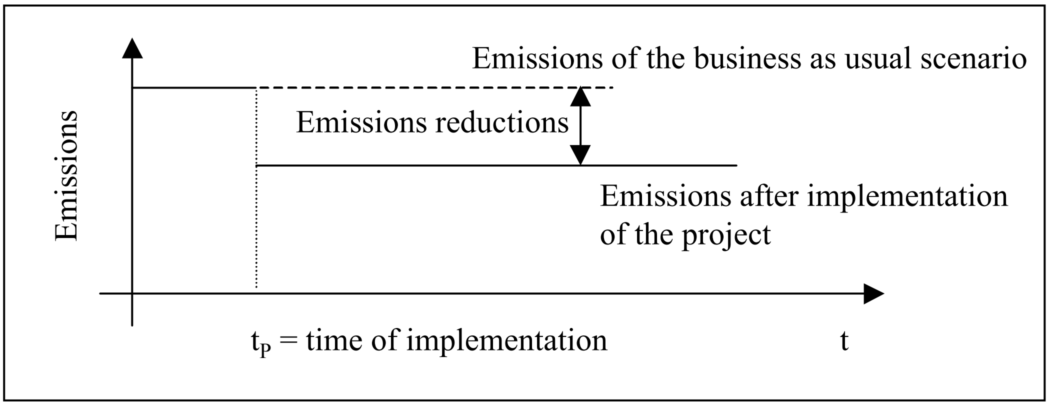
- A project baseline, or reference scenario, that estimates what would have happened in the absence of the project

- Methods for quantifying a project's GHG emissions, which are assumed to be zero for RE in this paper

- A quantitative comparison of actual emissions to baseline projections.

The steps are visualised in Figure 2.1.

Figure 2.1
Schematic graph of quantification of emission reductions



The schematic graph in Figure 2.1 may be deceptive since the determination of the reference scenario is anything but trivial. First of all there are several possible approaches as shown in Figure 2.2. Furthermore, even for the standardised approaches, there are several parameters that must be determined before emissions reductions can be quantified. For example:

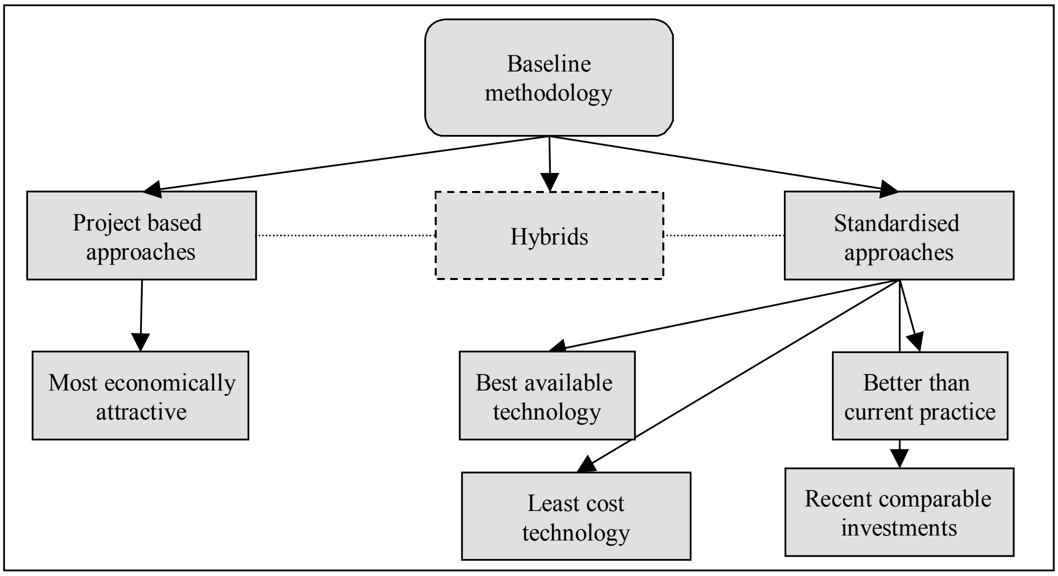
- Geographical range of the baseline, i.e. regional, national, supra-national range

- Sectoral range of the benchmark, encompassing a single fuel or all fuels

- If a technology standard is chosen: Should it be based on industrialised or developing countries standards of technology?

The aforementioned problems are discussed in length in several papers (OECD 1999, WB 1998, Michaelowa et al. 1999).

Figure 2.2
Important baseline methodologies



However, we do not want to comment on the different methodologies, nor discuss the pros and cons at this point. We rather acknowledge the fact that there are different approaches. and that consequently even "standardised" baselines may result in different quantities of emission reductions for the same kind of project undertaken at different sites.[8] This is the case when dealing with the decision upon which methodology to use, is taken in a national context only. We will focus on the analysis of the impacts of the different granting strategies.

2.2 Factual Reductions

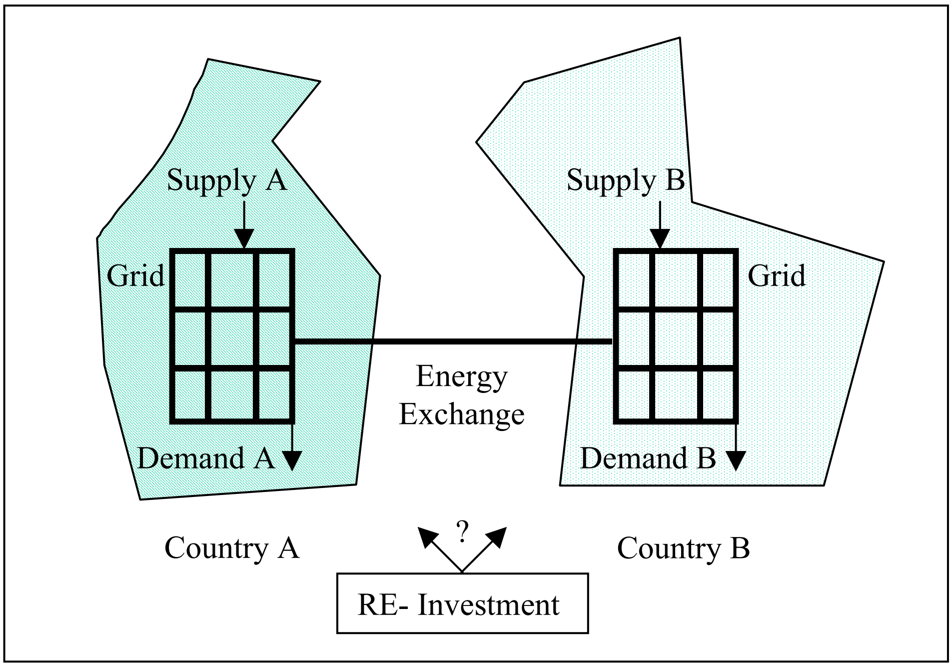
As previously mentioned there may be a difference between the emission reductions quantified according to a particular baseline methodology and the factual reductions by the project. In this context, it is of crucial importance to note

8 Referring to Figure 2.1, this means two different horizontal dashed lines.

that the factual reductions must be considered as one uniform figure for each electricity grid and load period, regardless of the quantity of credits granted according to whatever baseline methodology. It is irrelevant whether it is a grid in a single country or a grid extended over several countries.

Figure 2.3 shows a situation that can be found throughout the world: Two countries have their electricity grids that are connected and each of them has a national portfolio of power plants. Energy may flow in both directions during a certain period, for example due to the specific demand curves.

Figure 2.3
Common structure of electricity grids in and between two countries



Provided that any demand for electricity is met sooner or later, two cases must be considered when investing in RE:

(a) Constant demand and thus early replacement of a fossil fuelled power plant in operation

(b) Increasing demand and thus enlargement of total capacity

Keeping in mind that energy is exchanged, one can see that for both cases it is unimportant to emission reductions where a RE-project is undertaken. For case (a) one would argue that energy from the fossil fuelled power plant with the highest variable production costs would be driven out of the market. The quantity of CO_2 reduced would be equal to the quantity that would have been released by that power plant. It is irrelevant, whether it is located in the same country where the RE-project is undertaken.[9] For case (b) the argument is slightly different: When the demand for energy increases, total emissions cannot decrease. In the best case, they remain constant.[10] In this scenario, it is necessary to construct a business as usual scenario in order to quantify emission reductions. However, if the additional demand was to be met by the construction of a conventional plant and if we assume that there was an optimal location for its construction, it would be irrelevant, compared to the BAU-scenario, if the RE-project was located in the same country. For an overview on the potential extension of international electricity grids and the scope of international trade in electricity see Figure A2.1 and A2.2 in the annex.

3. Investment Additionality – Assuring Environmental Integrity

Apart from the question of how much emissions are reduced, one has to ask if and how many emission reduction credits should be granted to the project in question. An important issue in this context is the so-called investment additionality[11]. The wording in the Kyoto Protocol states that a JI-project must provide “a reduction in

9 The investor‘s decision whether to invest in country A of B is discussed later.

10 For example, if additional demand is met by increase of efficiency.

11 Note that Investment Additionality as it is understood in this paper, is called Financial Additionality by other authors (see for example Baumert 1999). However, we understand

emissions by sources, or an enhancement of removals by sinks, that is additional to any that would otherwise occur" (Art. 6.1) and that a CDM-project must provide "reductions in emissions that are additional to any that would occur in the absence of the certified project activity" (Art. 12.5). This IA-criterion states that any project that is already sufficiently attractive in terms of both financial and non-financial aspects cannot be granted any emission reduction credits. Thus, it is of crucial importance to distinguish between *real and measurable* emission reductions which may occur anyway and the *crediting* of these reductions resulting in terms of Emission Reduction Units (ERU) or Certified Emission Reductions (CER) for JI and CDM-projects respectively. The rationale behind the IA-argument is the integrity of environmental targets. However, this is not relevant in the case of JI, since emission reductions from JI projects are deducted from the host's emission budget. However, the risk of non-compliance may increase.

For CDM-projects the call for IA seems quite reasonable since CERs enhance the industrialised countries' emissions budgets and any crediting of "fake" emission reductions would inflate the industrialised countries' emission target. This is why in the following sections only CERs are considered. Emission reductions not motivated by the Kyoto-mechanisms as mentioned above are also summarised under CERs for simplicity. Furthermore, we concentrate on financial aspects[12] only, as they are likely to play an important role when defining IA, because they are less vulnerable to manipulation than qualitative criteria. For a detailed discussion see Langrock et al. (2000).

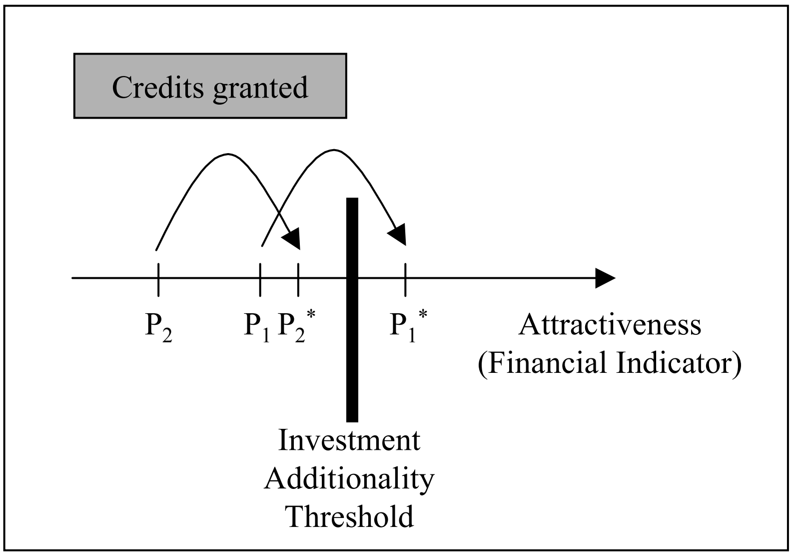
The credited emission reductions are commodities that can be sold and thus provide additional revenues and increase the economic attractiveness of a project. Figure 2.4 illustrates this effect. By receiving reduction credits, a project may

Financial Additionality in the sense "additional to Official Development Assistance (ODA)" which is now an accepted term in the international climate negotiations.

12 There is a large variety of parameters to judge on attractiveness as for example the internal rate of return, the net present value, the payback period etc. We go into detail later.

either overstep the IA threshold (P_1) or simply become more attractive without overstepping it (P_2).

Figure 2.4
Granting of CERs and change of attractiveness of a project



For other projects not expressively labelled CDM, the IA requirement can also be found (Climate Trust 2001): "The Requesters will only fund projects where mitigation measures would not occur in absence of offset project funding."

4. Individual Investor's Optimisation Behaviour and Macro-Economic CO_2 Abatement Costs

In the interest of simplicity, a single investor who is trying to maximise his profit is analysed. When talking about RE it is of crucial importance to note, that – in contrast to conventional power plants - the yield, and thus cost, of renewable energy devices is heavily dependent on the site where the plant is constructed. Different average wind speeds in coastal areas and inland or more or less increasing irradiation from the poles to the equator may serve as an example. On the other hand electricity is a homogenous good, the price of which is set on the market and can only be influenced to small degree by the investor. Assuming that the investor wants to carry out a RE-project, he will attempt to maximise the profit over the project life-time by choosing the site with the maximum expected yield of energy.

By carrying out a RE project he may also reduce CO_2 emissions depending on the specific circumstances. Apart from the investor's considerations whether to invest or not, we can thus determine macro-economic CO_2 abatement costs (see equation A2.1 in the annex).

If we take into account that the investor may get additional revenues from the sale of emission reductions, we can determine his profit[13] P:

$$P = (p^{el} - c_v) * x_i - c_f + x_i * e_i * p^{co_2} \tag{2.1}$$

where p^{el} = Price of electricity

x_i = Quantity of electricity produced at site i

c_f = fixed costs [14]

c_v = variable costs [15]

p^{co_2} = Price of emission reductions credits which is assumed to be determined exogenously since a single RE-project is unlikely to generate an amount of certificates big enough to influence the price

e_i = emission reduction factor at site i

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13 We neglect discounting of future costs and revenues at this point. It is important to note that the investor will decide in favour of the site with the highest expected yield of energy.

14 Set up costs may also vary from site to site. However, there is no correlation between average expected yield and set up costs so that we regard fixed costs as independent of the site of installation.

15 During the following investigation we neglect variable costs. Most costs considered to be variable are rather dependent on the size of the installation (as for example insurance, rent for the ground) but not the exact number of kWh produced. There are of course some costs for wear and tear. However, we do not consider them, since RE-devices are normally designed for high utilisation (e.g. high wind speed). Reduced utilisation does consequently not result in

5. The Impact of Differences in Reduction Factors

As mentioned above, the costs for renewable energies vary from site to site. In the event that two different emission reduction factors are calculated within the range of a single electricity grid, a new situation is faced. This can be the case if a national range is set for standardised baselines in the electricity sector or if project-based baselines are to be used. It should be noted, that it is still unclear which one to apply (UNFCCC 2001, p. 26). Table 2.1 shows emission intensity for heat and power generation in different Annex I countries.

Table 2.1
Emissions from electricity and heat generation in Annex I countries in 1998 (OECD 2000a, pp. 84-87)[16]

(g CO_2/kWh)	Low	Country	High	Country	Difference
Emissions from Electricity and Heat Generation (incl. RE)	3	Iceland	865	Greece	862
Emissions from Electricity and Heat Generation using Coal	407	Lithuania	1435	Slovak Republic	1028
Emissions from Electricity and Heat Generation using Oil	322	Germany	1258	Ukraine	936
Emissions from Electricity and Heat Generation using Gas	204	Czech Republic	1327	Ukraine	1123
Emissions from Electricity and Heat Generation Fossil Average	**311**	n.a.	**1340**	n.a.	**1029**

The investor – still maximising his profit – has to decide whether to invest at site A or B by comparing the following options:

$$p^{el} * x_A - c_f + x_A * e_A * p^{co_2} > ? < p^{el} * x_B - c_f + x_B * e_B * p^{co_2} \quad (2.2)$$

considerable savings. Interestingly, none the major wind turbine manufacturers contacted by the authors was able to provide any detailed data on “real“ variable costs.

16 Since emissions per kWh varied significantly from one year to the next it is not reasonable to consider maximum and minimum figures even though it would be desirable.

Let A be a site with less favourable conditions (e.g. lower average wind speed) than at site B. At the same time e_A be greater e_B, i. e. the baseline emission reduction factor at A is higher even though the same unit of energy in the same grid is replaced.

A rational investor has the incentive to invest in the worse region A when his additional revenues from sale of emission reductions at B offset the lower yield of energy at A. By transforming equation (2.2) we can determine the criteria to be met for a decision in favour of unfavourable site A (see equation A2.2 in the annex). The decision is of course dependent on the emission reduction factor, on the price of emission reduction credits and of the electricity itself.

Since the energy yield curve is theoretically continuous, there will always be a marginal site at which the inequality can be satisfied by the investor's choice, as long as all variables are greater than zero. However, for practical decision making there is no reason to distinguish between sites that differ from each other in the 10^{th} decimal place, since, for example, wind speed or data for irradiation vary from year to year and mean values for investment appraisal provide only an expected value.

We still assume that A is the site with the less favourable conditions (i.e. $x_A < x_B$). If inequality (A2.2) is satisfied, the investor decides in favour of A. However, with x_A being smaller than x_B, macro-economic abatement costs are greater at site A than at site B. This is to say, that by maximising his profit, the investor realises higher abatement costs than without any crediting system. By granting CERs, questionable incentives for investors can be given. To overcome this problem, there must be only one single emission reduction factor e_i^* for each discrete electric grid. Furthermore, it would be desirable that e_i^* equals e_F, i.e. equals the real reductions. However, the later issue is not discussed in this investigation.

6. Renewable Energies and Investment Additionality

As mentioned, the yield of energy, and thus costs of renewable energy devices, is heavily dependent on the site where the device is installed. Consequently, an investor has an influence on the fact, whether his RE-project is classified additional or not and whether he will thus be granted CERs by simply choosing an appropriate site. If we assume that site A is more unfavourable than site B, that is to say that projects at A would be additional and thus be granted credits compared to site B where no CERs are granted, he faces the following problem:

$$p^{el} * x_A - c_f + x_A * e_A * p^{co_2} > ? < p^{el} * x_B - c_f \qquad (2.3)$$

This degree of freedom leads to the following phenomenon:

As mentioned in the section *Investment Additionality* a financial indicator has to be calculated when judging on additionality. We will continue using the general expression *FI* for further discussions.

Let FI_U and FI_F be the financial indicator for an RE project at an unfavourable and an favourable site respectively.

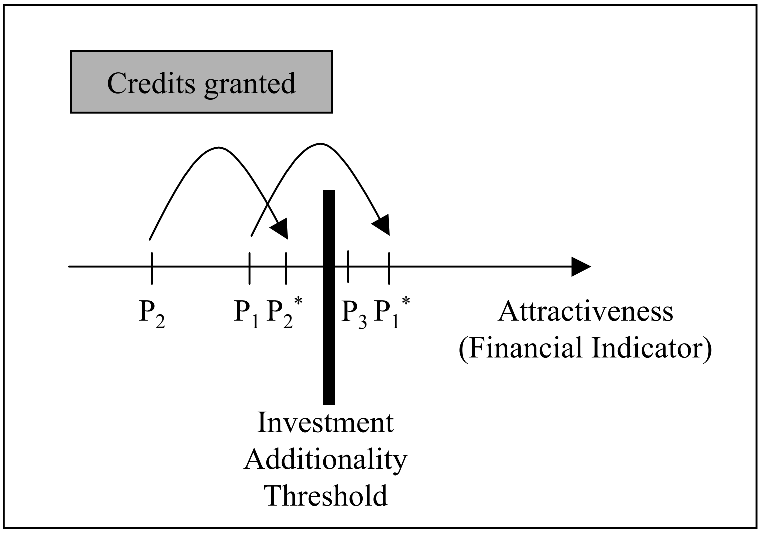
If

$$FI_U > \text{IA-threshold} > FI_F \qquad (2.4)$$

that is to say only the investment at the unfavourable site is additional and is thus granted CERs that can be sold, the investor has an incentive to invest at an unfavourable site as long as the additional revenues from CER sale offset the reduced income from the energy sale from that site.

However, assuming that the price of the CERs and the reduction factor cannot become infinite, the unfavourable site cannot not become infinitely bad either: Installing wind turbines in a forest will definitely result in production costs that meet any IA-threshold but they will not generate enough CERs to offset these costs. This fact is illustrated generally in Figure 2.5.

Figure 2.5
Over-crediting of unattractive RE-projects



Both, P_1 and P_2, are granted credits and thus become more attractive. Taking into account these credits, P_1* may become even more attractive than a project that was not classified as additional (P_3). It should be mentioned that this effect may occur for every type of investment and not only for renewable energy projects.

7. Simulation of RE-Projects

If we change inequality (2.2) such a way that we do not focus on absolute emission reduction factors but rather on the difference, we get

$$p^{el} * x_A - c_{fA} + x_A * e_\Delta * p^{co_2} > ? < p^{el} * x_B - c_{fB} \quad (2.5)$$

where e_Δ denotes the difference in the reduction factors $e_\Delta = e_A - e_B$. If we prescribe that region A has always the greater emission reduction factor, e_Δ must always be greater zero.

If we compare inequality (2.4) and (2.5), we can then see that the structure of the problem is the same for both, differences in reduction factors and the IA issue. However, the outcome must be interpreted differently.

In the following simulation, the internal rate of return (IRR) was chosen as parameter to compare different projects. An investor will decide in favour of the project with the highest IRR. Other parameters, for example the net present value or the pay back period, can also be applied. Furthermore, the simulation is restricted to wind turbines and solar modules. This selection was judged to be representative for other RE- technologies.

For all cycles of the simulation we set p^{el} = 0,05 €/kWh. c^*, i.e. the average specific costs of electricity from alternative investment, is set to 0,03 €/kWh. This is to represent average production costs of fossil fuelled power plants. This selection is necessary since it can be assumed that wind energy replaces power in the middle load range where fossil fuelled power plants set in (Mayer 2000, p. 56). Consequently, nuclear power plants are not considered.

In order to undertake a sensitivity analysis, the CER price, the difference in emission reduction factors and the investment costs are changed during the simulation.

7.1 Investments in Wind Turbines

From the variety of available wind turbines a *NEG-Micon NM 750/48* (rated power: 750 kW) was selected. Measured power curve and costs were taken from literature (BVW 1999). Other parameters (see Table 2.2) were set by the authors.

Table 2.2
Costs for wind power

Investment Costs ('000€):	600
Set up Costs: 30% of Investment Costs ('000 €):	180
Subtotal ('000 €):	780
Operation Time (y):	18
Discount Rate*):	12%
Capital Costs ('000 €/y):	108
Maintenance: 1,5% of subtotal ('000 €/y):	12
Total Costs ('000 €/y):	**119**

*) Discount rates vary from investor to investor. The figure applied seemed to us to be a reasonable level even though it is a somewhat arbitrarily one.

The yield of the sites with different wind speeds was always calculated using the Raleigh-distribution.

Simulation 1: Low CER Price, Small Difference in Emission Reduction Factors and Investment in Wind Turbines at Current Costs

For the first simulation we assumed a benchmark of 0,5 t_{CO2} per MWh. This represents either the differences in emission reduction factors in different countries (see Table 2.1) or the reductions assigned to a project that was judged to be additional[17]. The price for CER is 5 € / t_{CO2}. Results for different sites are depicted in Table 2.3.

17 For example if emissions from a natural gas fired power plant with an efficiency of about 40% are avoided.

Table 2.3
IRR with low CER price, small difference in emission reduction factors and investment in wind turbines at current costs

No	Average Wind Speed (m/s):	Yield (MWh/y)	IRR (without CER-Revenues)	CO2 Reduction (t/y)	Revenues from sales of CERs (€/y)	IRR (incl. CER-Revenues)	Macro-CO2 Abatement Costs (€/t)
1	4.00	428	-14%	214	1071	-13%	497
2	4.50	632	-8%	316	1580	-7%	317
3	5.00	865	-4%	432	2162	-3%	216
4	5.50	1126	0%	563	2816	0%	152
5	6.00	1399	3%	699	3497	4%	111
6	6.50	1682	6%	841	4205	6%	82
7	7.00	1971	8%	986	4928	9%	61
8	7.50	2257	11%	1128	5641	12%	46

To see whether one of the aforementioned effects appears, one has to compare the IRR including CER revenues in line i with the IRR without CER revenues in line i + x.

With the boundary conditions set in simulation 1, none of the aforementioned effects occurred.

Simulation 2: High CER Price, Small Difference in Emission Reduction Factors and Investment in Wind Turbines at Current Costs

As already mentioned the price of the CERs is of crucial importance. Table 2.4 shows the simulation results for a CER price of 25 €.

Table 2.4
IRR with high CER Price, small difference in emission reduction factors and investment in wind turbines at current costs

No	Average Wind Speed (m/s):	Yield (MWh/y)	IRR (without CER-Revenues)	CO2 Reduction (t/y)	Revenues from sales of CERs (€/y)	IRR (incl. CER-Revenues)	Macro-CO2 Abatement Costs (€/t)
1	4.00	428	-14%	214	5355	-10%	497
2	4.50	632	-8%	316	7901	-5%	317
3	5.00	865	-4%	432	10808	-1%	216
4	5.50	1126	0%	563	14079	3%	152
5	6.00	1399	3%	699	17483	6%	111
6	6.50	1682	6%	841	21023	9%	82
7	7.00	1971	8%	986	24641	12%	61
8	7.50	2257	11%	1128	28207	15%	46

As one might have expected, the distorting effect appears with a higher CER price. Depending on the sites available, an investor can have the incentive to invest at unfavourable sites.

Example:

Case a): Differences in Emission Reduction Factors

Assuming that the investor can for example decide between site no. 6 where the emission reduction factor is higher and site 7, he is likely to invest at no. 6 instead of site no.7, since the IRR is higher at the former.

While there is nothing to argue against this decision on microeconomic level, it turns out that from a macroeconomic point of view this decision does not lead to an efficient abatement policy: By optimising his personal investment strategy the investor realises higher CO_2 abatement costs as can be seen in the last row.

Case b): Investment Additionality

We assume that the IA-threshold was set to an IRR of 7%. In this case the project at site 6 would be additional, whereas the one at site 7 would not. It becomes apparent when the IRR of site 6 and 7 in the 4th row from the left are compared. This would imply the same result as in case a) even in the same region with only one emission reduction factor.

Simulation 3: High CER Price, Big Difference in Emission Reduction Factors and Investment in Wind Turbines at Current Costs

Furthermore, the influence of difference in emission reduction factors must also be investigated.[18] We suggest a difference in reduction factors of 1 t_{CO2} per MWh. This corresponds also to emissions from a hard coal fired power plant with an efficiency of about 33% that may be avoided and credited for a project found to be additional. The price is still 25 € per t_{CO2}. The results are given in Table 2.5.

Table 2.5
IRR with high CER Price, big difference in emission reduction factors and investment in wind turbines at current costs

No	Average Wind Speed (m/s):	Yield (MWh/y)	IRR (without CER-Revenues)	CO2 Reduction (t/y)	Revenues from sales of CERs (€/y)	IRR (incl. CER-Revenues)	Macro- CO2 Abatement Costs (€/t)
1	4.00	428	-14%	428	10711	-8%	248
2	4.50	632	-8%	632	15802	-3%	159
3	5.00	865	-4%	865	21617	2%	108
4	5.50	1126	0%	1126	28157	6%	76
5	6.00	1399	3%	1399	34967	9%	55
6	6.50	1682	6%	1682	42047	13%	41
7	7.00	1971	8%	1971	49282	16%	31
8	7.50	2257	11%	2257	56414	19%	23

18 For conceivable differences in emission reduction factors see also Table 2.1.

As it can be seen, the distorting effect is now occurring for a wider range of sites. It first appears for decisions between sites no. 3 and 4. If site no. 6 was the best available selection in region A, even more favourable sites like no. 8 in region B could not compete. Again, higher CO_2 abatement costs are realised.

Simulation 4: Low CER Price, Small Difference in Emission Reduction Factors and Investment in Wind Turbines at Future Costs

As stated earlier, an enormous cost cutting potential can be expected for wind power. To analyse this effect, we cut costs by 75% (as predicted in FME 2000, p. 14) from 600.000 € to 150.000 €.

The results are shown in Table 2.6.

Table 2.6
IRR with low CER price, small difference in emission reduction factors and investment in wind turbines at future costs

No	Average Wind Speed (m/s):	Yield (MWh/y)	IRR (without CER-Revenues)	CO2 Reduction (t/y)	Revenues from sales of CERs (€/y)	IRR (incl. CER Revenues)	Macro-CO2 Abatement Costs (€/t)
1	4.00	428	6%	214	1071	7%	79
2	4.50	632	13%	316	1580	14%	34
3	5.00	865	20%	432	2162	21%	9
4	5.50	1126	27%	563	2816	28%	-7
5	6.00	1399	34%	699	3497	36%	-17
6	6.50	1682	42%	841	4205	44%	-25
7	7.00	1971	49%	986	4928	52%	-30
8	7.50	2257	56%	1128	5641	59%	-34

As in the first cycle, the distorting effect does not occur since with decreasing investment costs both IRR with and without revenues from the sale of CERs are reduced.

7.2 Investments in Solar Modules

In contrast to the approach for wind turbines, no specific type of solar module is selected. The key parameters are rather modelled in a way that they represent the physics of existing modules. Details are given in Table 2.7.

Table 2.7
Costs for photovoltaics

Installed Surface A (m2):	1000
Efficiency Factor η (System):	0.13
Power (kWp):	130
Specific. Costs ('000€)/kWp):	2[19]
Investment Costs ('000€):	260
Lifetime (y):	20
Discount rate*):	12%
Capital Costs ('000€/y):	35
Maintenance (1.5% of Inv. Costs) ('000€/y):	4
Total Costs ('000€/y):	**39**

*) Discount rates vary from investor to investor. The figure applied seemed to us to be a reasonable level even though it is a somewhat arbitrarily one.

19 Current costs amount to about 6000 € / kWh_p.

Simulation 5: High CER Price, Large Difference in Emission Reduction Factors and Investment in Photovoltaics at Future Costs

We assume again a difference in emission reduction factors of 1 t_{CO2} per MWh. The price for CER is 25 € / t_{CO2}. Results for different sites are depicted in Table 2.8.

It was necessary to restrict the simulation of photovoltaics to these boundary conditions as otherwise it would not have been possible to calculate any IRR using standard software.

Table 2.8
IRR with high CER Price, big difference in emission reduction factors and investment in photovoltaics at future costs

No	H (kWh/ (m^2*d)) *)	Yield (MWh/y) **)	IRR (without CER-Revenues)	CO2 Reduction (t/y)	Revenues from sales of CERs (€/y)	IRR (incl. CER Revenues)	Macro-CO2 Abatement Costs (€/t)
1	2.5	118.63	-	118.63	2966	-9%	296
2	3	142.35	-12%	142.35	3559	-6%	242
3	3.5	166.08	-9%	166.08	4152	-4%	203
4	4	189.80	-8%	189.80	4745	-3%	174
5	4.5	213.53	-6%	213.53	5338	-1%	151
6	5	237.25	-5%	237.25	5931	0%	133
7	5.5	260.98	-4%	260.98	6524	1%	118
8	6	284.70	-3%	284.70	7118	3%	106
9	6.5	308.43	-2%	308.43	7711	4%	96

*) Annual Average of Global irradiation on vertical surfaces

**) Simplified Formula: Yield = H * A * η

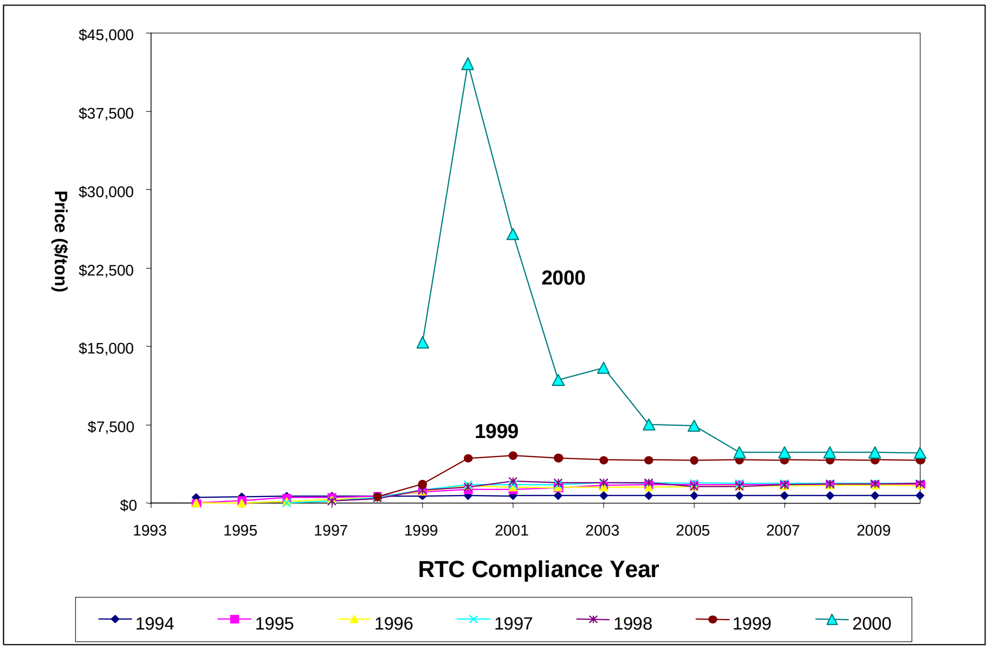
As for wind power, the questionable effect occurs for photovoltaic projects when certain boundary conditions are assumed.

7.3 Results of the Simulation and Conclusion

The simulation revealed that the distorting incentive to invest at unfavourable sites as theoretically described in the sections "*The Impact of Differences in Reduction Factors*" and "*Investment Additionality – Assuring Environmental Integrity*" may also occur in project implementation, when using actual data. It was shown that the microeconomic decision making aiming at maximising profit can result in macroeconomic inefficiencies.

However, it seems to be impossible to say whether or not the effect will occur. Current grey-market prices range from 0.6-3 € (Natsource 2001, p. 3) and thus are lower than the price assumed in the simulation. On the other hand, other studies suggest even higher prices than assumed. For example up to 59 € per t CO_2 for an Annex I emission trading scenario (EcoSecurities 2001). Furthermore, future prices will strongly depend on emission targets in subsequent commitment periods and on the emitters' abatement strategies. The importance of the latter aspect can currently be seen from the NOx price development in the US-Reclaim program.

Figure 2.6
Development of NOx prices in the US-Reclaim program (SCAQMD 2001)



Consequently, this issue should be immediately addressed in order to avoid problems and confusion in the future. One might argue that there will only be a short term struggle for the relevant sites that are a scarce resource. But with increasing prices for carbon credits in the future, the number of sites affected will also continuously increase so that action is required.

Apart from the influence of the price, the crucial role of emission reduction factors – i.e. the baseline – becomes obvious. In contrast to other CO_2 abatement options such as fuel switch or energy efficiency improvements, a unified baseline methodology for each electricity grid seems to be necessary for renewable energies, in order to prevent unreasonable investments from the macroeconomic point of view. Apart from this prerequisite, one must find a way to determine the emission reduction factor for a grid that is close to factual reductions.

Finally, we suggest a more fuzzy Investment Additionality threshold as depicted in Figure 2.7 - at least for renewable energies. In so doing, the negative incentive to invest at unfavourable sites is alleviated.[20] Furthermore, the determination of the threshold which is anything else but trivial (see Langrock 2000 et al.), is simplified in the sense that no choice of an exact threshold is necessary and that consequently the risk of an unsuitable choice is reduced.

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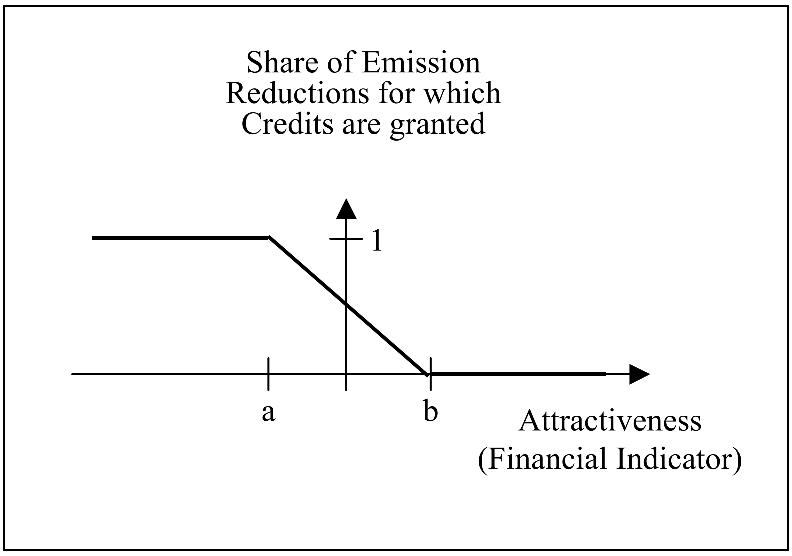
20 The effect might still occur at marginal sites in theoretical analysis, however, this is not of relevance for practical decision making.

Figure 2.7
Fuzzy Investment Additionality Threshold



However, the question of how to determine the parameters (a) and (b) must be answered. Often, one can find interest rates of state bonds to be relevant investment alternatives when defining appropriate discount rates for projects. We follow this approach but still face the problem that interest rates of state bonds vary from country to country and over time. We find that the range between a = 0% and b = 10% is quite reasonable. However, this is a more or less arbitrary choice.

When the simulations is run with the fuzzy IA-threshold, one can see that the perverse effect can be erased for simulation 2 (see Table 2.9) and clearly be lessened for simulation 3 (see Table 2.10).

Table 2.9
IRR with high CER Price, small difference in emission reduction factors and investment in wind turbines at current costs and fuzzy IA threshold (a = 0 %; b = 10 %)

No	Average Wind Speed (m/s)	Yield (MWh/y)	IRR (without CER-Revenues)	CO2 Reduction (t/y)	CO2 Reductions Credited (t/y)	Revenues from sales of CERs (Euro/y)	IRR (incl. CER-Revenues)	Macro-CO2 Abatement Costs (Euro/t)
1	4,00	428,44	-14%	214	214	5355	-10%	497
2	4,50	632,09	-8%	316	316	7901	-5%	317
3	5,00	864,67	-4%	432	432	10808	-1%	216
4	5,50	1126,29	0%	563	563	14079	3%	152
5	6,00	1398,67	3%	699	504	12610	5%	111
6	6,50	1681,86	6%	841	369	9221	7%	82
7	7,00	1971,29	8%	986	174	4345	9%	61
8	7,50	2256,57	11%	1128	0	0	11%	46

Table 2.10
IRR with high CER Price, big difference in emission reduction factors and investment in wind turbines at current costs and fuzzy IA threshold (a = 0 %; b = 10 %)

No	Average Wind Speed (m/s)	Yield (MWh/y)	IRR (without CER-Revenues)	CO2 Reduction (t/y)	CO2 Reductions Credited (t/y)	Revenues from sales of CERs (Euro/y)	IRR (incl. CER Revenues)	Macro-CO2 Abatement Costs (Euro/t)
1	4,00	428,44	-14%	428	428	10711	-8%	248
2	4,50	632,09	-8%	632	632	15802	-3%	159
3	5,00	864,67	-4%	865	865	21617	2%	108
4	5,50	1126,29	0%	1126	1126	28157	6%	76
5	6,00	1398,67	3%	1399	1009	25220	8%	55
6	6,50	1681,86	6%	1682	738	18442	9%	41
7	7,00	1971,29	8%	1971	348	8691	10%	31
8	7,50	2256,57	11%	2257	0	0	11%	23

Low thresholds of approximately zero percent may, however, in certain cases (see Table 2.10) remain a bit problematic. A lower threshold smaller than zero (e.g. a = -10%) can solve this problem, but it seems reasonable to support economically unviable projects (IRR < 0) by the full granting of CERs. The s-shaped form of the yield function of wind turbines may also contribute to this effect.

8. Summary

Among the variety of open questions within the international climate negotiations, two issues are important: detailed rules for quantifying emission reductions by single a project and the question of how to define projects that deliver additional reductions in emissions compared to any that would have happened without the project. Unfortunately, there has been no systematic analysis of the impact of the different rules under discussion on investors' decision making.

In this paper we show that the concrete design of the climate regime is, however, of crucial importance. Firstly, a uniform emission reduction factor for each electricity grid and load period is necessary. Otherwise, investors can have the incentive to invest at unfavourable sites, since the disadvantages from the reduced yield of energy can be more than offset by the revenues from the sale of the additional reduction credits. Consequently, an investor can realise higher macroeconomic abatement costs by maximising his personal profit.

The concept of Investment Additionality as discussed so far must be reconsidered. Though it attempts to insure environmental integrity when applying the Clean Development Mechanism under the Kyoto Protocol, it can give undesirable incentives to invest at unfavourable sites, and thus result in higher CO_2 abatement costs. This is quite unsatisfactory since the flexible mechanisms were introduced to reduce overall compliance costs. The use of a fuzzy investment additionality threshold can help overcome this problem from the authors' point of view.

The findings have not only been derived from theoretical conclusions but have also been analysed with realistic data. As a result, it is likely that the effects occur in reality. The price of emission reduction certificates and the emission reduction factor applied are the most important parameters.

Annex

Equations:

Determination of the macro-economic CO_2 abatement costs C^{CO_2} :

$$C^{CO_2} = \frac{c_f - x_i * c^*}{x_i * e_F} \quad \text{(A2.1)}$$

where c^* = average specific costs of electricity from alternative investment, c_f = fixed costs, x_i = quantity of electricity produced at site i, e_F = real emission reduction

By introducing the factor (x_i * c^*) we take into consideration that the electricity produced by the RE-device would have had to be generated by a conventional power plant in the absence of the RE project.

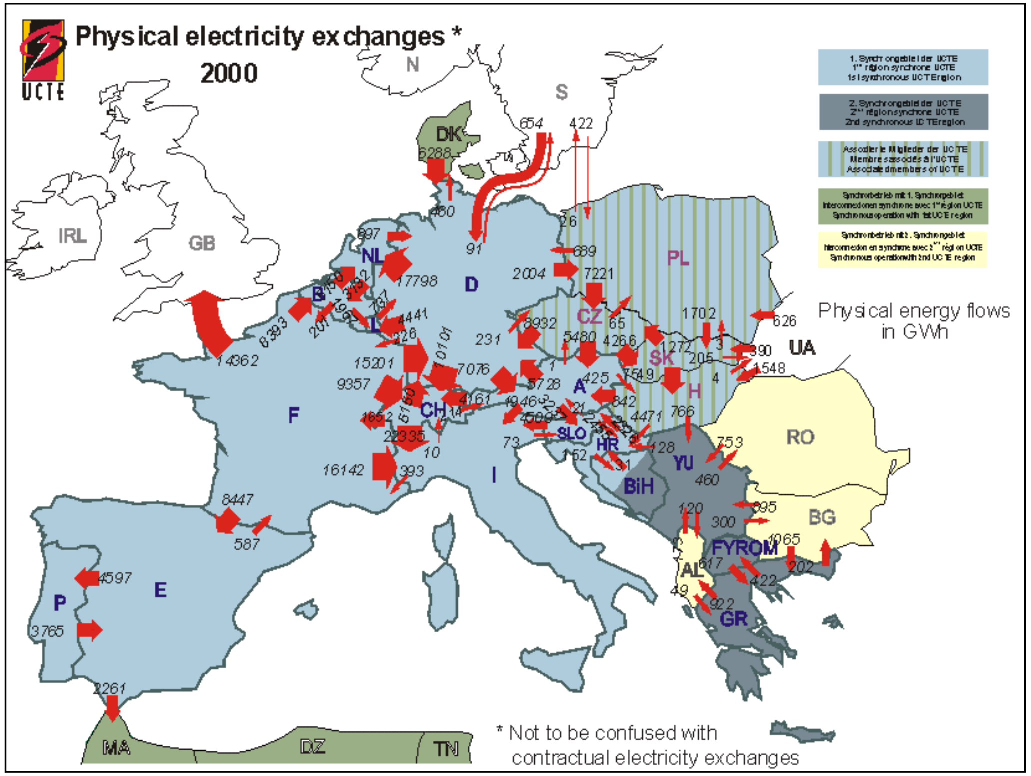
Condition to be met for a decision in favour of unfavourable site A.

$$\frac{x_B}{x_A} < \frac{1 + e_A * \frac{p^{CO_2}}{p^{el}}}{1 + e_B * \frac{p^{CO_2}}{p^{el}}} \quad \text{(A2.2)}$$

Figure A 2.1 Mediterranean electric networks

(Source: Medelec, no year)

Figure A 2.2 Physical electricity exchanges within UTCE



(Source: UTCE 2000)

One should note that there is a connection between grids in Annex I and Non-Annex I countries.

Chapter 3

Equal Emissions per Capita over Time - A Proposal to Combine Responsibility and Equity of Rights

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Contents

This chapter was presented at the workshop “International Climate Policy after 2012” which took place in November 2003 at the University of Ghent. A first version was published as HWWA Discussion Paper 253 in 2003, a revised and shortened version followed in: European Environment 14 (2004) pp. 300-316. I would like to thank Jörg Drechsler, intern at HWWA in August 2003 for his support in setting up the model.

Abstract

Any effective future climate policy regime based on the Kyoto-Protocol requires the determination of the concrete contribution regarding time and quantity for each Party. Based on the two justice principle responsibility and equity of rights that form the basis for the so-called Brazilian Proposal and Contraction & Convergence respectively, a new approach is developed: Future emission rights are allocated on the basis of equal emissions per capita over time. By so doing not only are emissions per capita (EPC) taken into account during the allocation but also their evolution over time. This may result in negative quantities of emissions right for some Parties due to their historical "burden". On the other hand, Parties with low EPC would be allocated large amounts of "fair air". Even though this approach may currently lack political support by powerful Parties, it offers another analytical reference point for the political bargaining process on future allocations.

1. Introduction

Assuming a future evolution of the Kyoto Protocol, there are two basic options with regard to the determination of future allocations of emission permits[21]. The first option are rolling agreements restricted to the next commitment period, be it five years as the first one from 2008 to 2012 or another duration. Secondly, a long-term - if not eternal – approach for allocating emission permits to the Parties of the Convention could be agreed upon (see also Berk et al. 2001 p. 466). An unexpected advocate of the later approach could be industry. In the run-up of the emission trading scheme on the entity level in the European Union (EU 2003), industry has asked for clear perspectives with regard to the allowance allocation (Anonymous 2003). Business seeks certainty because of the long life-time of a number of installations as for example coal-fired power plants (see also Aldy et al. (2003) p. 10). Furthermore, by establishing a long-term allocation scheme, there would be no incentive to re-negotiate the target of an upcoming commitment period. This could be of interest in case a Party fears non-compliance in an earlier period (Barrett 2002, p. 4, similar Aldy et al. 2003, p. 8).

However, the earlier the targets are set for long-term GHG emissions, the more difficult the negotiations on international level are. Currently, the principle of "common but differentiated responsibility", as set in the UNFCCC, is widely accepted but in the long-run developing countries will also be asked to contribute to limiting absolute global GHG emissions. And while trying to determine a Party's contribution each is likely to call for a "fair" allocation. There are, however, different justice principles the Parties can refer to. Table 3.1 gives some examples on justice principles discussed in the context of climate change.

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21 The terms emission permit, entitlement and right are used equivalently throughout this paper. Note that the term *permit* is used differently in the EU-directive on emissions trading (EU 2003).

Table 3.1
Examples for justice principles discussed in the context of climate change

Author:	Rose (1992) [a]	Blanchard et al. (2001)	Torvanger et al. (2002) [b]
Principle:	Horizontal (initial) [a]	Equity of rights,	Responsibility
	Vertical (initial)	Utilitarian equality	Need
	Ability to pay (outcome)	Democratic equality	Capacity
	Sovereignty (outcome)	Causal responsibility	
	Egalitarian (outcome)	Merit	
	Market justice (process)	Proportional equality	
	Consensus (initial)		
	Compensation (process)		
	Rawls‘ Maxim (process)		
	Environmental equity		

[a] Rose et al. (1998) point out that it is important to distinguish whether a “criterion applies to the process by which a criterion is chosen, the initial allocation of permits, or to be the final outcome of the implementation of the policy instrument...”

[b] Apart from the three fairness principles, six operational requirements are applied.

Some of these justice principles form the basis of different proposals for global burden sharing schemes.[22] In this context, the present paper offers a new approach for the determination of a long-term future allocation. It is based on the so-called Brazilian Proposal (UNFCCC 1997) and the Contraction & Convergence approach (Meyer 2000). Thus, it combines the two justice principles

22 Even though we have a more or less clear understanding of these different principles, two major problems are faced when applying them for allocations of emission entitlements: Firstly, the different principles are in most cases equally justified. This is to say that one cannot say which principle is to be preferred in case there are different opinions. To overcome this problem, Müller (2001) proposes the so-called *preference score method* to reach a “compromise-solution” between different principles or approaches. Secondly, apart from the principle, a reference base, e.g. population, as well as an operational rule for applying the principle, e.g. allocate in proportion to population, is required (Rose 1992). However, “there is no one-to-one relation between a fairness principle and a specific formula, meaning that one formula ca be supported by more than one principle, and one principle can support more than one formula” (Torvanger et al. 1999, p. 15). Finally, Rose et al. (1998) showed that a mere philosophical distinction between different criteria may well be mathematically equivalent and thus have the same welfare outcomes. Nevertheless, different principles are referred in the international climate negotiations.

responsibility and *equity of rights*. In the paper I assume that the future climate policy regime makes use of two important principles underlying the Kyoto Protocol, namely the quantification of absolute emission budgets for each Party as well as emission trading. I concentrate on the participation method and the determination on the emission targets only. Neither the allocation of burdens from adaptation to climate change nor the distribution of benefits from mitigation is considered.

The paper is structured as follows. The following section discusses the key issues for the allocation of emission permits in the future climate policy regime assuming that it is based on the Kyoto-principles. In section three, a general version of a new approach for the determination of time of participation as well as the quantification of contributions for further Parties is presented, followed by a numerical example in the subsequent chapter. Section five concludes.

2. Key Issues for Mitigation Efforts in the Future Climate PolicyRegime

There has been a large discussion on the Kyoto-Protocol itself, its future development as well as on possible alternatives.[23] However, as mentioned, I assume that the future climate policy regime is based on the Framework Convention and the Kyoto principles: This means the objective formulated in Art. 2 of the Convention[24], the quantification of absolute emission budgets for each nation as well as emissions trading. Furthermore, a long-term approach for allocating emission permits is discussed. Shaping this allocation in the future climate policy regime thus requires a discussion of the following:

(a) Global targets (final and interim targets, i.e. path)

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23 For example emission trading itself has been criticised and taxes have been favoured instead (Pizer 1997, Cooper 2000). An overview and evaluation on 13 alternatives to the Kyoto-Protocol is provided by Aldy et al. (2003).

24 The ultimate objective of the Framework Convention (Art. 2) is the "...stabilization of greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system....".

(b) Determination of time of participation [25]

(c) Quantification of contributions to limiting GHG emissions by participants

2.1 Global Targets and Path

Generally, there are several ways to determine a global emission target in terms of net GHG emissions to the atmosphere. One may for example, minimise the sum of total abatement costs plus total damage costs. However, the approach faces some general drawbacks in the context of pollution control (see for example Perman et al. 1999, pp. 290-291). Another option is to define a *concentration target* as mentioned in Art. 2 of the Framework Convention without directly referring to costs.

Even though the objective of the Convention seems quite precise, a lack of clarity remains. The understanding of a *dangerous interference,* a *threat to food production* or other issues may differ among people and nations. This may complicate the finding of an agreement on the ultimate global emission. Furthermore, the relationship between GHG emissions, atmospheric GHG concentration, radiative forcing and the temperature increase or extreme weather events is not fully understood, as is the role of solar and volcanic forcing or the effects of aerosols (IPCC 2001a). Nevertheless, a general idea of allowable total emissions exists (see Table 3.2).

Apart from the ultimate emission target there has been an intensive discussion on the interim targets, i.e. the path to take to get there. The most important argument in this discussion has not been the technical feasibility for near term cuts in emissions, but rather the associated costs. Some authors argued that postponing emission reductions would result in lower costs as otherwise existing capital stock would have to be prematurely retired (Wigley et al. 1996). Others have argued

25 It should be noted that the stabilisation target does not inevitably require all countries to limit their emissions. Technically it would be conceivable that some countries continue to emit while other invest in removal from the atmosphere including biological sinks and technical removal as suggest by Lackner et al. (no year).

that by postponing reductions the benefits from learning-by-doing would be foregone (Vuuren et al. 2001). Other points of discussion have been the way to consider technical change in economic models or the discount rate to be used (SEPA 2002, pp. 22-25). Until economists come up with a coherent solution, policy makers are likely to set interim targets that are somewhere in between the possible extremes. For the ultimate concentration target, Jacoby et al. (1999, p. 7) state that it seems most likely that an atmospheric concentration of 550 ppmv will be selected as it is "...in the middle of what has become the standard range of numbers, making it a moderate compromise."

Once the total target(s) have been set, a discussion on the contribution of the different Parties in order to reach the goal is necessary.[26] As this burden sharing is a zero sum game, it is all but trivial and Parties are likely to put "good" arguments forward in order to get a sufficiently big piece of the pie.

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26 A theoretically straightforward way to avoid such discussion implying high transaction costs would be to auction the permits already on the international level.

Table 3.2
Stabilisation level and related allowable emissions

WRE CO2 Stabilisation profile (ppm)	Accumulated CO_2 emissions 2001-2100 (Gt CO_2)	Year in which global emissions peak
450	1314-2646	2005-2015
550	2124-4068	2020-2030
650	2646-4932	2030-2045
750	2952-5400	2040-2060
1000	3258-5832	2065-2090

Source: IPCC (2001b, p. 108).

2.2 Proposals for Allocations of Permits

The first proposals and analyses for allocation of permits date back to the beginning of the 1990's (for example Barret 1992, Rose 1990). Subsequently, a larger number of proposals emerged as a result of the Ad Hoc Group of the Berlin Mandate (AGBM). These proposals differ with regard to their specification as well as to the reference basis chosen (Torvanger et al. 1999). An overview is given in Table 3.3.

Table 3.3
Type of reference base and frequency in 16 proposals from the AGBM
(based on Torvanger et al. 1999, p. 18)

Operational reference basis	CDE	CDE / Cap.	CDE / GDP	GDP / Cap	Cum CDE	CDE exp / CDE tot	dPop/ dt	EXP/FF	CDE / km^2	Other
Number of time applied	3	9	7	7	5 *)	2 *)	2	2	1	4

CDE = (Level of) $CO2_{-eq}$ emissions, Cap. = Capita, GDP = Gross domestic Product, Cum = cumulative historical, CDE exp / CDE tot = share of emissions resulting from production of goods for export relative to total emissions, dPop/ dt = Population growth, EXP/FF = Fossil fuel intensity of export, CDE / km^2 = emissions per square kilometre of a country's territorial basis

*) one proposal based on projected data

Additionally to the proposals presented during the climate negotiations, various approaches for the allocation of permits – also called burden-sharing – have been proposed in literature. They differ strongly in specification. Some analyse different burden-sharing rules applied to a limited number of countries (for example Winkler et al. 2002, Groenenberg et al. 2001) whereas others provide an allocation scheme for the whole world (Meyer 2000). It would be out of the scope of this paper to review all proposals currently in circulation. A review of selected literature until 1998 is provided by Torvanger et al. (1999 pp. 31-33). Evans (2002) discusses some other proposals, which have gained particular attention in the past. The implications of these approaches with regard to costs have been studied by others as well (den Elzen 2002, den Elzen undated).

Apart from the specification, the proposals differ with respect to the degree of differentiation. Based on the experience from the European burden-sharing negotiations, Ringius (1997, p. 5) argues for differentiated agreements, as "the symmetrical approach ... might result in inefficient and unfair agreements and country obligation." On the other hand, Torvanger et al. (1999, p. 28) questions whether the EU case can be transferred to greater number of countries. Furthermore, it may be difficult to define the indicator for differentiation on a global level, especially if differences among countries to be considered are based on differences in preferences. Below, I only discuss the two proposals, which form the basis for the concept presented in the next section, in more detail.

- The Brazilian proposal

The Brazilian proposal (UNFCCC 1997) has been prepared for the 7th session of the AGBM. The core element is the allocation of emission permits in proportion to the historical responsibility[27] for global warming in terms of accumulated

27 In a national context this concept is also referred to as the polluter-pays-principle.

contribution to radiative forcing or temperature increase of certain Parties.[28] Indeed, an allocation of permits was only suggested for Annex-I countries and an overall budget of 30 % below 1990 emissions by 2020 was proposed. CO_2 emissions from the energy sector and cement production should be considered. Non-Annex-I countries were not to make any binding commitment with regard to emission limitations.

The initial Brazilian proposal has been criticised for several reasons, as for example the restriction to CO_2 emissions from limited sources or the methodology used for calculating the contributions to global warming. The proposal had been revised but still some drawbacks remained. Nevertheless, a group of experts came to the conclusion that "... these deficiencies can in general be readily addressed by improving the model by corrections or by importing techniques and processes already available in other models." (den Elzen et al. 1999). Even though the discussion among experts continued (for an overview see: IISD 2003) no final applicable methodology has been found yet. Most important issues are the indicators for climate change, the consideration of non-linearities and feedbacks, as well as the databases. However, they conclude that "... the Brazilian Proposal is probably the best one to deal with the "common but differentiated responsibilities ..."" (IISD 2003). In order to solve these "technical" problems, I consider the historic emissions instead of the contribution to radiative forcing. Emissions are much easier to quantify. For CO_2 emissions from fuel combustion, historic data exists for the last 200 years.

Apart from the technical problems mentioned above, the concept of responsibility has been criticised for philosophical reasons. An overview of pros and cons is given by Neumayer (2000). As it is much more difficult to conclude this philosophical discussion, I do not go into detail at this point. The interested reader is referred to the sources mentioned. What seems worthwhile to be mentioned is

28 Another element was the Clean Development Funds that should be financed by the non-compliance penalties of Annex-I countries. The fund later became the Clean Development Mechanism.

"…that a right principle is not refuted by the mere fact of not currently being political feasible." (Neumayer 2000, p. 190)

- Contraction & Convergence

The idea of Contraction & Convergence has been presented by the Global Common Institute (Meyer 2000). The contraction part refers to the cutting back of emissions in order to reach an CO_2 concentration target, which must be fixed on an international level. As already discussed above, once a global target has been defined, an allocation of the resulting emission permits has to be agreed upon. The convergence part reflects the idea that this allocation should be carried out on an equal basis to all of human kind – i.e. an equal per capita allocation of emission rights which can be traded.

Apart from the concentration target an agreement on the time of convergence is required. Berk et al. (2001 p. 475) point out that a late date of convergence is disadvantageous for developing countries since it results in less cumulative emission permits. This potential drawback will be solved by the approach presented below.

Like the Brazilian Proposal, the idea of Contraction & Convergence has also been judged as a very good concept for future allocation of emission permits by several members of governments in both Annex-I and non-Annex-I countries (for a summary see Meyer 2000 pp. 70-75).[29]

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29 However, one should also keep in mind that a strict adherence to an equal per capita allocation neglects the fact that (per capita) emissions do not only depend on individuals' behaviour or preferences but also on climatic conditions. For example, people living in the higher latitudes are likely to need more heat for space heating than people living in the middle latitudes. Such aspects may be considered in subsequent analyses.

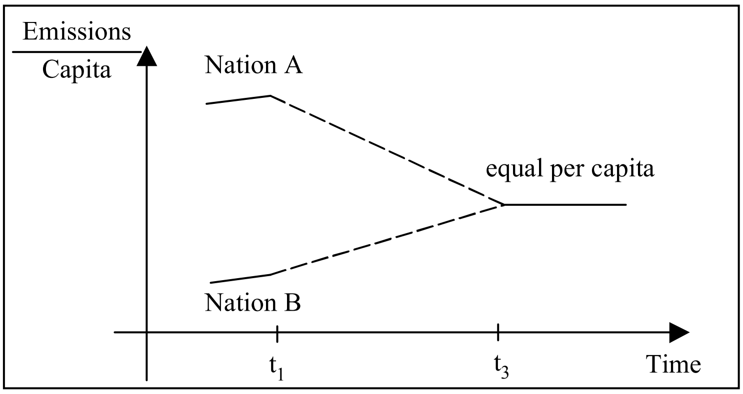
3. Equal Emissions per Capita over Time (EECT)

In the previous section several options for quantifying the Parties' contributions to the reduction of global GHG emissions have been discussed. As mentioned some multi-criteria approaches have also been proposed so far. In this section I present a new approach for the development of the future climate policy regime by combining the equal per capita allocation with the historical responsibility approach.

As mentioned above, one may generally question whether an allocation based on equal per capita emissions or on historical responsibility is "equitable" (e.g. Beckerman et al. 1995). However, I neglect this theoretical discussion and rather analyse the implications of such an allocation based on these two principles as practical politics may well decide on such a rule regardless of its support by any justice principle. And as mentioned above, the two approaches have been judged to be a good candidate for forming the basis of future burden sharing schemes.

Even though it has not been explicitly said, the path for reaching an allocation based on equal per capita emissions so far has generally been understood as an monotonously decreasing curve from the day a Party participates (t_1 in Fig 3.1) until equal per capita emissions are reached (t_3 in Fig 3.1) for those Parties that have emissions above considered equal per capita emissions (for example: Torvanger et al. 1999, pp. 20-22, Groenenberg et al. 2001, p. 1018). On the other hand, those with lower than average emissions would face an allocation based on a monotonously increasing curve until equal per capita emissions are reached as depicted in Figure 3.1.

Figure 3.1
General understanding of the path to equal per capita emissions



As can be seen in Figure 3.1, a simple allocation based on equal EPC would result in a “fair” allocation from the point t_3, but if looking at a nation’s average emissions (allocation) per capita over time one can see that there would be a difference between high and low emitting countries, which could still be judged as “unfair”. Rose (1992 p. 66) states: “Industrialized countries have developed by abusing the global commons with little or no penalty. Ignoring the past build-up and simply basing reduction requirements on subsequent emissions would be equivalent to penalizing developing countries for the progress, when no such sanction was imposed on industrialized countries.” Shukla (1999) argues the same way and suggests a more equitable convergence scheme with crossing curves as depicted in Figure 3.2. Regarding the slope of the curves after the intersection, reference to the income effect is made. However, the scheme is not further specified. Neumayer (2000) also provides a general idea on the allocation of emissions entitlements with historical accountability. However, no detailed analysis follows. Regarding the result I present below, it should be mentioned that Neumayer does not allow for a negative allocation.

I build on this idea and propose to allocate emission rights based on a path such that *average* emissions per capita are also equal for a certain period prior to t_3. Denoting the beginning of this period by t_1, this means that the sum of the emissions per capita in the period between t_1 and t_3 has to be equal for all nations.

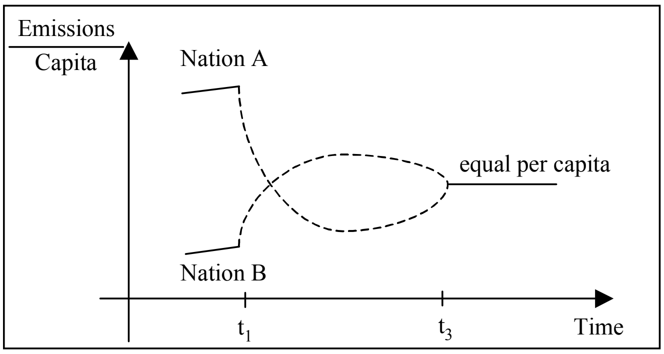
Mathematically, this means that the integral in the limits of t_1 and t_3 of a (piecewise – see below) continuous function $\Phi_i(t)$ which describes the allowed emissions per capita at the time t in country i has to be equal to a certain value *A* for all nations. Mathematically,

$$\int_{t_1}^{t_3} \Phi_i(t)dt \overset{!}{=} A \qquad \forall i \tag{1}$$

A would have to be agreed upon politically. The condition in (1) does not inevitably imply that all Parties are allocated a certain assigned amount from the point t_1. This may happen at a later point t_i^* with $t_1 < t_i^* < t_3$ and would allow for some flexibility with regard to the timing of participation. This is important, as not every Party would even be technically able to take on an absolute emission budget promptly. (This would be the consequence if all countries were to start at the same time, as most Annex B countries are likely to have absolute targets with the Kyoto-Protocol entering into force soon.) Other authors have argued for example for an initial voluntary GHG intensity target to take this aspect into account (Baumert et al. 1999). However, the emissions released between t_1 and t_{i*} would have an impact on the allocation between t_{i*} and t_3 as the condition in (1) has to be satisfied. Incentives for early participation are discussed after the presentation of the numerical example.

Keeping in mind that current emissions per capita differ strongly between nations, it becomes obvious that nations with low EPC would receive higher allocations than average emissions in future years (see Figure 3.2). The opposite would hold true for nations with higher EPC - regardless of whether or not they have an absolute target in the first commitment period. It is important to note, that only the allocation of the permits is based on the curves as shown in Figure 3.2. As these permits are traded there would be no need for abrupt cuts in emissions.

Figure 3.2
Schematic depiction of the path for equal emission per capita over time



To determine the concrete allocation in the future for a single nation, it would thus be necessary:

1. to determine the allowed "sum" in the period between t_1 and t_3 for the Parties
2. to gather historical emission data, if t_1 lies in the past
3. to determine the time of participation for nation i (i.e. t_i^*)
4. to determine a rule, e.g. equation, how to distribute the "remaining" budget of permits for the period between t_i^* and t_3.

In this context it is worthwhile to note, that by the allocation of emission entitlements, emission reductions obligations are only allocated implicitly. The reduction obligation is calculated by the subtraction of the entitlements from the real emissions. However, the future development of the latter is highly uncertain, especially when considering long time horizons as in this paper. Thus, the resulting long-term reduction obligations are uncertain, too.

In the next section a concrete option for the determination of the four steps is presented.

3.1 Numerical Example

During the discussion of the concrete option in this chapter one should remember that many other options are equally conceivable when specifying the approach. The numerical example is based on CO_2 emission from energy combustion as this data was the most accessible. It goes without saying that the approach can be applied with the whole basket of GHG specified in the Kyoto Protocol.

Determination of the allowed average emissions per capita

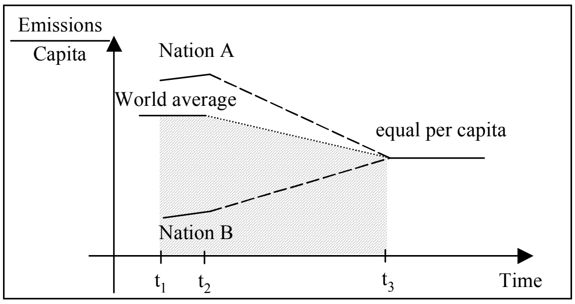
The average emissions per capita are determined as follows: A piecewise continuous curve is constructed consisting of

a) the world average emissions per capita in the interval from t_1 to t_2 (where t_1 = 1992, the year the Framework Convention on Climate Change has been adopted and t_2 = 2013 the beginning of the second commitment period)

b) a straight line connecting world average emissions in t_2 = 2013 and equal per capita emissions in t_3 (where t_3 = 2092, 100 years after the Framework Convention was adopted). For the determination of the equal per capita emission in 2092 see Annex 1.

A (see equation (1)) is set equal to the area under this curve (see hatched area in Figure 3.3). For determining the actual allowed emissions, one has to multiply the allowed per capita emissions with the corresponding population of the year analysed.

Figure 3.3
Quantification of allowable average emissions per capita over time



Determination of time of participation

As mentioned above no specific time for participation is set - except for those Annex B countries having ratified the Protocol. This allows for some flexibility. The only rule assumed is that once a country takes on an absolute allocation of permits, it cannot leave the system anymore. As we discuss later, incentives for early participation depend on the level of current emissions per capita, the treatment of CDM, expectations on future permit prices, etc.

Determination of a function for future allocation

As emissions per capita generally differ among countries, a function for each single Party is needed. I propose to use the same quadratic function of the form

$$\Phi_i = a_i t^2 + b_i t + c_i \tag{2}$$

for all Parties with only the coefficients *a*, *b* and *c* changing.

Keeping in mind the historical emissions per capita of nation i since t_1, equation (1) is specified as:

$$\int_{t_i^*}^{t_3} (a_i t^2 + b_i t + c_i)\,dt = A - D_{i,t_i^*} \tag{3}$$

where $D_{i,t}$ describes the cumulative emissions per capita between 1992 and the point when nation i starts contributing to the global mitigation efforts.

For the determination of the coefficients a_i, b_i and c_i see Annex 2.

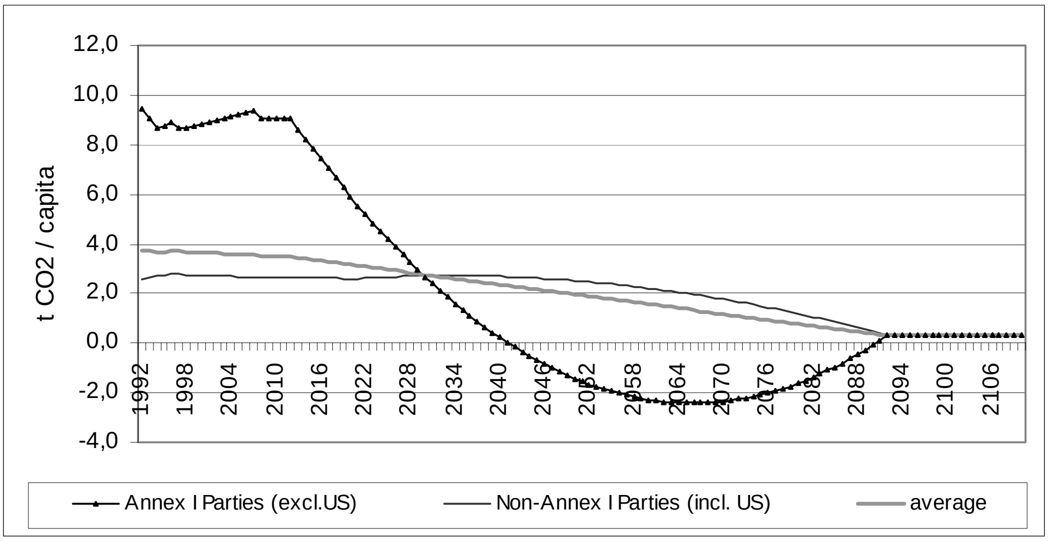
For the finalisation of the numerical example the start of participation of the single countries (t_i^*) has to be determined. This is done for a selection of countries below. Note that, as future commitment periods after 2012 are studied, all calculations are based on prognoses only (see Annex 1). Later allocations could be based on, at that time historical, data from “recent” years as also suggested by GCI (2003).

Figure 3.4 shows the path for allowed emissions per capita assuming that the non-Annex-I countries (including the US)[30] take on an absolute emission budget in 2022. All other Annex I countries, other than the US, are assumed to accept and continue with an absolute budget in 2013. By multiplying per capita emissions by the corresponding population, one gets the total emissions and assigned amount respectively (Figure 3.5). Data is given for both cases, where the US ratifies the Kyoto-Protocol and where it starts to limit GHG emissions in 2022 as the other non-Annex I countries. Regarding both figures it is important to remember that they only show the allocation of emission entitlements. No Party would be obliged to actually reduce emissions accordingly. It could rather buy emission entitlements on the market.[31]

Another aspect which is worthwhile to be mentioned is the potential problem of dominant market roles by some countries. This is a general problem to be considered for every allocation scheme. However, the fact that under the new approach some Parties get a negative allocation implies that others get a very big share of the emission entitlements what may render this aspect very important in this special case. However, this has not been investigated in detail in this paper but will rather be part of future work.

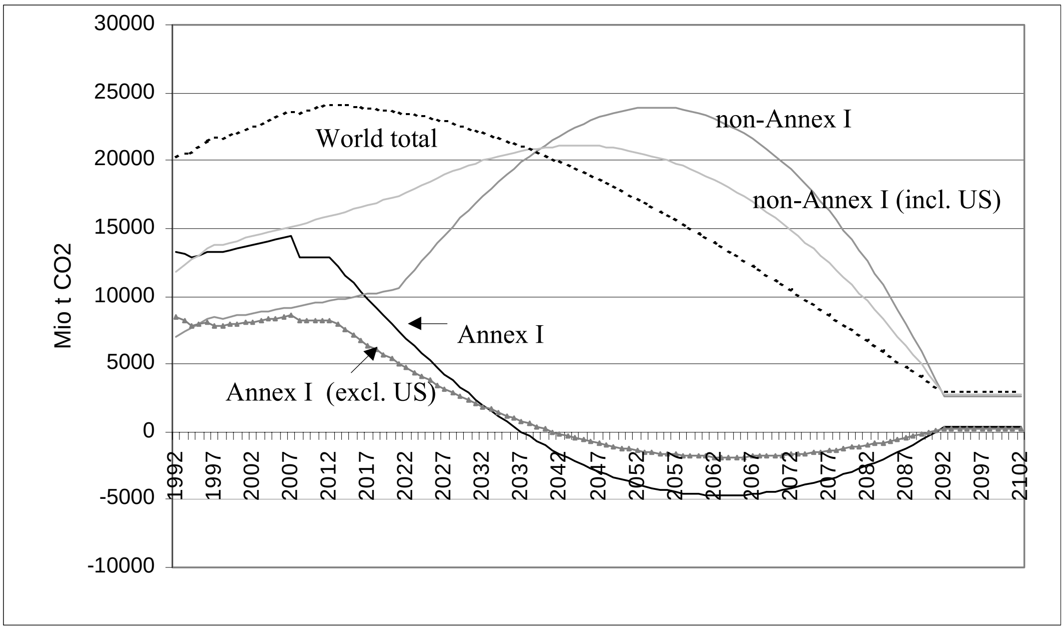
30 Australia has been assumed to ratify the Protocol in order to simplify calculations. Given the minor share of global GHG emissions (esp. compared to the US) this seems acceptable.

Figure 3.4
(Assigned) Emissions per capita (CO_2 from fuel combustion)
with non-Annex-I incl. US taking on an absolute emission budget in 2022



31 An extreme case would be a decreasing *allocation* per capita with increasing *emissions* per capita. However, buy purchasing additional entitlements on the market the Party could still be compliant.

Figure 3.5
Emissions and assigned amount (CO_2 from fuel combustion) with non-Annex-I incl. US taking on an absolute emission budget in 2022*



*) World total emissions indeed slightly differ depending on whether or not the US participates early: This decision influences average per capita emission in 2013 that form the starting point for the reduction path until 2092. Cumulative emission from 1992 to 2100 are about 1,700 b t CO_2 .

It goes without saying the individual allocation can strongly differ from the highly aggregated schedule presented in Figure 3.5. Table 3.4 provides less aggregated data for some countries for the allocation in the next commitment periods. Remember that the figures given dependent on the simplified prognoses for population and emissions.

Furthermore, one has to note that for non-Annex-I countries the starting point of participation is of crucial importance with regard to a country's allocation at a certain time. Figure 3.6 and 3.7 visualise this aspect for two countries: Qatar representing countries with currently above average emissions per capita and India for below average countries. As we can see in the case of Qatar, postponing the start of contributing to the global mitigation efforts allows for a business-as-usual, and therefore increasing emissions path. However, the increasing emissions are taken into account later and result in a (more) negative allocation in the last third of the century. The situation for India is similar. Due to its very low emissions per capita, it will be allocated many permits after taking on an absolute emission budget. The later the participation the bigger the allocation at the end of the century. Incentives for a certain decision with regard to the participation are discussed in the next chapter.

Table 3.4
Emissions (italic figures) and assigned amount for selected countries*

	Start	2nd CP 2013-17	%90*)	3rd CP 2018-22	%90*)	4th CP 2023-27	%90*)	5th CP 2028-32	%90*)	6th CP 2033-20	%90*)	7th CP 2038-42	%90*)	8th CP 2043-47	%90*)	9th CP 2048-52	%90*)
Australia	2013	1193	0,92	845	0,65	513	0,40	207	0,16	-65	-0,05	-380	-0,29	-484	-0,37	-626	-0,48
Canada	2013	1733	0,81	1231	0,57	751	0,35	304	0,14	-98	-0,05	-568	-0,26	-728	-0,34	-945	-0,44
Germany	2013	3223	0,67	2337	0,49	1549	0,32	863	0,18	284	0,06	-275	-0,06	-558	-0,12	-827	-0,17
Japan	2013	4099	0,80	3043	0,60	2112	0,41	1318	0,26	660	0,13	109	0,02	-269	-0,05	-560	-0,11
Spain	2013	1056	1,02	847	0,82	658	0,64	491	0,48	346	0,34	255	0,25	122	0,12	41	0,04
Argentina	2022	*1323*	2,71	*1376*	2,81	1185	2,42	928	1,90	688	1,41	541	1,11	280	0,57	119	0,24
Brazil	2022	*2890*	3,00	*3034*	3,15	3140	3,26	3201	3,32	3207	3,32	3777	3,92	3053	3,16	2912	3,02
China	2022	*29033*	2,55	*30282*	2,66	27877	2,45	24375	2,14	20959	1,84	20915	1,84	14760	1,30	12100	1,06
India	2022	*8913*	3,15	*9367*	3,31	9845	3,48	10347	3,65	10875	3,84	13785	4,87	12013	4,24	13085	4,62
Nigeria	2022	*441*	3,01	*505*	3,44	1299	8,85	2343	15,96	3374	22,99	5348	36,43	5274	35,93	6026	41,05
Saudi Arabia	2022	*2623*	2,98	*2737*	3,11	2280	2,59	1461	1,66	522	0,59	-736	-0,84	-1578	-1,79	-2600	-2,96
United States	2022	*32177*	1,33	*33254*	1,38	24605	1,02	13321	0,55	2831	0,12	-9050	-0,37	-14992	-0,62	-21827	-0,90
Uzbekistan	2022	*1099*	1,96	*1145*	2,04	998	1,78	777	1,38	556	0,99	385	0,69	140	0,25	-39	-0,07

*) equal per capita emission in 2092, Global assigned amount in 2092: 3 b t CO_2.

Table 3.4 continued

	Start	10th CP 2053-57	%92*)	11th CP 2058-62	%90*)	12th CP 2063-67	%90*)	13th CP 2068-72	%90*)	14th CP 2073-77	%90*)	15th CP 2078-82	%90*)	16th CP 2083-87	%90*)	17th CP 2088-92	%90*)
Australia	2013	-724	-0,56	-773	-0,60	-774	-0,60	-727	-0,56	-634	-0,49	-494	-0,38	-305	-0,24	-69	-0,05
Canada	2013	-1089	-0,51	-1160	-0,54	-1157	-0,54	-1080	-0,50	-933	-0,43	-717	-0,33	-436	-0,20	-92	-0,04
Germany	2013	-1003	-0,21	-1089	-0,23	-1093	-0,23	-1019	-0,21	-874	-0,18	-663	-0,14	-388	-0,08	-54	-0,01
Japan	2013	-753	-0,15	-856	-0,17	-880	-0,17	-833	-0,16	-721	-0,14	-547	-0,11	-310	-0,06	-8	0,00
Spain	2013	-18	-0,02	-59	-0,06	-82	-0,08	-89	-0,09	-81	-0,08	-59	-0,06	-24	-0,02	22	0,02
Argentina	2022	-10	-0,02	-107	-0,22	-171	-0,35	-201	-0,41	-197	-0,40	-158	-0,32	-84	-0,17	25	0,05
Brazil	2022	2751	2,85	2538	2,63	2288	2,37	2005	2,08	1688	1,75	1338	1,39	954	0,99	534	0,55
China	2022	9795	0,86	7762	0,68	6050	0,53	4654	0,41	3564	0,31	2766	0,24	2249	0,20	2002	0,18
India	2022	21825	7,71	30575	10,80	35960	12,70	37814	13,36	36035	12,73	30573	10,80	21422	7,57	8610	3,04
Nigeria	2022	6523	44,44	6812	46,41	6812	46,40	6485	44,18	5802	39,52	4741	32,30	3295	22,44	1461	9,95
Saudi Arabia	2022	-3440	-3,91	-4099	-4,66	-4475	-5,09	-4507	-5,12	-4148	-4,72	-3372	-3,83	-2169	-2,47	-549	-0,62
United States	2022	-26831	-1,11	-30024	-1,24	-31159	-1,29	-30120	-1,25	-26843	-1,11	-21316	-0,88	-13582	-0,56	-3737	-0,15
Uzbekistan	2022	-187	-0,33	-297	-0,53	-364	-0,65	-385	-0,69	-359	-0,64	-284	-0,51	-163	-0,29	2	0,00

Figure 3.6
Emissions (prognosis) and Assigned Amount as a function of timing of contributing to mitigation efforts in the case of Qatar

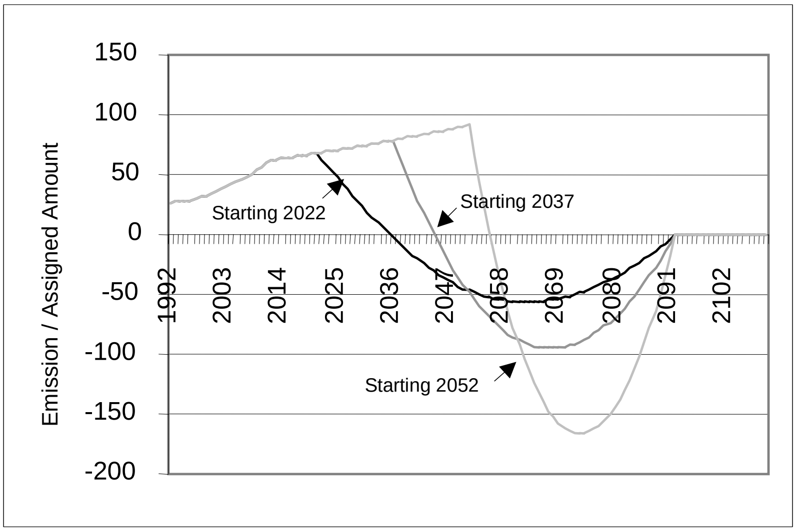
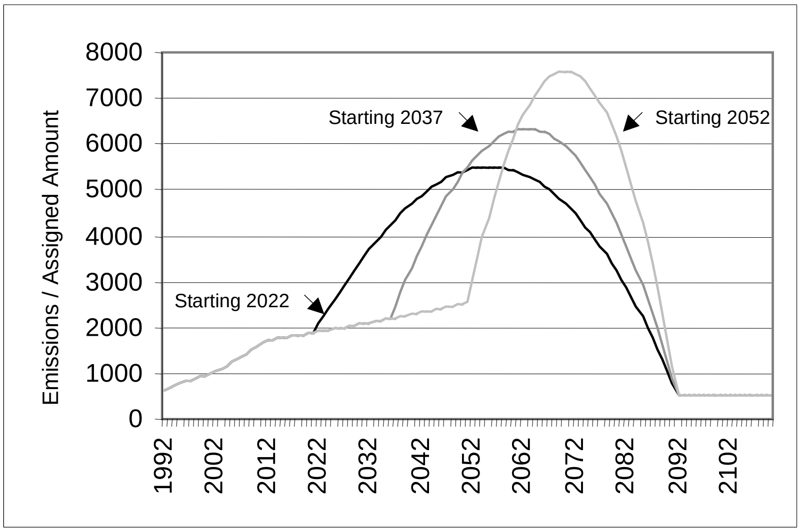


Figure 3.7
Emission (prognosis) and Assigned Amount as a function of timing of contributing to mitigation efforts in the case of India



3.2 Discussion

The numerical example presented above revealed two important implications of the approach presented in the previous section.

Firstly, an allocation based on equal per capita emissions considering the historical load can result in a negative allocation in some future commitment periods for countries with emission per capita above average – regardless of whether or not they are already Annex-I countries. The negative allocation is inter alia a result of the assumption on the allowable future budget of emission entitlements.[32] With a larger budget the negative allocations may become positive. However, the proportional distribution would remain the same as it is mostly a result of the past and current above average emissions per capita in the Annex I countries.

The negative allocation on its own, however, is no reason to reject this proposal for theoretical reasons. Indeed, a negative allocation may conflict with the need principle (CICERO 2001, p. 20), but on the other hand it takes into account the historical burden concept. Nevertheless, the approach may not be capable of obtaining a majority right now.[33] As the Annex I countries, which are powerful participants in the negotiations, face low and even negative allocations they are likely to object to such an approach. Whether the positive statements on a per capita allocation by Annex-I representatives as cited above are serious remains to be seen. On the other hand one could see from the WTO negotiations at Cancun that developing countries may be powerful participants in international negotiations when organised appropriately. Thus, the approach presented may become more capable of obtaining a majority in the future. A political economy analysis, taking into account the concrete negotiation power of the Parties with

32 The period considered is also important. A reduction to, let’s say 2042 to 2092, is likely to change the result in favour of the Annex I countries. However, such a reduction would conflict with the idea of allocating equal over time.

33 Apart from the political feasibility Baumert et al. (2003) point out at some other aspects (as for example net benefits for developing countries) which should be considered for global allocations schemes. The new approach presented here could also be restricted to a selected number of countries as suggested by Baumert et al. (2003, p. 146).

high and low emissions per capita respectively, is an interesting next step. Regardless, the approach provides another analytical input for the political discussion.

The potential financial transfer implied could also be considered as "fair air", given the historical burden of the Annex-I countries, and the need for the eradication of poverty is mentioned several times in the Convention.[34] On the other hand one has to keep in mind that there are also many non-Annex-I countries with per capita emissions above average. They would not benefit from such fair air. However, regarding the costs implications of the allocation scheme presented, one must remember that the long-term reduction obligation resulting from the allocation of CO_2 entitlements is highly uncertain, as it depends on the future business as usual emission path. The same uncertainty is faced with regard to the abatement costs, especially when considering a time frame of about one hundred years as proposed in this paper. This is why I refrained from presenting any quantitative data on this issue.

Secondly, the incentives for non-Annex-I countries to join early depend on several factors. First of all, one has to remember that the overall allocation of permits is dependent on the population. This can provide certain incentives. For example, a country with higher than average emissions per capita and decreasing population may opt for a late entry when calculating the overall allocation: The low or even negative computed emissions per capita after entry would be multiplied by a small number of people. The opposite is true for Parties with lower than average emissions per capita and decreasing population. They could enter early in order to get a larger allocation in the first half of the century. Whether the aforementioned fact could give rise to a change in population policy is discussible, even though I do not think it is likely: An increase of population growth would only be reasonable for countries with per capita emissions lower than the calculated value

34 In case one fears that the revenue from the sale of surplus AAUs could be misused for whatever purposes, one could dedicate the financial means for climate protecation fund that helps to promote GHG emission reductions. Whether they should be used for adaption is discussible.

for the allocation. The number of these countries is likely to reduce over time, especially with allowable per capita emissions decreasing. When per capita emissions are higher than the calculated allocation value, a reduction of population would be reasonable, however not realistic from the author's point of view. Other models also considered population growth as an exogeneously driven factor (Byrne et al. 1998 p. 339).

Apart from changes in population other factors would also play an important role for the decision to join. As mentioned above, not all non-Annex I countries may even be technically capable to take on an absolute emission budget due to a lack of human capacity. So far national communications have been submitted much later than envisioned in the 1990's.

A country's market position with regard to both surplus permits and marginal abatement costs would also be important in this context. Furthermore, a country's expectation on technical change and thus future carbon prices is also to be considered.[35]

Finally, it is worth mentioning that the approach offers no long-term incentive for carbon leakage. It has been argued in the past that industry may move from countries with emission targets, and thus resulting stronger environmental regulations, to non-capped countries in which GHG emission would be free of charge. In the short run this would still be possible. But the higher early emissions in the un-capped country would be taken into account and result in reduced allocations in the subsequent periods. Thus, the overall emissions over time would be unaffected.[36]

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35 The flexibility with regard to the time of accepting an emission target indeed allows borrowing for countries, especially when their cumulative emissions per capita exceed their budget.

36 However, total cumulative emissions would be effected if the CDM continued to be an eligible mechanism. This is due to the fact that the countries' overall assigned amount is independent of the emissions in a certain period (see equation (1)). If a Party, which has not accepted an absolute emission budget yet, hosts a CDM project, its emissions are reduced compared to the non-CDM case. Thus, its emission budget after entry into the scheme would increase. This alone would postpone emissions to a later time and would even be desirable.

4. Conclusions

A first step to limiting human greenhouse gas emissions into the atmosphere has been taken by adopting the Kyoto-Protocol in 1997. However, as emission targets have only been agreed upon for a limited number of countries for the so-called first commitment period from 2008 to 2012, some challenging tasks are waiting for the climate negotiators when discussing future contributions to further limit GHG emissions.

A major source of conflict is the different notion of what an equitable contribution is. Literature provides many justice principles. However, none of these principles is per se more just than the others. Some kind of compromise will have to be found. And apart from these theoretical considerations, it is not easy to institutionalise principles with regard to the allocation of emission rights either. Nevertheless, a number of proposals have now been suggested. They differ with regard to their specification and to the justice principles they refer to. Thus, they are supported differently by developing and industrialised countries as the burden implied changes considerably.

In this framework, a new proposal for the long-term allocation of emissions rights based on the so-called Brazilian Proposal and the Contraction & Convergence approach was presented. It is thus based on the two principles *responsibility* and *equity of rights*. The main feature of the proposal is that the average emission per capita in a period to be defined has to be the same for all countries. By determining this allowable average value, the question of the exact starting point of contributing to limitation of global GHG emissions becomes less important. With an overall fixed budget set, higher emissions in the near future result in a smaller allocation of emission permits after a Party decides to join the scheme. This allows for a lot of flexibility for the countries that do not want to accept an emission target right now, be it because they are technically unable to do so or for

However, this affect would be compensated as the issuance of CERs allows the buying country to increase its current emissions. Against this background, a continuation of the CDM under the scheme presented above is not reasonable for environmental reasons.

other reasons. Flexibility in timing can also be one aspect of "differentiated responsibility" (Matsui 2002).

As the overall allocation is calculated on the basis of a per capita value, the total population is a dominating factor in this calculation. Whether this gives incentives to change population policy is discussible. A numerical example that considered emission since 1992 showed that the allocation may well be negative in some periods for certain countries. In this context, one should note that for the latter issue it is not important whether it is a developing or industrialised country, but rather whether it has considerably higher per capita emissions than average.

The numerical example was restricted on CO_2 emissions from energy combustion. The number of sources could be extended. Future work could also analyse the resulting costs which have not been studied for certain reasons so far. The same goes for the impact on atmospheric GHG concentrations. All errors are mine.

Annex

Annex 1

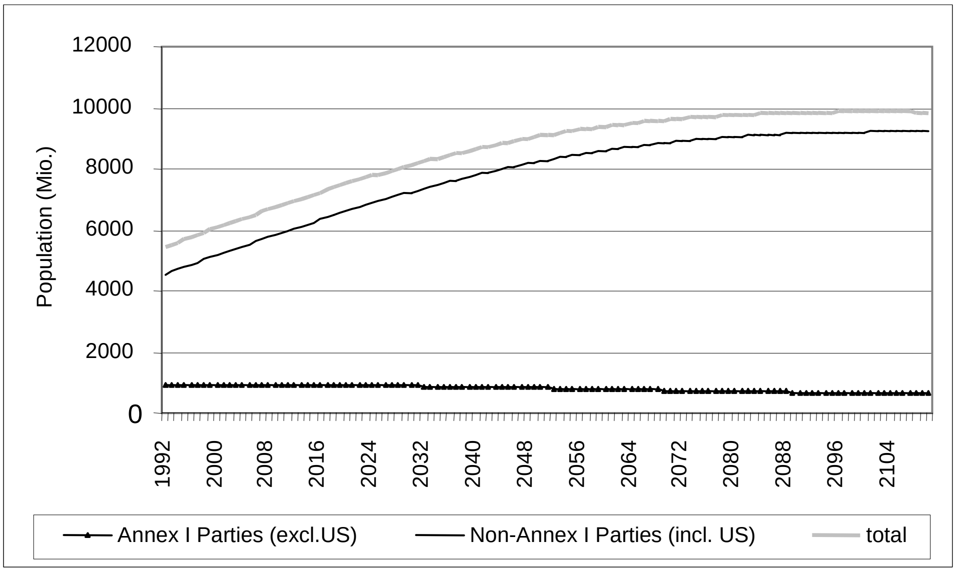
Data used for the numerical example.

Population:

Population data and prognoses until 2050 on country level have been taken from USBC (2003). For the prognoses, the medium variant was used.

Further projections are only given for the year 2150 on continental level (UN 1999). The continental trend between the period 2050 and 2150 has been used on the country level as well. For the time in between, a regression curve of the type $f(x)=ax^6+bx^5+cx^4+dx^3+ex^2+fx+g$ has been used. Population was assumed to be constant from 2150 onwards. Figure A 3.1 shows the population development for selected regions.

Figure A 3.1
Population development as assumed for the numerical example



Emissions:

For the future development of GHG emissions, a great number of scenarios is available (see IPCC (2000) that provide a wide range of potential GHG emissions in 2100. In this report, it is stated that “no judgement is offered in this report as to the preference for any of the scenarios and they are not assigned probabilities of occurrence...”.

This is why a rather straightforward approach has been used to calculate future emission on country level for the numerical example. Historical emissions for the years 1992 to 1998 have been taken. Emissions have been restricted to CO_2 emissions from energy combustion. Data was taken from OECD/IEA (2000). After 1998 emission were assumed to grow annually by 1%. Note that emissions in the numerical example are only shown as long as a Party has not accepted an absolute emission target. Once it participates, the assigned amount is presented. The difference between emissions and assigned amount is not analysed further.

The global budget for CO_2 from energy combustion in 2092 has been set somewhat arbitrarily to 3000 Mio. t CO_2.

Annex 2

Three equations are available for the determination of the allocation function $\Phi_i(t)$:

$$\int_{t_i^*}^{t_3} (a_i t^2 + b_i t + c_i) dt = A - D_{i,t_i^*} \qquad \text{(A1)}$$

$$\Phi_i(t_3) = eepc \qquad \text{(A2)}$$

$$\Phi_i(t_i^*) = epc_{i,t} \qquad \text{(A3)}$$

(A1) specifies the remaining budget on per capita basis, when Party i accepts an emission target in t_i^*.

(A2) describes the *equal emissions per capita* to be reached in t_3. The same value applies for all countries.

(A3) are the emissions per capita for Party i when it starts to join the system.

The system of the three equations solves as follows:

$$a_i = \frac{3(t_i^* y_1 + t_i^* y_2 + 2(A - D_{i,t_i^*}) - t_3 y_2 - t_3 y_1)}{t_i^{*3} - 3t_3 t_i^{*2} + 3t_i^* t_3^{\,2} - t_3^{\,3}}$$

$$b_i = \frac{-2(t_i^{*2} y_1 + 2t_i^{*2} y_2 + 3At_i^* - t_3 y_2 t_i^* + t_i^* t_3 y_1 - 2t_3^{\,2} y_1 + 3At_3 - t_3^{\,2} y_2)}{(t_i^* - t_3)(t_i^{*2} + t_3^{\,2} - 2t_i^* t_3)}$$

$$c_i = \frac{t_i^{*3} y_2 + 2y_1 t_3 t_i^{*2} + t_i^{*2} t_3 y_2 - 2y_2 t_i^* t_3^{\,2} - y_1 t_i^* t_3^{\,2} + 6At_i^* t_3 - y_1 t_3^{\,3}}{(t_i^* - t_3)(t_i^{*2} + t_3^{\,2} - 2t_i^* t_3)}$$

Chapter 4

European Climate Policy: Burden Sharing after 2012

Sven Bode

Contents

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Abstract

Regardless of whether or not the Kyoto Protocol enters into force, the EU may decide to set itself a long-term greenhouse gas emission target and thus to continue its leadership role in international climate policy. As for the first commitment period of the Kyoto Protocol, the EU may decide on a burden-sharing agreement as an integral part of such a long-term climate policy. Against this background I analyse three different options to distribute an overall budget of emission entitlements until 2042 among the member states of an enlarged EU. It is shown who wins and who loses with regard to compliance costs. As the member states' attitudes towards the different approaches are likely to depend on the relative attractiveness of the allocation options, a relevance threshold is introduced which may help to predict and understand the complexity of future climate negotiations in Europe.

Keywords:

Accession countries, allocation of GHG emission entitlements, burden sharing, European climate policy, EU-enlargement, future commitment periods

1. Introduction

The EU has been perceived / described as leader in the context of international climate policy. The implementation of an EU-wide emission trading scheme on installation level (EU 2003) may serve as the latest proof. Consequently, it may also set itself an (ambitious) emission target for the time after 2012, i.e. when the first commitment period of the Kyoto Protocol ends. This target setting may of course take place in the context of the negotiations in the framework of the United Nations Framework Conventions on Climate Change (UNFCCC) as well as in a European framework only in case the Kyoto Protocol does not enter into force.[37] An EU-wide target may then be symmetrically broken down to each member state (MS), i.e. a uniform reduction rate would apply for all MS. Alternatively, a differentiated agreement as it has been reached among member states for the first commitment period of the Kyoto Protocol could also be agreed upon. Both approaches offer advantages and disadvantages (for a discussion see for example Ringius 1997).

Against this background I analyse three different burden sharing rules, namely an allocation based on equal emissions per capita, on equal emissions per capita over time and based on the sovereignty principle.

During the analysis I assume that, regardless of the option chosen, emission trading is always possible. Thus, member states are not required to meet the emission targets through national measures only. They can rather buy emission rights[38] on the market in case they are cheaper than national actions. Provided this market is competitive and neglecting transaction costs, allocating a total EU budget differently among member states does not affect the overall efficiency of

37 Agreements between like-minded countries may generally, i.e. not only in Europe, emerge instead of a global consensus (Sugiyama 2003).

38 The terms emission allowance, entitlement and right are used equivalently throughout this paper.

the trading scheme[39]. It is rather a distributional issue as the member states compliance costs' may be affected. As the absolute costs implications over such a long period are difficult to quantify, a qualitative analysis is provided instead. This analysis then forms the basis for an investigation of the consequences for the political bargaining process.

As the EU will see ten new members in Mai 2004 these should also be considered in any analysis of future European climate policy, especially when focussing on burden sharing rules. This aspect has been neglected so far. However, as Bulgaria and Romania may also be members of the EU in 2013, they are included in the following analysis, too.

The paper is structured as follows. The next section briefly discusses some aspects of justice principles. Section three reviews the burden sharing for the period 2008 to 2012 with a focus on the EU. Section four shortly describes some aspects for post 2012 commitment on the global level before the focus is again on the European level in the section that follows. Section 6 concludes.

2. Climate Policy, Burden Sharing and Justice Principles

When the signs of a changing climate due to human activity became clearer at the end of the eighties of the last century, a discussion on sharing the burden of limiting GHG emission started, too (d'Arge 1989, Rose 1990). Since then, different sets of justice principles, which imply certain allocations, have been presented (and applied). Some of them are quite similar, though they are called by different names. Rose (1992) for example discusses ten different principles which later have been distinguished with regard to whether a "criterion applies to the

39 With regard to an allocation to entities *within* member states as for example describe in the EU directive on Emissions trading (EU 2003), different options do matter. See for example Burtraw et al. (2001) and Burtraw et al. (2002).

process by which a criterion is chosen, the initial allocation of allowances, or to be the final outcome of the implementation of the policy instrument...” (Rose et al. 1998). Blanchard et al. (2001) discuss six principles and Torvanger et al. (2002) present a set of three.[40]

The principles have mostly been considered in the global discussion, i.e. in a burden sharing between industrialised and developing countries. However, when applying them for allocations of emission entitlements two major problems arise: Firstly, the different principles are in most cases equally justified. This is to say that one cannot decide which principle is to be preferred in case there are different opinions. The views on industrialised and developing countries are quite contrary.[41] To overcome this problem, Müller (2001) proposes the so-called *preference score method* to reach a “compromise-solution” between different principles or approaches, as discussed below. Secondly, apart from the principle, a reference base, e.g. population, as well as an operational rule for applying the principle, e.g. allocate in proportion to population, is required (Rose 1992). However, “there is no one-to-one relation between a fairness principle and a specific formula, meaning that one formula can be supported by more than one principle, and one principle can support more than one formula” (Torvanger et al. 1999, p. 15).

Regardless of these theoretical considerations agreements on burden sharing for the period up to 2012 have been reached. On the global level the distinction between Annex I and non-Annex I countries in the UNFCCC as well as the distinction between Annex B and non-Annex B countries in the Kyoto Protocol can be mentioned. The latter is described in more detail in the next section. Another example is the European burden-sharing agreement which was reached in 1998. It is also further analysed below.

40 For a more information see Chapter 3.

41 Interestingly, Rose et al. (1998) showed that different philosophical criteria may be mathematically equivalent and thus have the same welfare outcomes.

3. The First Commitment Period 2008 to 2012

3.1 The International Level

After the United Framework Convention on Climate Change entered into force remarkably quick, it turned out at the first Conference of Parties that the non-binding targets in the Convention for the year 2000 were too vague and inadequate to address the global and long-term problem of climate change. As a consequence the ad-hoc Group on the Berlin Mandate was initiated, which had its first full session in 1995. Appropriate policies and emission targets were intensively discussed and different positions between the Parties become obvious (Grubb et al. 1999). During this process a number of proposals for determining a Party's contribution to limiting GHG emission have been presented. They differ mostly with regard to the justice principle they refer to and the corresponding indicators they use. Torvanger et al. (1999) provide an overview on differentiated proposals.

Table 4.1
Differentiated proposals for sharing the burden of limiting GHG emissions presented in the run-op 3rd Conference of Parties*)

Feature	Party
Convergence (of emissions per capita)	France
	Switzerland
	EU
Historical Responsibility	Brazil
	Brazil RIVM
Multi-criteria formula	Norway
	Iceland
Fossil fuel dependency	Australia
	Iran
Menu-approach	Japan I
	Japan II
GDP per Capita	Poland et al.
	Estonia
	Poland and Russia
	Korea
Cost-effectiveness	New Zealand

*) Source: Torvanger et al. (1999)

Finally, at the third Conference of Parties the Kyoto Protocol was adopted which sets differentiated, binding emission targets for most of the OECD countries. On average, a reduction of 5.2% compared to 1990 was agreed upon. It is interesting to note that there has been no "principled logic" (Babiker et al. 2002, p. 411) for the determination of the emission targets. They are rather the outcome of a political bargaining process with limited time (Torvanger et al. 1999, p. 13, Grubb et al. 1999, p. 86). The targets are listed in Table A4.1 in the annex.

Already during the Kyoto negotiations the EU raised the question of how it could allocate its commitment among its member states. To give an example, in March 1997 an agreement was found which foresaw a reduction of minus 30% for Luxembourg as the strictest target while on the other side Portugal was allowed to increase emissions by 40%. This in turn led to condemnations by other OECD countries as the EU was calling for equal reduction obligations for other Parties (Grubb et al. 1999, pp. 85-86, also Gupta et al. 2001). In the end the EU accepted a target of minus 8% and the so-called "bubble" (Art. 4) found its way into the Kyoto Protocol.[42]

According to Haites (2001) forming a bubble and transferring emission rights under the other flexible mechanisms are economically similar, but differ operationally. With regard to these differences he argues correctly that forming a bubble should not confer any benefits to the members of a bubble. Economically, forming a bubble thus simply implies a reallocation of assigned amount units[43] without payment. So far the European Union (EU 15) formed the only bubble.

42 Apart from the bubble three other flexible mechanisms were introduced that shall allow a cost-efficient meeting of the targets. This is international emissions trading (Art. 17) and the two project-based mechanisms joint implementation (JI, Art. 6) and the Clean Development Mechanism (CDM, Art. 12).

43 assigned amount units = tradable emission rights allocated to Annex B countries of the Kyoto Protocol.

3.2 The European Level

The Burden Sharing for the First Commitment Period

Having an emission target for the EU as whole and subsequently differentiate the commitments between member states has been a guiding idea for the European climate police early in the 1990s. The rationale was to allow cohesion countries[44] to increase emissions while the richer ones in the North would reduce them. In 1991 the Commission proposed a burden sharing with the following three levels: - 5% for Denmark, Germany and The Netherlands, + 15% for the cohesion countries and stabilisation for the rest. However, it was rejected by several countries and thus not pursued any further. Only in the run-up to the Kyoto Protocol and the negotiations on binding targets did the discussion on the burden-sharing re-start. A new proposal by the Commission which foresaw a 10% reduction for 2005, however, was not approved. Only when the Dutch presidency commissioned a study by some experts from The Netherlands did the BSA negotiations really got ahead (Michaelowa et al. 2001, p. 268).

The so-called Triptych approach (Phylipsen et al. 1998), developed by these experts, distinguishes between three sectors for each of which a target was defined. Theses targets were, however, not meant to be sector targets, but rather the basis for the national targets. The underlying idea was to find a compromise between a simple symmetrical approach which was judged to be political unacceptable on the one hand and differentiated but complex and in-transparent agreements on the other hand.

The three sectors are: domestic (households, light industry and agriculture) energy intensive, export-orientated industry and electricity generation. For the domestic sector emissions per capita were to converge in all member states by 2030 at level 30% below the EU 1990 level. Climatic aspects in the different countries have been considered. For the energy intensive, export-orientated industry sector an annual increase in energy efficiency by 1.2 and 1.5% per year between was assumed. Production growth rate was assumed to be 1.1 and 2.1%. For the energy sector an increase in demand of 1.9% and 1% was assumed for the cohesion

44 Cohesion countries at that time were Greece, Ireland, Portugal and Spain, which are low-income countries within the EU.

countries and the other respectively. However, a tailor-made approach combining a country-to-country approach and general guidelines was followed to determine the electricity sector's final allowances (Ringius 1997).

The first proposal of early 1997 had been passed through several negotiations before a final agreement was reached in March of the same year. The latest negotiation result included methane and nitrous oxide, too (Phylipsen et al. 1998, p. 939). After the Kyoto Protocol had been adapted the agreement had to be renegotiated due to the inclusion of three more gases and a lower target for the EU (Michaelowa et al. 2001, p. 269). Table 4.2 provides an overview on the evolution of the first BSA.

Table 4.2
Burden sharing "agreements" for EU 15 in the run-up to the 3rd Conference of Parties

Country	Original triptique 1997 [1)]	Dutch proposal 1997 [2)]	1997 agreement [3)]	UK proposal 1998 [4)]	1998 agreement [5)]
Austria	-1 to -25	-25	-25	-20.5	**-13**
Belgium	-12 to -15	-15	-10	-9	**-7.5**
Denmark	-12 to -25	-25	-25	-22.5	**-21**
Finland	-4 to -7	-10	0	0	**0**
France	-4 to -12	-5	0	0	**0**
Germany	-17 to -30	-30	-25	-22.5	**-21**
Greece	-2 to 2	5	30	23	**25**
Ireland	-2 to -5	15	15	11	**13**
Italy	-5 to -9	-10	-7	-7	**-6.5**
Luxembourg	-17 to -20	-40	-30	-30	**-28**
Netherlands	-6 to -9	-10	-10	-8	**-6**
Portugal	16 to 21	25	40	24	**27**
Spain	6 to 11	14	17	15	**15**
Sweden	5 to 26	5	5	5	**4**
UK	-17 to -20	-20	-10	-12	**-12.5**
EU	**-9 to -17**	**-15**	**-9.2**	**-8.5**	**-8**

1) Range of four variants; Blok et al. (1997); 2) Ringius (1997); 3) EU Council (1997); 4) Michaelowa et al. (2001); 5) EU Council (1998)

As mentioned the rational behind the Triptych approach was to offer an acceptable compromise. The evaluation of the burden sharing agreement, however, depends on criteria considered while judging. And the closer the agreement is coming to be effective, the higher is the opposition. Only recently did the Spanish employers' federation CEOE urge Madrid to renegotiate the burden-sharing deal as "Spain miscalculated emissions levels when it signed up" (PointCarbon 2003).

Table 4.3 gives some examples for selected criteria. As one can see, the burden already changes when the factual reduction obligation, i.e. the difference between baseline emissions and the emission target without any additional climate policy, is calculated (second column). The economic effects are shown in the next two columns. Again, effects differ strongly among member states and are not related to the 1998 agreement. For example, while the minus 12.5% target of the UK seems rather strict compared to the minus 6% target of The Netherlands, the model calculations suggest that the economic implications are rather modest for the UK compared to those for The Netherlands. Differences between welfare and GNP changes are inter alia due to favourable changes in terms-of-trade patterns.

Also when looking at the marginal abatement costs in case the member states were to meet their targets by domestic action only, large differences are found.[45] Blok et al. (2001, p. 27) for example report a range between $€_{99}$ 1 and $€_{99}$ 100 per t $CO_{2\text{-eq}}$. Thus, even though some authors have (implicitly) argued that considering economical metrics would be one fair burden sharing rule[46], there are still problems when trying to determine "the one and only" fair rule.

Apart from that, in the contest of elaborating the national allocation plans for the European trading scheme on entity level Zhang (1999) and Viguier (2001) point out that no harmonisation is required. If national preferences differ among member states, different allocation plans (and thus costs) can still be efficient. The same is true for the discussion on the burden sharing among member states.

Given this discussion one may also consider non-economical-metric-based burden sharing rules. Column six shows the implicit allocation per capita of the 1998 agreement while column seven shows what a burden sharing based on equal

45 Note that absolute figures for abatement costs strongly depend on the baseline assumptions. Figures given above are to show the difference among member states only.

46 See for example Hauch (2003, pp. 517) who writes that "national emission targets that imply equal marginal costs internationally can be seen as one fair international sharing of reduction costs." One the other hand Dessai et al. (2001, p. 333) present a table which is labelled with "Emission change until 2010 under a fair burden sharing rule …" and which provides data on equal burden per unit of GDP and equal marginal cost.

emissions per capita would have had to look like. Column eight and nine provide two economic approaches. Note again that the results strongly depend on the assumption on future GHG emission development.

Table 4.3
Implications of the 1998 burden sharing agreement and alternatives

Country	Change in % compared to 1990[1]	Change in % compared to baseline[2]	Change of Welfare in % with BSA[3]	Change of GNP in % with BSA[4]	Implicit annual allocation per capita of BSA 1998 (kg/capita)[5]	Change in % compared to 1990 if BSA had been based on equal emissions per capita[6]	Change in % compared to 1990 if BSA had been based on equal burden per Unit GDP[7]	Change in % compared to 1990 if BSA had been based on equal marginal costs[8]
Austria	-13	--	--	--	8.8	3.8	--	--
Belgium	-7.5	--	--	--	13.1	-25.9	1.1	-0.6
Denmark	-21	-43.4	-3.97	-5.72	10.6	-22.1	1.2	0.1
Finland	0	-31.5	-1.90	-2.73	15.5	-32.3	18.2	12.1
France	0	-16.0	-0.67	-1.11	9.9	6.1	-9.7	-8.0
Germany	-21	-17.8	-0.63	-1.17	12.1	-31.3	-26.6	-25.8
Greece	25	--	--	--	12.9	1.4	36.7	26.5
Ireland	13	--	--	--	17.2	-31.1	--	--
Italy	-6.5	-13.0	-1.01	-1.47	8.4	17.0	8.4	9.6
Luxembg.	-28	--	--	--	20.5	-63.1	--	--
Netherlds.	-6	-33.1	-4.92	-7.19	13.2	-25.3	5.5	3.4
Portugal	27	--	--	--	7.9	69.4	15.6	9.6
Spain	15	-27.2	-2.83	-4.76	8.4	43.5	3.0	7.3
Sweden	4	-31.0	-3.47	-5.11	8.8	24.0	5.8	9.1
UK	-12.5	-12,7	-0.96	-1.14	10.8	-15.3	-12.0	-10.8
EU	**-8**	**-19.7**	--	--	**10.5**	**-8**	**-8**	**-8**

[1] 1998 agreement; [2] Baseline without any climate policy, source: Viguier et al. (2003, p. 474); [3] Change of welfare without international emission trading, i.e. targets must be met domestically, BSA = 1998 agreement, source Viguier et al. (2003, p. 478), [4] Change of GNP without international emission trading, i.e. targets must be met domestically, BSA = 1998 agreement, source Viguier et al. (2003, p. 478), [5] population in 1990, emissions from EEA (2003), source: own calculations, [6] population in 1990, own calculations, [7] [8] source: Gielen et al. (1998)

The EU Bubble and the Accession Countries

As the EU member states have ratified the Protocol and submitted their corresponding documents to the UN, there is no possibility to include the accession countries joining in May 2004 in the EU bubble for the first commitment period. This would only be possible from 2013 onwards. As the accession countries have also ratified the Protocol there is no option for them to form a bubble of their own as suggested by Michaelowa et al. (2001, p. 277). They also propose that the EU and the accession countries could form an implicit strategic bubble to co-ordinate sale of emission rights and JI projects. The latter aspect is discussed in more detail by Armenteros et al. (2003).

4. Emission Targets on the Global Level after 2012

As mentioned above the discussion on the contribution to limiting GHG emissions on the global scale started end of the eighties of the last century. The different views on equity between developing and industrialised countries which became obvious during the negotiation for the first commitment periods will continue to play a dominant rule for post 2012 negotiations that shall start in 2005 latest (Art. 3.9 Kyoto Protocol). A number of proposals which are differently specified exists as for example the Global Triptych (Groenenberg 2001), which transfers the European experience to the global scale, the Brazilian Proposal (UNFCCC 1997b, IISD 2003) which bases on the historical responsibility for climate change, Contraction & Convergence (Meyer 2000) which bases on equity of rights and equal emissions per capita over time which combines the two former ideas (see Chapter 3).

With regard to the European climate policy it goes without saying that the international negotiations may influence the European discussion (for example Aidt et al. 2002). Indeed, most of the global approaches mentioned above imply a certain allocation for the single EU member states. However, this is not a must. The discussion of post 2012 emission targets within the EU does not necessarily require an agreement on the global level nor the ratification of the Kyoto Protocol. Setting a long-term emission target independently of the global discussion could rather put the EU in the position of the “directional leader” [47]. Finally, apart from any agreement reached on international level, EU member states can always

47 As used by Gupta et al. (2001).

decide to re-allocate emission entitlements among each other according to whatever rule they like to.

5. European Burden Sharing after 2012

In the run-up of the negotiations in Kyoto the EU-Council concluded that "…given the serious risk of such an increase [of global average temperature] and particularly the very high rate of change, the Council believes that global average temperatures should not exceed 2 degrees above pre-industrial level and that therefore concentration levels lower than 550 ppm CO_2 should guide global limitation and reduction efforts" (EU Council 1996). The council's conclusion was recalled in 1997 adding that this "…calls for early action on emission reduction and indicates the need for significant reductions from industrialised countries in the 2000-2020 time-frame" (EU Council 1996).

Even though the two target figures of 550 ppm and a 2 degree Celsius increase seem quite clear, it is difficult to draw concrete emission targets from that. Apart from uncertainty in climate modelling the role of timing is of crucial importance. Nevertheless, some rough ideas are possible as for example shown in Table 3.1. However, it is not straightforward to determine the European share of the pie.

Interestingly, there has been no co-ordinated discussion on a post-2012 burden sharing agreement within (an enlarged) European community by now. Michaelowa et al. (2001, p. 278) state that the EU should negotiate a bubble when negotiations on CoP-level on post 2012 commitments start in 2005 with all members at this time. However, no concrete options for the burden-sharing agreement are mentioned. Armenteros et al. (2003, p. 271) state that there is no real strategy by the EU on climate policies in the accession countries. Nevertheless there will be an implicit climate policy due to the adoption of the acquis communautaire which includes lots of environmental regulation as for example the IPPC-directive.

On the other hand some statements by individual member states have been made. In the 2003 Energy White Paper on the UK government accepted "…the Royal Commission on Environmental Pollution's (RCEP's) recommendation that the

UK should put itself on a path towards a reduction in carbon dioxide emissions of some 60% from current levels by about 2050" (UK 2003, p. 4 and also RCEP 2003). In Germany the Socialist and the Green Party stated in their coalition treaty (SPD/Bündnis 90 Die Grünen 2000) that Germany would reduce emission by 40% compared to the 1990 level by 2020 in case the remainder of the EU accepts a reduction target of 30%.[48]

Against this background I discuss three burden-sharing options for the European Union for the time after 2012, namely equal emissions per capita, equal emissions per capita over time and the sovereignty principle. The approaches are discussed in detail in the next section. At this point it is only worthwhile to mention that an allocation of emission rights on the global scale based on equal emissions per capita has been supported by different European (and non-European) policy makers. Some examples which are all taken from Meyer (2000) are given below. The concept of Contraction & Convergence includes a reduction of global GHG emission (Contraction) and an allocation of tradable emission entitlements carried out on an equal basis to all of human kind – i.e. an equal per capita allocation (Convergence). One should remember that no allocation requires specific *domestic* emission reductions at any costs for any MS. There would always be the possibility to buy emission rights on the market.

- September 1998: The European Parliament adopts a resolution on climate change that calls for global constitutional principles for the long-term management of global climate change using Contraction & Convergence.

- October 1998: Tony Blair, UK Prime Minister, writes: "I agree that, in the fight against climate change (C&C) makes an important contribution to the debate on how we achieve long-term climate stability, taking into account the principles of equity and sustainability …"

48 However, one has to keep in mind that Germany already has a target of minus 21 percent. Thus, the additional commitment is about 19 percent points. As the remaining member states in the EU do have less stringent target until 2012, the German proposal implies much stricter commitments by the other MS in the future. Furthermore, it was unclear whether EU 15 or an enlarged EU was considered.

- April 1999: Svend Auken, Danish Environment Minister: “The approach ‘Contraction & Convergence’ is precisely such an idea. It secures a regime that would allow all nations to join efforts to protect our global commons from being over-exploited, without the risk that any country would be deprived of its fair long-term share of the common environmental emission space.”

- June 2000: Jan Pronk, Netherlands Environment Minister said that C&C is the most equitable, the cheapest and easiest and the most effective.

Given these statements one can quite reasonably imagine that an allocation within the European Community will take equal emissions per capita to a higher extend into account than in the Triptych approach. The sovereignty principle is included in the analysis as it offers a straightforward approach for sharing the burden.

For all analyses a “double fifty” approach is assumed, i.e. I assume that the EU sets itself a target of minus 50% compared to the 1990 level. The target is to be met in 2042, i.e. 50 years after the Framework Convention was adopted in Rio de Janeiro.[49] Apart from environmental concerns industry, too, is likely to support long-term targets. This has become obvious in the recent discussion on the national allocation plans for the EU trading scheme.[50] For all cases I assume that the future commitment periods are of 5 years length which is by no means decided yet. If not stated otherwise EU means EU 27, i.e. EU 15 plus EU 10 (the accession countries joining in May 2004) plus Bulgaria and Romania.[51] Where required, emission data for the year 1991 to 2007 are based on real data until 2001 for EU 15 (EEA 2003) and for Cyprus and Malta (IEA 2003) and on data until 1999 for EU 10 (except Slovenia), Bulgaria and Romania (UNFCCC 2002). Data for Slovenia is taken from (Slovenia 2002). In subsequent years after the latest data on record emissions are assumed to linearly[52] reach the Kyoto-target in 2008[53].

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49 There is no economically motivated rational behind this target. It is rather the two times 50 approach that might be adopted by policy makers which sometimes like simple figures.

50 This is especially true for those industries with long-living investment as in the power sector. In Germany for example, this long-term aspect has been on the agenda in top-level discussions among Chancellor Schröder and CEO from major utilities (Anonymous 2003).

51 Accession for Bulgaria and Romania is targeted in 2007.

52 For Lithuania emissions are also assumed to change linearly between 1990 and 1998.

5.1 Equal Emissions per Capita

For the allocation based on equal emissions per capita (EEC) a linear decrease of emissions from the EU-budget in 2012[54] until the target is reached in 2042 is assumed. The available annual budget is distributed among the member states according to the member states share of total population in that year.[55] Population data is taken from USBC (2003). Of course, population changes differently among member states.[56] The highest increase can be observed in Luxembourg (+ 88% in 2050 compared to 1990) whereas the biggest decrease is predicted in Bulgaria (- 47% in 2050 compared to 1990). A corresponding graph is given in the annex. The results for each commitment period until 2042 are given in Table A4.2 in the annex. Cumulative emission rights for the period from 2013 to 2042 are shown in Table 4.5.

5.2 Equal Emissions per Capita over Time (EECT)

An allocation based on equal emissions over time has been presented in Chapter 3. The approach was applied on a global level. However, it is also applicable in the European context. The rationale behind this approach was as follows: With an allocation based on equal emissions per capita as analysed in the previous section, the distribution may be perceived as fair from the point when EEC are reached. Until this point is reached, however, they may differ considerably (see also Figure 4.1a). This is why it was proposed to allocate emissions entitlements in such a way that average emissions per capita in a period to be specified are also the same prior to the time when equal emissions per capita are reached (hatched area in

53 Here: Kyoto target for 2008 = Assigned Amount for the five-year period 2008-12 divided by five. One may also argue that the emissions in 2008 can be higher when emissions in 2012 are lower to meet the emission budget. However, as below only five year periods are analysed the discussion of intra commitment period distribution is not important.

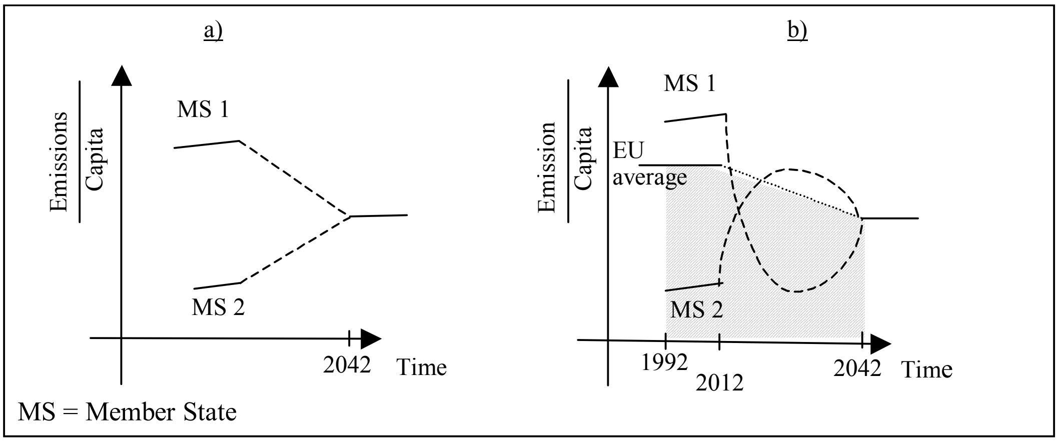
54 EU-budget in 2012 is one fifth of the Assigned Amount in the first commitment period. For Cyprus and Malta, which are no Annex B countries yet, an 8% reduction obligation has been assumed.

55 Later allocations could also be based on population data of the previous year(s) instead of relying on prognoses for the year considered.

56 In case one thinks that these changes imply to much uncertainty with regard to the allocation in a future year, one may consider to allocate on the basis of the member states' seats in the European Parliament which are based on population, too.

Figure 4.1b). Thus, when looking at per capita emissions in 2042 one cannot only say that the allocation is based on equity of rights in that year and later. One can also look back and see that average emissions per capita in different countries have already been the same for the period considered. For the analysis below, the period is to start in 1992 the year the UNFCCC was adopted. Regarding the global discussion the approach allows for some interesting flexibility with regard to the start of entering an international agreement.

Figure 4.1
Schematic representation of a) converging emissions per capita and b) equal emissions over time



With the total emission budget in 2042 set and the population prognoses at hand one can calculate the allowed budget of average emissions per capita for the 50 year period from 1992 to 2042. Similar to the analysis is section 5.1, the allowed emissions per capita decrease linearly from the value in 2012 until the target value in 2042 which is of course identical to the first EEC approach. What is different is the allocation of emission entitlements.[57] Depending on a member state's cumulative emissions per capita until 2012, the allocation from 2013 onwards

57 As there is already a burden sharing agreement for the first commitment period the approach can only be applied from 2013 onwards.

may take a form as shown in Figure 4.1b. For the exact determination of the allocation, I use the same quadratic function[58] as in Chapter 3.

$$\int_{2013_i}^{2042} (a_i t^2 + b_i t + c_i)dt = A - D_i \tag{4.1}$$

where a, b, c coefficients, t = time, A allowable budget, D_i describes the cumulative emissions per capita and year between 1992 and 2012 for member state i.

With the emissions per capita in 2012 and 2042 known for each member state, equation (4.1) can be solved.[59]

As for the equal per capita approach the results for each commitment period until 2042 are given in the annex. Cumulative emission rights for the period from 2013 to 2042 are also shown in Table 4.5.

5.3 Sovereignty Principle

The basic idea of the Sovereignty principle is that "all nations have an equal right to pollute and to be protected from pollution." An operational rule would be to "cut back emissions in a proportional manner across all nations" (Rose et al. 1998, p. 30). In the European context this means that all MS would have to reduce emissions by a uniform rate equal to the common target. The rationale behind this approach would be the idea of sovereign states with equal bargaining power negotiating over the allocation. The principle finally results in a protection of rights that have been established by usage or custom (Aidt et al. 2002, p. 13). Inequalities regarding the release of GHG emissions would thus be perpetuated (Blanchard et al. 2001). Regardless of any philosophical considerations, the sovereignty rule can be perceived as the simplest form of an allowances allocation (for example Schmidt et al. 1998) what makes it worth to analyse it. The results are given in Table 4.5 and Table A4.4 respectively.

58 There is no economical rational behind the specific form of the quadratic function. It is rather used to be able to shift the vertex as required by the country specific emission balance (see also Figure 4.1b).

5.4 Discussion

As turned out during the discussion of the 1998 burden sharing agreement there are different ways to analyse the “fairness” of allocation schemes. Table 4.4 summarises some important aspects. Column two to four show the member states’ reduction obligation in 2042 compared to 1990 levels for the three approaches studied above. As can be seen, the individual allocation varies considerably depending on the approach while the total budget for the EU is always the same. However, this is only the specific outcome for the year 2042. From a member state’s perspective the resulting cumulative emission entitlements are likely to be of the same importance. This is why the next three columns show the cumulative emission entitlements for the each MS for the period between 2013 and 2042, i.e. the period that can still be negotiated. To get an idea of the relative difference among the three approaches, column 8 shows the ratio between the minimum and the maximum allocation. A small figure indicates a high difference. As can be seen for most member states the number of allowances with an allocation based on equal emissions per capita lies between those of the two other approaches. Implications of the differences are discussed below.

Regarding EECT one should note that this approach would imply some bias as it would only be applied from 2013 on. Member states which are net allowance buying countries in the first commitment period will incur higher emissions compared to a no-trade or scenario. These higher emissions (per capita) would be deducted from the countries budget after 2012, although they would be in line with the rule during the first period.

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59 For the analytic solution see annex of Chapter 3.

Table 4.4
Implications of different allocation methods for (future) member states of the EU[1)]

	Change in % in 2042 compared to 1990			Cumulative emission rights 2013-42 (1000 t)			
	Equal per Cap.	EECT	Sovereignty	Equal per Cap.	EECT	Sovereignty	Ratio (min/max)
Austria	-39	-39	-50	1.979	2.175 [2)]	1.590	0,731
Belgium	-56	-56	-50	2.533	1.806	2.988	0,604
Bulgaria	-80	-80	-50	1.505	1.110	3.054	0,363
Cyprus	33	33	-50	206	283	82	0,290
Czech Rep.	-71	-71	-50	2.373	1.364	3.973	0,343
Denmark	-50	-50	-50	1.382	1.147	1.329	0,830
Estonia	-82	-82	-50	314	74	812	0,091
Finland	-61	-61	-50	1.268	769	1.718	0,448
France	-32	-32	-50	15.309	16.895	12.477	0,739
Germany	-62	-62	-50	19.502	16.707	23.268	0,718
Greece	-40	-40	-50	2.589	2.314	2.711	0,854
Hungary	-48	-48	-50	2.282	2.806	1.908	0,680
Ireland	-40	-40	-50	1.182	608	1.289	0,471
Italy	-37	-37	-50	13.615	15.738	10.838	0,689
Latvia	-63	-63	-50	504	643	554	0,784
Lithuania	-60	-60	-50	851	826	1.125	0,734
Luxembourg	-62	-62	-50	144	61	198	0,307
Malta	17	17	-50	108	137	49	0,355
Netherlands	-49	-49	-50	4.255	3.272	4.490	0,729
Poland	-62	-62	-50	9.166	8.859	10.641	0,833
Portugal	-6	-6	-50	2.422	3.053	1.608	0,527
Romania	-55	-55	-50	5.140	5.990	5.208	0,858
Slovak Rep.	-57	-57	-50	1.317	1.277	1.531	0,834
Slovenia	-45	-45	-50	458	502	398	0,792
Spain	-21	-21	-50	9.580	11.335	7.025	0,620
Sweden	-23	-23	-50	2.254	2.716	1.661	0,612
UK	-47	-47	-50	15.495	14.683	15.208	0,948
Total	**-50**	**-50**	**-50**	**117.732**	**117.151**	**117.732**	**0,995**

[1)] Overall emission target for EU in 2042: 50% of 1990 levels (in lieu of 1990 for: Bulgaria (1988); Hungary (1985-87); Poland (1988); Romania (1989)); For Cyprus and Malta only CO_2 emission form energy combustion have been considered. [2)] Underlined figures show the maximum allocation

Cost Implications of Different Allocation Options

Different allocations of emission entitlements imply different compliance costs for the single member states. Compliance costs depend on the emission reduction obligation and the emission (reduction) costs. The reduction obligation to be considered before a certain commitment period has started is the difference of business as usual emissions less the entitlements distributed.[60] Compliance costs are the costs incurred due to domestic abatement plus the costs for the purchase of entitlements on the market. An exact quantification of the different compliance costs is out of the scope of this paper. Yet, one may question whether it is reasonable to do so for a period of more than 20 years. First of all the development of future emissions and thus reduction obligations is highly unclear. A great number of scenarios exist (see for example IPCC 2000; Zhang 2002 gives an overview on estimates on EU baseline emissions in 2010 that already differ by factor 2). Secondly, development of the future abatement costs for the time horizon considered costs are also highly uncertain. On the other hand some qualitative relations may be of interest.

Given the differences in cumulative emissions in the period 1992 to 2042, consider a one period game. Assuming a competitive market and neglecting transaction costs one would always, for a given EU emission target, expect the same allowance price within the EU market regardless of the allocation to the individual member state.[61] Only the member states' compliance costs may change. This change will depend on whether the country is a net-seller or net-buyer of entitlements.

The net-buyer's and seller's situation in a one period game is depicted in Figure 4.2. Assuming a certain allocation option as a reference which results in a reduction obligation of q^1, the *buyer* will reduce the quantity q^* at home and buy the remaining entitlements q^1-q^* on the market at the equilibrium price p^*. Let us denote the *highest* reduction obligation a country can face under one of the three allocation approaches discussed above with q^b and the lowest obligation with q^s. With a different allocation method, the number of allowances received may either be smaller or bigger than the initial one. In case the number is smaller a buying country must reduce more what results in additional costs L amounting to

$$L = (q^b - q^1)p^* \tag{4.2}$$

60 In case banking of entitlements is allowed they also have to be considered.

61 In case the EU market is linked to other (regional) market the price may change depending on the stringency of emission targets in the other countries. For a discussion of resulting impacts see Haites et al. (2001), for options to deal with different stringency of targets see for example Rehdanz et al. (2002).

In case the number is higher the country has to reduce less and will realise a relative benefit *B* compared to the initial allocation amounting to:

$B = (q^1 - q^s)p^*$ for $q^s \geq q^*$ and (4.3)

$B = (q^1 - q^*)p^* + [(q^* - q^s)p^* - (q^* - q^s)c(q)]$ for $q^s < q^*$ (4.4)

where $c(q)$ is the marginal abatement costs curve for domestic reduction measures at home (i.e. the term $(q^* - q^s)c(q)$ equals area A in Figure 4.2a)

While in case (2) the country only buys less allowances on the market it also benefits from selling entitlements in the third case (see area B in Figure 4.2a).

For the selling country the situation is slightly different. Supposing it receives a bigger allocation it has to reduce less and can sell additional allowances resulting in an increased benefit *B* of

$B = (q^1 - q^s)p^* - (q^1 - q^s)c(q)$ (4.5)

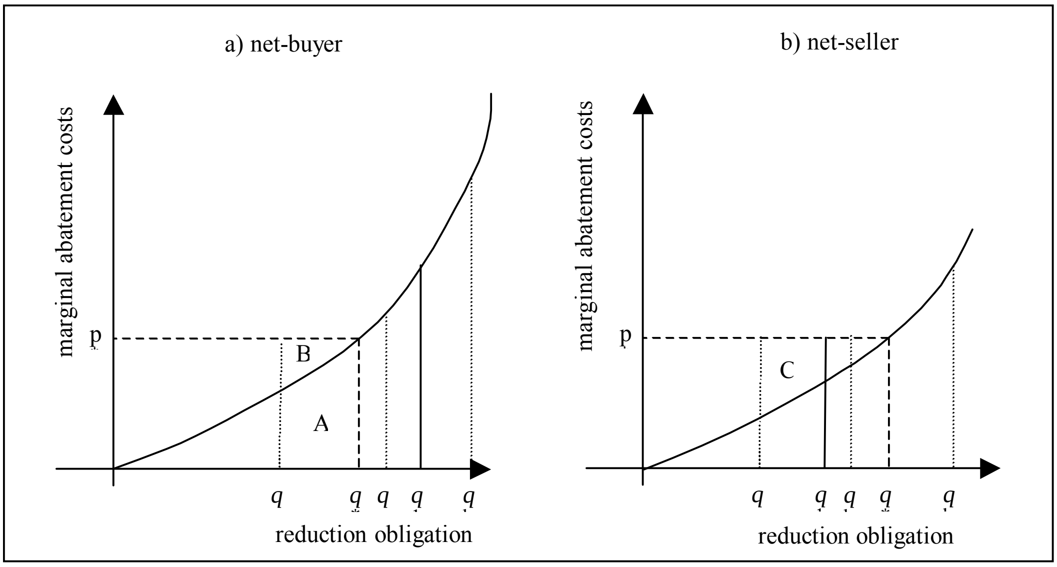
which equals area C in Figure 4.2b). If it is allocated a smaller number of allowances compared to the reference allocation it incurs a relative loss *L* compared to the reference allocation amounting to:

$L = (q^b - q^1)p^* - (q^b - q^1)c(q)$ for $q^b \leq q^*$ and (4.6)

$L = [(q^* - q^1)p^* - (q^* - q^1)c(q)] + (q^b - q^*)p^*$ for $q^b > q^*$ (4.7)

In the last case the selling country would turn to a buying country.

Figure 4.2
Impact of different reduction obligations on abatement and compliance costs



Against this background one can quantify the maximum relative losses L^{max} due to a change of the burden sharing rule. [62] They occur when the reference allocation was the best possible one, i.e. $q^1 = q^s$ and amount to

$$L^{max} = (q^b - q^s)p^* \tag{4.8}$$

when comparing the three possible allocation rules.

For the net-buyer this is obvious from (1) due to the fact that a buying country cannot benefit from any sale of allowances when its reduction obligation is increased. For the seller it can be derived from (5) and (6) when assuming that abatement costs for the reductions considered are zero.[63] Whether these maximum losses will be realised is discussible. In case of a relative stringent emission target abatement costs of zero are unlikely to occur, so that the relative losses for the sellers are likely to be smaller than the maximum.

62 Assume that negotiators are most interested in minimising losses from changing the allocation scheme. One could also argue the other way around and argue that relative benefits are most important for determining a member states priority.

63 In case abatement costs are even negative losses can be higher.

Though the carbon price is highly uncertain Table 4.5 provides an overview on financial implications of a price of 10 EUR. As absolute figures may distort the picture, annual costs are put in relation with the member states' GDP in 2000. As additional costs have to be born by someone, annual costs per capita are also presented. Such indicators may be relevant for policy implication as will be discussed in the next section.

As can be seen in Table 4.5 the annual costs as percentage of GDP in 2000 are highest for the accession countries incl. Bulgaria and Romania. Obviously, for those countries there is much more at stake. At the other end of the range the UK and Austria face rather low differences in costs with these three allocation options.

Table 4.5
Implications of different allocation options at a carbon price of 10 EUR/t $CO_{2\text{-}eq}$

	Allocation maximum (Mio. t) 1)	Allocation minimum (Mio. t) 1)	Delta (Mio. t)	Total costs 2013-42 (Mio. EUR)	Annual costs (Mio. EUR)	Annual Costs as % of GDP in 2000
Austria	2.175	1.590	585	5.852	195	0,09
Belgium	2.988	1.806	1.182	11.824	394	0,16
Bulgaria	3.054	1.110	1.944	19.441	648	4,73
Cyprus	283	82	201	2.011	67	0,70
Czech Rep.	3.973	1.364	2.608	26.082	869	1,44
Denmark	1.382	1.147	235	2.347	78	0,05
Estonia	812	74	737	7.375	246	4,39
Finland	1.718	769	949	9.491	316	0,24
France	16.895	12.477	4.418	44.180	1.473	0,10
Germany	23.268	16.707	6.561	65.613	2.187	0,11
Greece	2.711	2.314	397	3.966	132	0,11
Hungary	2.806	1.908	898	8.981	299	0,59
Ireland	1.289	608	682	6.815	227	0,22
Italy	15.738	10.838	4.901	49.009	1.634	0,14
Latvia	643	504	139	1.392	46	0,59
Lithuania	1.125	826	299	2.986	100	0,82
Luxembourg	198	61	137	1.371	46	0,21
Malta	137	49	88	883	29	0,72
Netherlands	4.490	3.272	1.218	12.180	406	0,10
Poland	10.641	8.859	1.781	17.814	594	0,33
Portugal	3.053	1.608	1.446	14.455	482	0,42
Romania	5.990	5.140	850	8.502	283	0,70
Slovak Rep.	1.531	1.277	255	2.548	85	0,39
Slovenia	502	398	104	1.043	35	0,17
Spain	11.335	7.025	4.311	43.106	1.437	0,24
Sweden	2.716	1.661	1.055	10.546	352	0,14
UK	15.495	14.683	812	8.120	271	0,02

1) see Table 4.4.

Policy Implications

Whether or not it is probable that in the case of the EU all *buying* countries receive a smaller allocation with a changing burden sharing rule can only be assumed. It might be possible for some countries which then would incur high losses. However, it is not possible to say, whether a certain member state will be a buying or a selling country under the different schemes as future abatement costs are highly uncertain. However, the difference between maximum and minimum allocation is computable. Indeed it has already been presented in Table 4.5 which showed the ratio of the two figures. The lower the figure the higher the difference and thus the more likely a member state will be interested in getting a certain burden sharing rule.

For this a "relevance indicator" based on the minimum-maximum ratio is introduced. The indicator which is country-specific is determined as follows:

$$I_i = 1 - \frac{allocation_{\min}}{allocation_{\max}} \qquad 0 \leq I_i \leq 1$$

A value of one would mean that much is at stake while of value of 0 would mean that nothing is at stake as the different allocation rules result in the same allocation. As decision makers are unlikely to think in black and white only, a relevance threshold can be introduced. By so doing, one can determine the (number of) countries that are likely to be active during the negotiations with regard to a certain outcome (see Figure 4.3). To give example, assume that member states only care about the allocation if the indicator is greater or equal than 0.8. In this case 21 MS care about the allocation rule.[64] This indicator may be relevant if politicians are guided during the negotiations by idea that they want to prove their electorate that they fought for the biggest allocation possible regardless of the economic importance.

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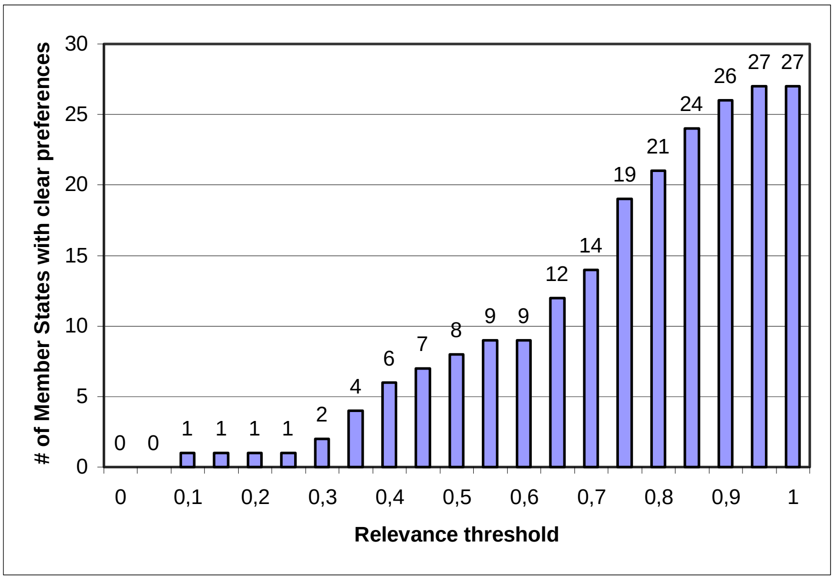
64 The outcome depends on the period analysed. If emissions (entitlements) prior to 2013 are considered, too, the ratio is converging towards one. This can be explained by the fact that emissions (entitlements) in the first part (1992-2012) are independent of the allocation from 2013. Dividing two increasing numbers that differ by the same absolute value gives a result converging to one. The rational of extending the period considered could be to reflect historic emission or contribution to climate change. Whether and to what extend past emissions should be referred to is a value judgement to be taken by political decision makers. During the negotiations of the first BSA it did not play a role (Ringius 1997, p. 41). The discussion could, however, resume and thus influence the complexity of the negotiations.

Figure 4.3
Number of member states interested in a certain allocation rule as function of the relevance threshold



However, politicians may also keep the economic implications in mind. Referring to Table 4.6, one can determine the threshold that has to be passed in order to make a certain number of MS interested in the final allocation rule (see Table 4.6).

Table 4.6
Thresholds to be passed for member states being interested in the allocation rule with a carbon price of 10 EUR/ t $CO_{2\text{-eq}}$

		Number of member states interested					
		5	10	15	20	25	27
Costs as % in GDP in 2000	Threshold ≥	0.781	0.417	0.221	0.135	0.094	0.017

Depending on the negotiators' attitude assumed, one can get an idea on how negotiations will be. Assuming that they rather tent to fight in Brussels for a high allocation in order to get their voters' favour at home, negotiations will be difficult. Already for a threshold of 0.75, i.e. ¾ of the total scale, 19 member states will be active. In case the economic implications are also taken into account, the analysis is much more difficult as it depends on the carbon price assumed. However, to allow for a rough idea note that for example the indicative target for ODA is 0.7% of *GNI* for industrialised countries. Though this figure does not seem very high, only very few states comply (OECD 2003). Thus, with carbon price of 10 EUR / t CO_2 negotiations may become complex as member states may feel that much is at stake.

In addition to that the new member states may ask for money and assistance when new commitments enter into force as Dessai et al. (2001, p. 331) report for the cohesion countries in the past. With regard to the EU financial system in an enlarged Community Hefeker (2003) argues that redistribution should be done as lump-sum transfer and not through the agriculture and social fond any more. This may also be considered in the context of climate policy.

6. Conclusion

Sharing the burden of limiting GHG emission to the atmosphere has been done between different countries in the past on both global and European level. It is likely to play a vital role in the future, too. Against this background three different options for allocating an EU-budget to its member states until 2042 have been analysed in the paper. The options studied are an allocation based on equal emissions per capita, on equal emissions per capita over time and based on the sovereignty principle. The three approaches result in considerably different allocations at least for single member states.

As the different allocations will influence the countries compliance costs they are likely to have (strong) negotiating positions in case this difference is large. To study this aspect in more detail a relevance factor has been introduced that describes from what ratio between minimum and maximum allocation MS care about the specific allocation rule. Assuming a rather high threshold, negotiations on a future burden sharing rule are likely to be complicated already with the limited number of allocation options discussed in this paper. Experienced and skilful negotiators may thus play a very important role in the future as they did in the past (Ringius 1997, p. 35). In order to avoid this complex bargaining process an auction of emission entitlements on EU level may serve this problem. However, some other questions as for example the issue of revenue use would emerge.

Future work may include other burden sharing rules. An extension of the Triptych approach is a very interesting option. A more detailed analysis of the cost implications that takes more information on the member states' abatement costs into account is also desirable.

Annex

Table A 4.1
Quantified emission limitation or reduction commitment

Party	Percentage of base year or period
Australia	108
Bulgaria	92
Canada	94
Croatia	95
Czech Republic	92
Estonia	92
European Community (EU 15)	92
Hungary	94
Iceland	110
Japan	94
Latvia	92
Liechtenstein	92
Lithuania	92
New Zealand	100
Norway	101
Poland	94
Romania	92
Russian Federation	100
Slovakia	92
Slovenia	92
Switzerland	92
Ukraine	100
United States of America	93

Figure A 4.1
Population development in Europe

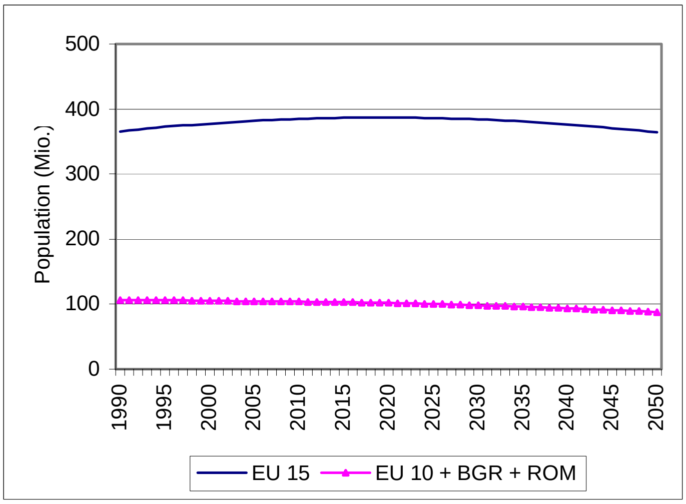


Table A 4.2
Assigned amount (AA) for EU member states with an allocation based on equal emission per capita (emissions and AA in Mio. t $CO_{2\text{-eq}}$)

	Emissions 1990 [2]	AA 2013-17	Change in % [1]	AA 2018-22	Change in %	AA 2023-27	Change in %	AA 2028-32	Change in %	AA 2033-37	Change in %	AA 2038-42	Change in %	AA 2043-47	Change in %
Austria	78	408	4	377	-3	346	-11	315	-19	283	-28	251	-36	237	-39
Belgium	141	518	-27	480	-32	442	-37	403	-43	365	-48	325	-54	310	-56
Bulgaria	157	341	-57	301	-62	265	-66	230	-71	199	-75	169	-78	154	-80
Cyprus [3]	4	41	109	38	97	36	85	33	70	30	55	27	40	26	34
Czech Rep.	190	502	-47	459	-52	416	-56	373	-61	331	-65	291	-69	272	-71
Denmark	69	277	-20	259	-25	241	-30	222	-36	202	-42	181	-48	174	-50
Estonia	41	67	-67	61	-70	55	-73	49	-76	44	-79	38	-81	36	-82
Finland	77	261	-32	242	-37	222	-43	202	-48	181	-53	160	-59	152	-61
France	561	3.091	10	2.881	3	2.666	-5	2.449	-13	2.226	-21	1.996	-29	1.910	-32
Germany	1.212	4.063	-33	3.734	-38	3.408	-44	3.084	-49	2.764	-54	2.448	-60	2.320	-62
Greece	105	534	2	493	-6	451	-14	410	-22	370	-29	330	-37	315	-40
Hungary	102	483	-5	440	-13	399	-21	359	-29	319	-37	281	-45	265	-48
Ireland	53	222	-17	214	-20	205	-23	193	-28	181	-32	167	-38	164	-38
Italy	509	2.860	12	2.616	3	2.377	-7	2.146	-16	1.920	-25	1.697	-33	1.600	-37
Latvia	31	109	-30	99	-36	88	-43	78	-50	69	-55	60	-61	56	-64
Lithuania	52	177	-31	163	-37	149	-42	134	-48	121	-53	107	-58	102	-61
Luxembourg	11	26	-52	25	-53	25	-54	24	-56	23	-58	21	-61	21	-61
Malta [3]	2	21	86	20	76	19	64	17	51	16	37	14	23	14	18
Netherlands	210	847	-19	795	-24	741	-29	685	-35	625	-40	562	-46	540	-49
Poland	564	1.917	-32	1.763	-38	1.606	-43	1.449	-49	1.292	-54	1.138	-60	1.072	-62
Portugal	61	504	64	463	51	423	38	383	25	344	12	304	-1	287	-6
Romania	265	1.089	-18	993	-25	899	-32	807	-39	719	-46	633	-52	595	-55

Table A 4.2 continued

	Emissions 1990 [2]	AA 2013-17	Change in % [1]	AA 2018-22	Change in %	AA 2023-27	Change in %	AA 2028-32	Change in %	AA 2033-37	Change in %	AA 2038-42	Change in %	AA 2043-47	Change in %
Slovak Rep.	73	272	-25	252	-31	231	-36	209	-42	187	-48	166	-54	157	-57
Slovenia	19	96	0	88	-9	80	-17	72	-25	64	-33	56	-42	53	-45
Spain	288	2.007	40	1.840	28	1.673	16	1.510	5	1.353	-6	1.198	-17	1.131	-21
Sweden	73	454	25	424	17	394	8	361	-1	328	-10	294	-19	282	-22
UK	744	3.083	-17	2.892	-22	2.697	-28	2.492	-33	2.277	-39	2.054	-45	1.982	-47
Total	**5.691**	**24.273**	-15	**22.413**	-21	**20.552**	-28	**18.692**	-34	**16.832**	-41	**14.971**	-47	**14.227**	**-50**
Emissions per Capita	12,06	9,9	-18	9,2	-24	8,5	-30	7,8	-36	7,1	-41	6,4	-47	6,2	-49

[1] compared to 1990 levels [2] In lieu of 1990 for: Bulgaria (1988); Hungary (1985-87); Poland (1988); Romania (1989) [3] CO_2 emissions from fuel combustion only (Source IEA 2003).

Table A 4.3
Assigned amount (AA) for EU member states with an allocation based on equal emission per capita over time (emissions and AA in Mio. t $CO_{2\text{-eq}}$), footnotes as for Table A 4.2

	Emissions 1990 [2]	AA 2013-17	Change in % [1]	AA 2018-22	Change in %	AA 2023-27	Change in %	AA 2028-32	Change in %	AA 2033-37	Change in %	AA 2038-42	Change in %	AA 2043-47	Change in %
Austria	78	370	-5	401	3	407	4	386	-1	340	-13	271	-31	237	-39
Belgium	141	527	-25	358	-49	248	-65	197	-72	205	-71	270	-62	310	-56
Bulgaria	157	465	-41	256	-67	126	-84	67	-91	70	-91	125	-84	154	-80
Cyprus [3]	4	32	62	49	151	58	199	59	202	51	162	35	77	26	34
Czech Rep.	190	623	-34	312	-67	119	-87	40	-96	70	-93	200	-79	272	-71
Denmark	69	248	-28	212	-39	186	-46	170	-51	164	-53	169	-51	174	-50
Estonia	41	108	-47	29	-86	-19	-109	-36	-117	-24	-112	15	-93	36	-82
Finland	77	290	-25	164	-58	83	-78	50	-87	63	-84	119	-69	152	-61
France	561	2970	6	3120	11	3111	11	2945	5	2618	-7	2133	-24	1910	-32
Germany	1.212	4148	-32	3274	-46	2649	-56	2271	-63	2135	-65	2231	-63	2320	-62
Greece	105	572	9	456	-13	370	-29	317	-40	295	-44	304	-42	315	-40
Hungary	102	452	-11	525	3	546	7	517	2	442	-13	323	-36	265	-48
Ireland	53	229	-14	124	-53	56	-79	29	-89	49	-81	120	-55	164	-38
Italy	509	2651	4	2936	15	2991	18	2827	11	2453	-4	1881	-26	1600	-37
Latvia	31	117	-24	126	-19	124	-20	113	-27	94	-39	69	-56	56	-64
Lithuania	52	217	-16	169	-34	133	-48	110	-57	98	-62	99	-62	102	-61
Luxembourg	11	29	-48	13	-76	3	-94	-1	-101	3	-95	14	-74	21	-61
Malta [3]	2	16	43	24	106	28	140	28	141	24	111	17	49	14	18
Netherlands	210	837	-20	628	-40	486	-54	415	-60	416	-60	490	-53	540	-49
Poland	564	1989	-29	1730	-39	1510	-46	1331	-53	1196	-58	1104	-61	1072	-62
Portugal	61	473	54	565	84	598	95	572	86	490	60	355	16	287	-6
Romania	265	1129	-15	1153	-13	1117	-16	1024	-23	880	-34	687	-48	595	-55

Table A 4.3 continued

	Emissions 1990 [2)]	AA 2013-17	Change in % [1)]	AA 2018-22	Change in %	AA 2023-27	Change in %	AA 2028-32	Change in %	AA 2033-37	Change in %	AA 2038-42	Change in %	AA 2043-47	Change in %
Slovak Rep.	73	301	-17	253	-30	214	-41	185	-49	166	-54	158	-56	157	-57
Slovenia	19	90	-6	95	-2	93	-3	87	-10	76	-21	60	-37	53	-45
Spain	288	1878	31	2115	47	2170	51	2053	43	1775	23	1344	-7	1131	-21
Sweden	73	434	19	497	37	520	43	499	37	435	20	331	-9	282	-22
UK	744	3059	-18	2752	-26	2491	-33	2275	-39	2109	-43	1996	-46	1982	-47
Total	**5.691**	**24255**	**-15**	**22336**	**-22**	**20418**	**-28**	**18530**	**-35**	**16694**	**-41**	**14919**	**-48**	**14227**	**-50**
Emissions per Capita	12.0	9.9		9.1		8.4		7.7		7.0		6.4		6,2	

Table A 4.4
Assigned amount (AA) for EU member states with an allocation based on the sovereignty principle (emissions and AA in Mio. t $CO_{2\text{-eq}}$), footnotes as for Table A 4.2

	Emissions 1990 [2]	AA 2013-17	Change in % [1]	AA 2018-22	Change in % [1]	AA 2023-27	Change in %	AA 2028-32	Change in %	AA 2033-37	Change in %	AA 2038-42	Change in %	AA 2043-47	Change in %
Austria	78	325	-17	301	-23	277	-29	253	-35	229	-41	205	-48	195	-50
Belgium	141	623	-12	573	-19	523	-26	473	-33	423	-40	373	-47	353	-50
Bulgaria	157	609	-22	569	-28	529	-33	489	-38	449	-43	409	-48	393	-50
Cyprus [3]	4	17	-12	16	-19	14	-26	13	-33	12	-40	10	-47	10	-50
Czech Rep.	190	824	-13	759	-20	694	-27	630	-34	565	-40	500	-47	475	-50
Denmark	69	263	-24	247	-29	230	-34	213	-38	196	-43	180	-48	173	-50
Estonia	41	164	-19	153	-25	141	-31	129	-36	118	-42	106	-48	102	-50
Finland	77	367	-5	335	-13	302	-22	270	-30	238	-38	206	-47	193	-50
France	561	2.664	-5	2.430	-13	2.196	-22	1.963	-30	1.729	-38	1.495	-47	1.402	-50
Germany	1.212	4.610	-24	4.317	-29	4.024	-34	3.732	-38	3.439	-43	3.146	-48	3.029	-50
Greece	105	615	18	550	5	484	-8	419	-20	354	-33	288	-45	262	-50
Hungary	102	373	-27	351	-31	329	-35	307	-40	285	-44	263	-48	254	-50
Ireland	53	285	7	257	-4	229	-14	201	-25	173	-35	145	-46	134	-50
Italy	509	2.267	-11	2.083	-18	1.898	-25	1.714	-33	1.530	-40	1.345	-47	1.272	-50
Latvia	31	105	-32	100	-36	95	-39	90	-42	85	-45	80	-49	78	-50
Lithuania	52	238	-8	218	-16	198	-23	177	-31	157	-39	137	-47	129	-50
Luxembourg	11	38	-30	36	-34	34	-38	32	-41	30	-45	28	-49	27	-50
Malta [3]	2	10	-12	9	-19	8	-26	8	-33	7	-40	6	-47	6	-50
Netherlands	210	941	-10	864	-18	787	-25	710	-32	633	-40	556	-47	525	-50
Poland	564	2.086	-26	1.961	-30	1.836	-35	1.711	-39	1.586	-44	1.461	-48	1.411	-50
Portugal	61	366	19	327	6	288	-6	248	-19	209	-32	169	-45	154	-50
Romania	265	1.045	-21	974	-26	903	-32	832	-37	762	-42	691	-48	662	-50

Table A 4.4 continued

	Emissions 1990 [2)]	AA 2013-17	Change in % [1)]	AA 2018-22	Change in % [1)]	AA 2023-27	Change in %	AA 2028-32	Change in %	AA 2033-37	Change in %	AA 2038-42	Change in %	AA 2043-47	Change in %
Slovak Rep.	73	319	-12	293	-19	268	-26	242	-33	217	-40	192	-47	181	-50
Slovenia	19	82	-15	76	-22	69	-28	63	-35	57	-41	51	-47	48	-50
Spain	288	1.560	9	1.404	-2	1.249	-13	1.093	-24	937	-35	781	-46	719	-50
Sweden	73	359	-1	326	-10	293	-19	260	-28	228	-37	195	-46	182	-50
UK	744	3.116	-16	2.884	-23	2.651	-29	2.418	-35	2.186	-41	1.953	-48	1.860	-50
Total	**5.691**	24.273	-15	**22.413**	-21	**20.552**	-28	**18.692**	-34	**16.832**	-41	**14.971**	-47	**14.227**	**-50**
Emissions per Capita	12,06	9,9	-18	9,2	-24	8,5	-30	7,8	-36	7,1	-41	6,4	-47	6,2	-49

Chapter 5

Climate Policy: Analysis of Ecological, Technical and Economic Implications for International Maritime Transport

Sven Bode, Jürgen Isensee, Karsten Krause, Axel Michaelowa

Contents

An early version of this chapter has been published in Intereconomics, 35 (2000) 3, pp. 127-136 by Michaelowa and Krause. A revised and extended version by Bode, Iseensee, Krause and Michaelowa was subsequently published in: International Journal of Maritime Economics (2002) 4, pp. 164-184.

Abstract

In 1997, the 3rd conference of parties to the UN Framework Convention on Climate Change adopted the Kyoto Protocol as a consequence of increasing evidence of a manmade global warming of the atmosphere. Binding greenhouse gas emission reduction targets for industrialized countries were agreed upon. However, bunker fuel emissions from international shipping have so far been excluded from any commitment in the Protocol. After looking at the magnitude of emissions from international shipping and likely trends, we make suggestions how shipping can be integrated into polices to control greenhouse gas emissions. The objective of policy instruments has to be the introduction of an effective and efficient stimulus for environmentally sound operational and technical improvements on existing and new ships. Consequently, the best solution would be for IMO to agree on a global shipping emissions target that would be comparable to targets of industrialized countries. However, for the time being, the introduction of a CDM type mechanism would be a promising step into the right direction.

1. Introduction

Ship transportation is considered the most environmentally-sound mode of transport. In public opinion, environmental problems of ships seem to be linked to accidents, in particular of oil tankers. Emissions of local and global air pollutants through the burning of marine bunker fuels are a relatively new area of environmental concern. Thus, the emissions of the international merchant fleet has become an increasing focus of global and regional environmental policies. The integration of the shipping industry into the global climate policy regime is currently a new challenge for policy makers and the industry.

Climate protection has to be considered as a cross-sectional policy area, dependent on the coherence of environmental objectives in related policy areas, such as transport or trade regulation. In the last decade, international climate policy has become one of the most important elements of national and international environmental policies. International negotiations on climate change started in the late 1980s and resulted in the signatory of a Framework Convention on Climate Change (FCCC) at the UN Conference on Environment and Development in 1992. They culminated in the negotiation of the Kyoto Protocol in 1997. It will be the initial step towards a comprehensive global greenhouse gas regime. Bunker fuel emissions account for about 1,8% of the world's CO_2 emissions in 1998 and are thus in the magnitude of OECD countries like France (1998: 1,6%) or Australia (1998: 1,4%) (OECD 2000b, pp. 38 + 44). Bunker fuel emissions from international shipping and emissions from air transport have so far been excluded from any commitment in the Kyoto Protocol. While emissions from international aviation have been targeted by many environmental NGOs and have been subject of a special report of the Intergovernmental Panel on Climate Change (IPCC), international shipping has so far been neglected in the debate. However, corresponding to the discussion on aviation, air emission from ships is likely to be integrated into the existing climate regime over the next years. This is all the more true against the background of the successful climate negotiations in July 2001 that paved the way to an international ratification of the Kyoto Protocol.

After looking at the magnitude of emissions from international shipping and likely trends, we make suggestions how this integration can be done in an economically efficient and politically feasible way.

Parallel to the debate on climate policy, international shipping is already experiencing the first effects of global warming. Ports in northern Canada are able to expand their shipping season and ship owners are exploring Arctic routes in order to bypass bottlenecks on established routes or to cut down on travel time. But the forecasted increase in stormy weather and the consequences of a sea level rise for ports make it unlikely that shipping will belong to the winners of climate change.

2. International Climate Policy and Shipping

Scientists have warned about a potential impact of human activities and in particular of the burning of fossil fuels on the global climate system for several decades before political negotiations started on an international level in the late 1980s. Today, there is a general consensus on the existence of an anthropogenic warming of the global atmosphere and the necessity of an international climate regime to limit the emission of greenhouse gases, such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). The most important GHG is carbon dioxide, particularly as exhaust gases from the combustion of fossil energy. The source of GHG emissions growing most quickly are transport services; in the industrialized countries they increased by over 13% between 1990 and 1998 (UNFCCC 2000).

The FCCC was the launching pad for stronger action in the future. By establishing an ongoing process for review, discussion, and information exchange, the Convention makes it possible to adopt additional commitments in response to changes in scientific understanding and political will. The third conference of parties to the FCCC held in December 1997 in Kyoto, Japan, adopted a Protocol with targets for industrialized countries' (so-called Annex B countries) greenhouse gas emissions. These targets range from –8% for the EU to +10% for Iceland compared to 1990 levels by the period 2008 – 2012. Developing countries have no targets. In July 2001, the part sixth conference of parties was continued in Bonn, Germany (COP 6bis). All crucial questions about the exact design of the four flexible mechanisms in the Kyoto Protocol were resolved and a sufficient number of relevant countries declared that they will now ratify the Protocol. Industrialized countries will thus be enabled to trade emission reductions internationally and use least-cost options for emission reductions on global markets instead of reducing emissions by internal measures.

2.1 Impacts of Climate Change on International Shipping

Climate change is likely to have substantial impacts on the oceans and thus on international shipping (Ittekot 1996). These impacts are not necessarily negative. Both the impacts on infrastructure (port facilities) and ships have to be considered.

Sea-level rise and increased storminess will have enormous impacts on ports. If the current infrastructure at the land/sea interface is to be protected, extremely high costs are to be expected. For example, it may cost 63 billion US$ to protect only Japanese ports (Scott 1996, p. 418). Dredging of waterways is already an important cost factor and considered as the most serious environmental problem for ports. Increased runoff and precipitation will lead to a higher sediment load of rivers. Demands for dredging operations thus can be expected to increase and lead to an increase in costs in ports (Ittekot 1996, p. 275). A sea-level rise, induced by global warming, is unlikely to compensate silting of waterways.

If the frequency and intensity of extreme weather conditions and in particular of tropical storms and cyclones increases, tropical routes become more dangerous, and higher losses can be expected. Weather conditions might force ships to change routes or speed, or to stay longer within protected areas. If the number of lost ships, the damage to ships, or the loss of cargo increases, insurance companies will reflect the higher risk level in their rates or compensation levels. Consequently, ship operators will face increase costs in any case: Either due to higher losses or in form or higher insurance fees.

But global warming will also lead to positive effects for international shipping, like the reduction of sea ice. Costs for icebreakers which can amount to annual double-digit million dollar figures for countries like Canada or Russia could be reduced. Both the Northwest passage and the Northern sea route around Russia are likely to be opened up for routine shipping in the next decades. Currently, high insurance costs, the iceberg threat, the need for icebreakers and expensive reinforced hulls, and the extremely short open-water season limit the traffic on Arctic routes. Furthermore, Arctic routes would reduce freight costs from East Asia to Europe considerably (Ittekot 1996, p. 282). Ships taking cargo from Rotterdam to Yokohama could cut 5,000 miles, almost cutting travel time in half from the Panama route. Using a route north of Russia similarly nearly halves the time and distance compared to the Suez Canal route between Hamburg and Yokohama (Anonymous 2000). It goes without saying that ship operators will take advantage of these effects while environmentalists may point out the possibility of further damages to these regions.

2.2 Factors Influencing Pollutant Emissions by Ships

Freight rates have shown a steady downward trend since the beginning of the 1980s, and sometimes freight rates have not covered the operational costs. Shipowners have developed different strategies to cut costs wherever possible. One way to do this is through registration in open registers. While the majority of all vessel transport is linked to trade between industrialized countries, an increasing share of the merchant tonnage is registered outside of the main trading countries, in open registers. Since the beginning of the 1980s the OECD registered tonnage has declined from 51% of the world tonnage to 24.4% by the end of 1999

(Lloyd's Register 2000). A large share of this decline is the result of the introduction of open registers and the OECD flagging-out. Flagging-out aims at minimizing operational costs and regulatory requirements. While it helps shipowners from OECD countries to compete on the global market, it promotes a race towards substandard shipping.

In addition to flagging-out, shipowners have passed their responsibility for asset marketing and day-to-day operation to ship management organizations. In many cases the focus of such a management company is on commercial aspects, neglecting aspects related to the safe operation of the ship (Nieuwpoort/Meinders 1998). Cost cutting has induced reckless loading practices in ports and operation at a higher speed, sometimes beyond permissible design limits.

Over the last 35 years remarkable improvements in fuel efficiency have been achieved, for instance by engine optimization. However, the highest priority for potential shipowners is the capacity and the speed of the vessel. Energy efficiency and environmental impact are of minor importance as long as no conflict occurs with international or regional legislation over the ship's lifetime, or as long as there are no economic incentives (e.g. graded port fees, taxes etc.).

GHG emissions from ship operations are often linked with emissions of other pollutants that create important environmental problems. Table 5.1 gives an overview of these links.

Table 5.1
Gaseous pollutants from ships and its environmental effects

POLLUTANTS CONSEQUENCES	SO_X	NO_X	VOCs	CO_2	CFCs	Halons	CH_3Br
Greenhouse effect				**X**	**X**	**X**	
Ozone-stratospheric					X	X	X
Ozone-ground level		X	X				
Acid rain	X	X					
Linked-up with:							
Fuel combustion	X	X	X	X			
Cargo handling			X		X		X
Ship's equipment					X	X	
Incinerators	X	X		X			

Source: de Keyzer (2000).

2.3 Maritime Transport in the FCCC Process

International bunker fuel emissions shall not be reported under the national emissions and are excluded from any commitment in the Kyoto Protocol. However, prior to Kyoto in 1996, a discussion on the allocation of bunker fuels was started in the international climate negotiations but did not lead to any results. Despite the exclusion from national targets Article 2, paragraph 2 of the Kyoto Protocol states: "The parties included in Annex I shall pursue the limitation or reduction of greenhouse gases not controlled by the Montreal Protocol from aviation and marine bunker fuels, working through the International Civil Aviation Organization and the International Maritime Organization, respectively".

Over the last decades, IMO has adopted several rules and regulations to improve the environmental and safety situation of maritime transportation. IMO's activities concerning environmental issues have so far centered on marine pollution. Emissions into the air have only lately come in and have been under consideration of the Marine Environment Protection Committee (MEPC) since 1990. IMO member states have signed Annex VI of the MARPOL Convention, providing a regulatory framework for the prevention of a variety of air pollutants from ships. However, Annex VI that has not entered into force yet does not address CO_2.

Although IMO was successful in producing standards, it was less successful in ensuring their application and enforcement (Nieuwpoort/Meinders 1998). This lack of the necessary executive power is hampering the adoption of environmental measures to control air emission in the shipping industry. There are currently no real economic incentives for shipowners to invest in low-polluting ships or in additional environment-friendly equipment of existing ships as non-compliance reduces the annual operating costs by 13-15% (OECD 1996). Therefore, it is obvious that Annex VI to the MARPOL will not have any major effect on reducing emissions of sulfur and nitrogen oxides in the foreseeable future (Kågeson 1999). This means that enforcement powers are necessary if IMO is going to play a role in setting climate policy instruments.

As mandated by resolution 8, adopted by the Conference of parties to MARPOL 73/78, and by the Kyoto Protocol the MEPC at its 42nd session agreed to invite the Secretariat of IMO to commission a study concerning greenhouse gas emissions from ships. The MEPC commissioned a study on the greenhouse gas emissions by ships in September 1999 (IMO 1999b), and a final report (IMO 2000a) was submitted to the IMO in March 2000. The report examines greenhouse gas emission reduction possibilities through different technical, operational, and market-based approaches. At MEPC`s 46. Meeting in April 2001 Norway submitted an information on mechanisms to curb greenhouse gas emissions (IMO 2001a). The MEPC agreed to establish a Working Group at the next session in March 2002 to evaluate proposals for greenhouse gas emissions reduction, to draw up a work plan and to prepare materials for consideration in developing an IMO strategy for greenhouse gas reduction.

3. Implementation of Climate Policy Concerning International Shipping

The starting point of a coherent concept to reduce GHG emissions from international shipping is the formulation of political objectives. Compared to other sources of GHG emissions, the introduction of effective and efficient policies for maritime transport is maybe the most complex task of the Kyoto process. The distinct characteristics of the industry have to be considered in order to find the most practical solution to global GHG emissions reduction:

- While the FCCC and the Kyoto Protocol are based on responsibilities assumed exclusively by nation-states, mainly Annex B countries, maritime transport services are provided by a global industry and take place outside of national control.

- The importance of transportation as an accelerator of economic growth, and the decentralized, mobile characteristics of emission sources limit even the introduction of effective domestic climate policies for land-based vehicles. Furthermore, almost all energy-intensive industries operating in international markets currently are fully exempted or pay reduced emissions or energy taxes.

- The impact of ship emissions on local and regional air quality will continue to be the dominant policy driver (IMO 2000a). In European waters for instance, SO2 and NOX emissions from ships represent 30% to 40% of the planned total EU emissions in 2010 (Davis et al. 2000, p. 49). A contribution of shipping, beyond the expected results of MARPOL's Annex VI requirements, might close the gap between the environmental standards for other transport modes, the available technological solutions and their application on seagoing vessels. It thus may be possible to combine climate policy and reduction of local and regional pollutants.

- Shipping has the potential to provide the most environmentally sound transport services. Nevertheless the industry has currently no incentive to use its potential for substantial GHG emission reductions. The induced costs to exploit these opportunities are feared to limit the (cost-) competitive advantage of shipping to other modes of transport.

3.1 Allocation of Emissions

A decisive question is the allocation of emissions and emission reduction objectives to the actual emitters. Corresponding to the Kyoto Protocol, objectives should be focused on quantitative emission levels. Practical allocation approaches, as well policy objectives, depend to a large extent on the applied policy instruments and their mechanism for motivating emitters in the shipping industry to achieve emission reductions. A number of possibilities are available for allocating bunker fuel emissions. UNFCCC (1996) lists the following options:

1. *No allocation;*
2. Allocation of bunker emissions to Parties in proportion to national emissions;
3. *Allocation to Parties according to the country where the bunker fuel is sold;*
4. Allocation to Parties according to the nationality of the transporting company, the country where the ship is registered, or the country of the operator;
5. *Allocation to Parties according to the country of departure or destination. Alternatively the emissions related to the journey could be shared between the country of departure and the country of arrival;*
6. *Allocation to Parties according to the country of departure or destination of passenger or cargo. Alternatively, the emissions related to the journey of a passenger or cargo could be shared by the country of departure and the country of arrival;*
7. *Allocation to Parties according to the country of origin of the passenger or owner of the cargo;*

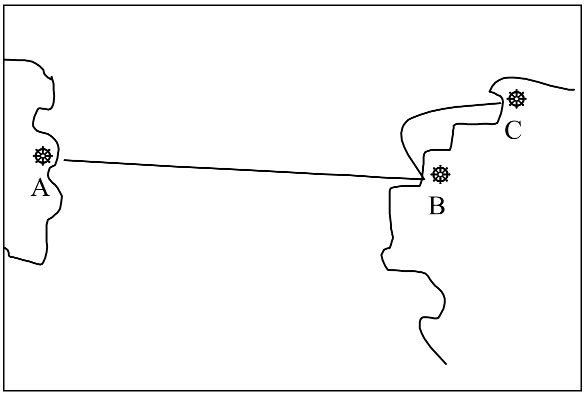
8. Allocation to the Party of emissions generated in its national space.

Options set in italics were stated to be the basis of further discussions and will be discussed below in more detail.

Allocating bunker fuels according to fuel sales (Option 3) is sure to lead to distortions as fuel sales do not correspond to transport shares of the country.

The seemingly easiest equitable way to allocate bunker fuels to national inventories is to split them 1:1 between the country where the ship started its trip and the country where the ship arrived (Option 5). However, this is more complicated than it seems. Often ships first stop in a major port after a long overseas trip and then go on to smaller ports in the area (see Figure 5.1).

Figure 5.1
Trip planning and emissions allocation



A ship travels from port A to port B and then on to port C. 25% of its cargo is unloaded at port B and 75% at port C. In the 1:1 allocation, port B´s country would be disadvantaged as it would have to bear 50% of the emissions of both the long trip A-B and the short trip B-C but only get 25% of the cargo. Port C´s country would be advantaged as it would only bear 50% of the emissions of the short trip B-C but get 75% of the cargo. Emissions per ton of freight would thus be allocated very unevenly.

In order to avoid this problem of unequal allocation, emissions per ton of freight could be shared 1:1 between exporting and importing country (Option 6). This would assume that each shipping company would have to keep records for each ship on:

- exporting country, importing country, amount of freight and transport distance for each shipment of goods
- total emissions

The reporting has to be on a per-ship basis to account for different degrees of efficiencies of ships. The data would annually be reported to the UNFCCC Secretariat. It is likely that shipping companies would object to this approach due to the high data demands.

Allocation could also be done on the basis of the shipping registries (see Table 5.2), i.e. the registering country would have to bear the emissions of its fleet. This allocation mode would of course lead to a huge transfer of emissions from Annex B countries into Non-Annex B countries (i.e. countries without emission target) such as Panama and Liberia.

Shares of Flag States in the World Fleet

Table 5.2
Shares of flag states in the world fleet above 2% end 1999

Country	Share
Panama	19.4
Liberia	10.0
Bahamas	5.4
Malta	5.2
Greece*	4.6
Cyprus	4.3
Norway*	4.3
Singapore	4.0
Japan*	3.1
China	3.0
U.S.*	2.2
Total Annex B	**27.3**

*Annex B country.

Raw data source: OECD (2000b, Table 12).

Allocation according to the country of origin of the passenger or owner of the cargo (Option 7) would help to integrate potential GHG emission offsets via the transport chain. Despite relatively high transaction costs, this option promotes the polluter-pays principle and supports cost-efficient measures to reduce emissions.

All national allocation approaches raise questions of equity, political acceptability, and, in particular, practical feasibility. However, the view that an integration of international bunkers and emissions into national emissions inventories would require a re-negotiation of emission reduction obligations of Annex B countries under the Kyoto Protocol (IMO 2000a, p. 152) seems far-fetched. Any change in national circumstances then could equally be used as pretext to renegotiate targets. One way to prevent national allocation (Option 1) would be to agree to a *worldwide* target for marine bunker fuels and make IMO responsible for reaching the target.

3.2 Policy Instruments and Compliance

The objective of policy instruments has to be the introduction of an effective and efficient stimulus for environmentally sound operational and technical improvements on existing and new ships. The application of the polluter-pays-principle is of highest priority, in correspondence with a utilization of the available potential of cost-efficient options to reduce GHG emissions and an integration of technical progress. Besides the intended environmental control, stimulation of innovation is one of the key tasks of environmental policies, due to its potential to reduce extra costs for environmental protection. Different policy instruments are considered feasible for a GHG reduction strategy in international shipping.

Emission Standards

Minimum efficiency standards or emission standards are the most established form of environmental policy. They could either be implemented by the IMO, regional, national or local authorities. Within their competencies, these institutions could develop regulations on how much and in what way GHG could be emitted or have to be reduced. Based on the knowledge of the technological state-of-the-art, these regulatory instruments could precisely prescribe emission reduction objectives to individual emitters. Another approach would be to divide the emission of GHG into a legal and illegal portion. The division can be done using an emission ceiling or technical requirements. International shipping has gained substantial experience in finding international solutions to common safety and pollution problems in the form of conventions based on global uniform minimum standards.

Because CO_2-emissions from ships are determined both by operational practices and the technical construction of the vessel, standards should ideally cover both (IMO 2000a, p. 154).

However, during the last decade, the inflexibility of regulatory instruments and the high differences of costs per emission reduction unit have led to criticism: Environmental standards are not suitable for differentiating sufficiently between emitters on the basis of their marginal reduction costs. Furthermore, the definition of standards depends on the best available technology. Once defined, standards are generally too inflexible to integrate technological progress as a dynamic factor or even to foster innovation.

To allow emitters more flexibility and to reduce the cost of emission control, market-based instruments, like tax incentives or environmental charges or tradable permits, are considered as a substitute for standards.

Tax Differentiation and Environmental Charges

In several Annex B countries, environmental taxation schemes are the most important elements of national climate policies. Energy taxes promote energy efficiency, while other concepts are directly based on GHG emissions. Compared to standards, taxes and charges introduce no clear emission limit but put a price on emissions. A carbon charge on bunker fuels will give ship owners increased incentives to reduce fuel use and related emissions. The reaction depends on individual ship types, the value of the cargo and the availability of alternative transport modes.

Michaelis (1997) has analyzed an emission tax on bunker fuels in detail. He asked industry representatives about their reactions to tax levels of $5, $25 and $125 per ton of carbon. These would represent about 5 per cent, 25 per cent and 125 per cent of the price for residual fuel oil (at $90/ton), and 3 per cent, 15 per cent and 75 per cent of marine diesel fuel prices (at $150/ton). Shipowners and charterers generally did not think that they would be able to pass the charge on by increasing their shipping rates and showed high preferences for avoiding payments by charging fuel offshore. The only maritime fuel tax that ever existed - California introduced a 8.5% sales tax in 1991 - led to an enormous reduction of fuels sales. Shipowners evaded the tax by fuelling in Panama and it was rescinded in late 1992 (Michaelis 1997, p. 40). This is why any taxation regime has to be implemented globally and needs support from at least a great majority of countries with most important ports. Otherwise, any charge would be limited by the costs for bringing fuel from untaxed sources in international waters for offshore refueling.

Various methods of tax collection are possible (e.g. based on sales of fuel from bunkers to ships, sales from oil companies to bunker dealers, fuel out of the refinery gate) which might influence the ease of implementation, potential for avoidance, and hence greenhouse gas impacts of the measure.

Emission Trading

In an emission trading system, the total emission volume is limited to the number of distributed permits. Emitters have to limit their emissions to their permitted volume. In case they want to increase their emissions they have to purchase additional permits, whereas they could sell permits they do not need. Compared to taxes or standards, not the price of emissions or the applicable technology is regulated, but the total emission quantity. Emission trading schemes have been used in the United States to limit SO_2-emissions. As flexible instruments, different forms of emission trading are central instruments of the Kyoto Protocol. The different instruments allow joint targets of countries, international trading of emission permits between governments and creation of emission permits through joint projects between private or public organizations in different countries. Such projects are called “Clean Development Mechanism” (CDM) if the project is hosted by a developing country without an emissions target and are otherwise known as “Joint Implementation”. Detailed rules and guidelines for the use of these mechanisms are currently being negotiated.

Emissions trading systems for shipping can be administrated at different levels. The level depends on the allocation mode. Allocation to national inventories would be possible but difficult as was shown above. Another possibility would be the establishment of a restriction (cap) on total emissions from international shipping under the auspices of IMO or others. As for Annex I countries, a cap for 2008-12 would have to integrate the anticipated growth rate and would be expressed in the relation of the expected emission from shipping to its 1990 levels (i.e. …should not exceed X % …). The negotiations about an emission cap could take place within the IMO, since almost all parties to the Kyoto Protocol are members of the IMO. According to Norway it would be a demanding task to achieve an agreement on the size of a cap on total emissions from shipping (IMO 2001a, p. 4) but on the other hand one has to recall the international climate negotiations that where very demanding, too, but nevertheless successful.

Finally, emissions could be allocated to single emitting ships (i.e. their owners). They could then be allocated permits for free (grandfathering) or have to buy them in an auction. Ship owners choosing to over-comply could sell surplus permits on the market.

It would also be possible for countries with targets to invest in emissions reduction projects in shipping and to get emission credits. If there is an overall cap for international shipping, such projects should be treated like Joint Implementation. The emission reduction achieved through the project would be deduced from the cap.

Even if there is no cap at all for the international shipping sector projects that reduce shipping emissions could be credited similarly to CDM projects. They then would have to calculate baseline emissions for what would have happened without the project and get a certificate by an independent, accredited certifier to receive emission credits.

Voluntary Agreements

Voluntary agreements are the result of negotiations between the government and an industry or a company on strategies to control environmental problems. They are a popular policy tool in many Annex B countries' energy-efficiency and climate-change policies. Voluntary agreements can range from declarations of intent, to binding contracts with industry, with penalties specified in the case of non-compliance. In most cases, there is an implicit or explicit threat from the regulator to impose other policy instruments if the company/industry is unwilling to negotiate.

In the shipping industry, a voluntary agreement could focus on the adoption of emission or efficiency standards, certain approved practices or prescribed actions or to report emissions or efficiency levels and to describe any actions being taken to improve them. Voluntary agreements with ship-builders and operators are, of course, another option to reduce greenhouse gas emissions. However, given the patchy performance of voluntary agreements in a national context, they are unlikely to go beyond business-as-usual in the context of an international sector with strong competition, as is the case in international shipping.

Environmental Indexing

In an environmental indexing system, a voluntary or compulsory label or index is used to indicate the environmental performance of the ship. The index given to a vessel can be used to differentiate taxes, port dues and charges, but also insurance rates. Different financial conditions may be differentiated on the basis of an indexing system. So far, indexing systems have only been introduced to a limited extent. In 1998 Sweden introduced measures to reduce ships' nitrogen oxide emissions, i.e. by the installation of catalytic converters, and to promote the use of low-sulfur bunker fuel. Environmentally differentiated fairway and harbor dues shall provide an economic incentive to stimulate the ferry traffic and other frequent vessel traffic to and from Swedish ports. An other example is the Rotterdam Green Award Foundation. The Green Award is a voluntary certificate, based on high environmental and safety standards. Qualified ships get discounts on port dues, pilot fees etc. The most comprehensive indexing system was developed in Norway and presented to the MEPC 1995. It has never been implemented internationally but has initiated a differentiation of shipping dues in Norway from January 2000. The problem arises that GHG emissions are only one factor among a multitude of others that influence overall environmental performance of ships.

An internationally accepted system for creating incentives for GHG emission reductions depends on a co-operation of potential bonus providers, ship owners and classification societies. A voluntary system for cleaner ships has no effect on old and low efficient ships, but reduces the current economic disadvantage of clean ships.

3.3 Strategic Options for IMO

Economic research has proven that the application of policy instruments on local, national, regional or international levels had to be adjusted to specific conditions and is often influenced by political interests, leading up to a reduction of their economic and/or environmental efficiency far below their theoretical potential. A successful environmental policy does normally depend on a single instrument than on the integration of a new instrument in a coherent policy framework with a strategic focus and a cooperative policy style (Klemmer et al. 1999, p. 110). In such a strategic concept, standards are often considered basic instruments for ensuring a minimum contribution by every emitter to an overall policy objective, while market oriented instruments provide economic incentives for additional investments in environmentally sound technical or operational measures and to set a counterweight to “grandfather clauses”.

Table 5.3 gives an overview about the potential contribution of individual instruments towards a strategic climate policy concept for international shipping.

Evaluation of Policy Instruments to Achieve GHG Emission Reduction Objectives

Table 5.3
Evaluation of policy instruments to achieve GHG emission reduction objectives

Instrumental focus to reduce emissions	Technology & Operation		Price differentiation		Emission ceilings
Function	Allowed emissions depend on the application of a prescribed level of technology		The higher emissions, the higher the costs		Emission requires the purchase of a licence
Instruments	**Emission standards**	**Voluntary agreements**	**Environmental indexing**	**Taxation**	**Tradable permits**
Institutional complexity	high	low	low	moderate	moderate
Environmental Effectiveness	high	low	moderate	moderate	high
Cost efficiency	low	high	high	moderate	high
Dynamic efficiency	low	low	moderate	high	high
Level of application	global / regional	global / regional	decentral	global / regional	global
Conformity with MARPOL VI	high	moderate	moderate	low	low

The IMO Study of Greenhouse Gas Emissions from Ships (IMO 2000a, p. 165) proposes the following strategy for policy implementation for IMO: To first explore the interests for entering into voluntary agreements on GHG emission limitations between the IMO and the ship owners, or to use environmental indexing. This recommendation is strange as the study also states that “Voluntary agreements were not found to be a viable approach to obtain significant global GHG emissions reductions from international shipping“ (IMO 2000a, p. 21), and that ”*Environmental indexing* does not seem to be a very efficient tool to reduce emissions, even if some reductions may be achieved on voluntary basis“ (ibid, p. 164). Second, start working on how to design emission standards for new and possibly also existing vessels. Third, pursue the possibilities of credit trading from additional abatement measures. From the authors’ point of view, this strategy would help with ratification of the Kyoto Protocol, and in the short term could contribute to the implementation of some of the cheapest abatement measures on new and existing ships.

These recommendations are rather modest and do certainly not fulfil the aim of integrating international shipping in climate policy. Their implementation would mean that emission growth from shipping could continue unchecked. Indeed, the shipping sector would be treated like developing countries as it would not have a distinct emissions target. Voluntary agreements would only be a very small step towards a specific participation of the shipping sector. IMO would not have any "teeth" to credibly threaten with stronger policy instruments given its lackluster performance of implementation of existing standards.

From the environmental point of view, however, a cap on emissions from international shipping is most desirable since total GHG emissions have to be limited (in the long run) if atmospheric CO_2 concentrations are to be stabilized (IPCCC 2001). The arguments against an emission trading system under the supervision of IMO are superficial – the difficulties would not be much higher than in the context of a domestic emission trading system. Also the argument that a carbon tax would not be feasible is not valid in the case of low tax rates.

But for the time being, the only real activities under such a regime would be through CDM type projects. They would set a financial incentive for GHG reduction that would be much more effective than any voluntary agreement. However, there may be problems in baseline determination and check of economic additionality of a project as discussed in Chapter 2. Their magnitude would be similar to those encountered in other sectors.

3.4 Wet CDM: First Step towards Integration of International Shipping into International Climate Policy

Against the background of the difficulties to introduce climate policy instruments into international shipping as described above, the adoption of the CDM model for non-Annex I countries could be a first and easy step to start (IMO 2001a, p. 1). A definition of a cap for the commitment period after 2012 remains desirable. This project-based emission offsets could start immediately after an agreement was reached and might inaugurate emission trading to the transport industry. Due to the possibility of international sales of emission reductions, this might be a win-win solution for the shipping industry. However, it is of crucial importance to note that by applying the CDM, emissions are only reduced compared to a reference scenario of a single project (see Figure 5.2). Absolute emissions might still increase depending on the project and baseline under investigation.

Furthermore, one has to keep in mind that each Certified Emission Reduction (CER) generated by an CDM-project increases the industrialized emission target as shown in Figure 5.3.

Since both, investor and host of project have an incentive to overstate GHG reductions it is absolutely necessary to have a surveillance by an independent third party. Figure 5.4 illustrates the potential structure of CDM-like projects in the international shipping industry.

Figure 5.2
Quantifying emission reductions with absolute emissions rising

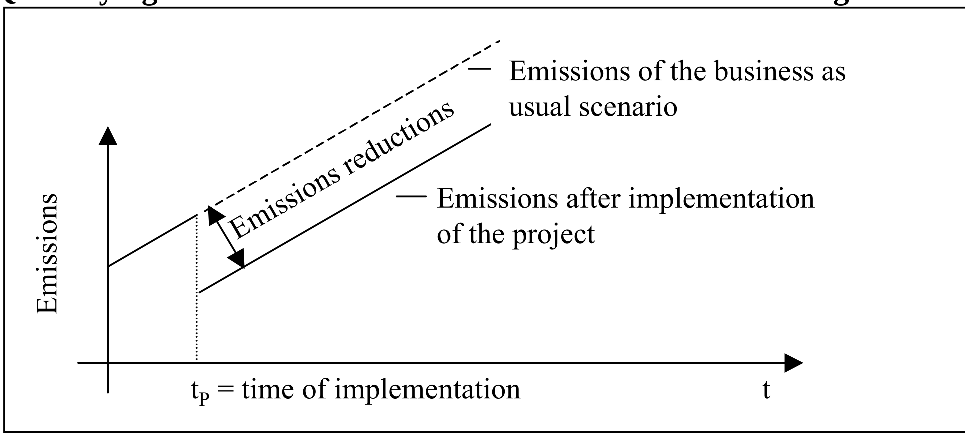


Figure 5.3
Flexible mechanisms under the Kyoto Protocol

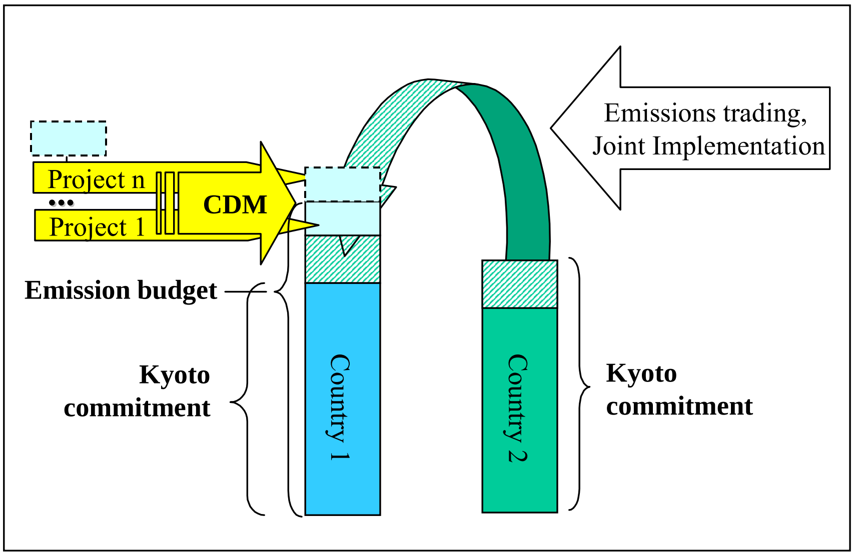
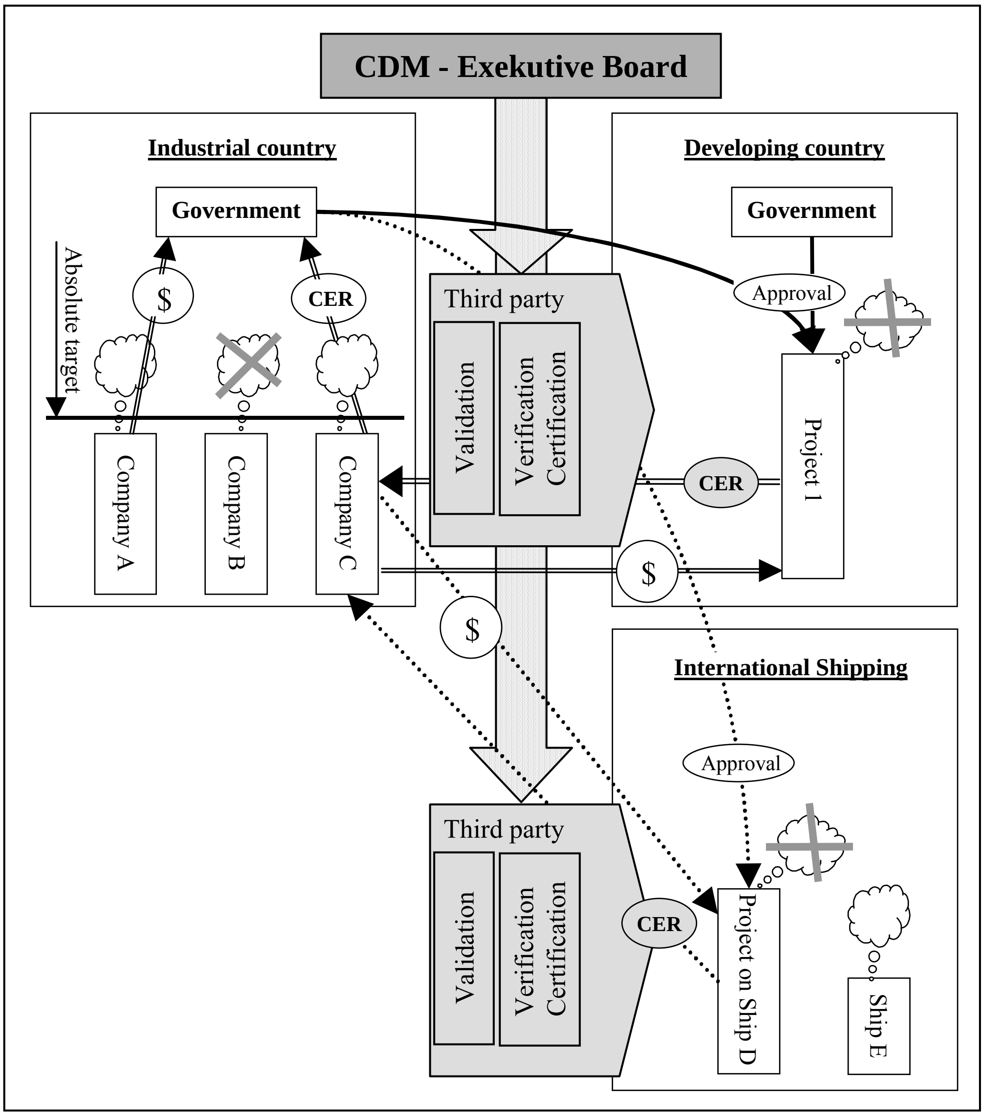


Figure 5.4
Schematic structure for integrating international shipping into the climate regime



A big advantage of the shipping industry in the context of CDM projects is due to the existence of organizations for controlling compliance to the requirements of applied policy instruments. The classification societies are already important actors in promoting environmental standards in the shipping industry and will have no problems in fulfilling the rules for CDM certifiers. They control the quality of ship design, the construction and operation period. Their network of surveyors enables the classification societies to take over the certification and regular control of ”green ships“ during their annual surveys. It should be noted that the classification societies would not be the one to set that standard but rather the one to apply the rules developed as part of the international climate negotiations.

There is a great variety of measures to reduce GHG emissions from shipping, that may all qualify as CDM project. Table 5.4 lists most common technical options.

Table 5.4
CO_2 reduction potential by technical measures

Measures new ships	Fuel/CO2 saving potential	Combined [1]	Total [1]
Optimised hull shape	5 - 20%	5 - 30%	
Choice of propeller	5 - 10%		
Efficiency optimised	10 - 12% [2]	14 - 17% [2]	
	2 - 5% [3]	6 - 10% [3]	15 - 50%
Fuel switch fuel oil → diesel	4 - 5%		
Plant concepts	4 - 6%	8 - 11% [4]	
Use of sails	10 - 20%		
Machinery monitoring	0.5 - 1%		
Measures existing ships			
Optimal hull maintenance	3 - 5%	4 - 8%	
Propeller maintenance	1 - 3%		
Fuel injection	1 - 2%	5 - 7%	
Fuel switch fuel oil → diesel	4 - 5%		4 - 20%
Efficiency rating	3 - 5%	7 - 10% [4]	
Eff. rating + TC upgrade	5 - 7%	9 - 12% [4]	

1) Where potential for reduction from individual measures are well documented by different sources, potential for combination of measures is based on estimates only.
2) State of art technique in new medium speed engines running on heavy fuel oil.
3) Slow speed engines when trade-off with NOx is accepted.
4) Including fuel switch.
Sources: IMO (2000a, p. 14), Michaelis (1996, p. 693).

For example, an investor may decide to switch fuel from residual oil to diesel. In terms of CO_2 emission, this fuel is superior due to its higher heating value and due to its lower carbon content. Table 5.5 summarizes important project characteristics.

Table 5.5
Emission reductions by fuel switch from residual oil to diesel

	Costs $/t	Carbon Content (%)	HV (kJ/g)	Mass for equivalent HV (kg)	Costs ($/$HV_{eq}$)	CO_2 Emissions (Kg/ HV_{eq})
Residual oil	180	89,1	40,5	1000	180	3564
Diesel	250	86,7	43	942	235,5	3267
Difference					54,5	297

Economic analysis of this project must, however, not only take into account direct cost but rather consider indirect effects as for example lower investment costs, reduced maintenance requirements and higher reliability for diesel engines. Furthermore, the net load capacity is extended what can also help to reduce costs. The contribution of revenues from sale of CERs to the overall finance of the project is strongly dependent on the world market price for emission allowances.

On the other hand, energy intensity can also be improved by operational changes such as a general introduction of GPS and the use of computers to optimize routing and scheduling. An other option is to lower design speed of new-built ships. A halving of maximum speeds will reduce motor power needed by about a factor of ten in the case of tankers, dry bulk and container ships and more than 20 for general cargo ships (IMO 2000a, Appendices p. 41, 46, 49, 52).

Table 5.6
Emission reductions by lowering travel speed

	Dimension	Fast Ships	Slow Ships	Change
Number of Ships		5	6	+ 20
Service Speed	kn	16	12.63	- 21
Emission Parameters				
Main Engine Power / Ship	KW	13250	5800	- 56
Fuel burned on all Ships Annually	t	71460	45180	- 37
CO_2 emitted per t and nm	g/t.nm	3.590	2.250	- 37
SO_2 emitted per t and nm	g/t.nm	0.086	0.054	- 37
NOx emitted per t and nm	g/t.nm	0.092	0.057	- 37
Principle Demension of Ship				
Length between Perpendicles	m	260	248.6	
Breadth	m	32.2	31.4	
Draft	m	12.9	12.9	
Displacement	t	87550	82740	- 5

Ships have been designed following an optimisation procedure by Lee (1983). Ships are designed for minimal required freight rate.

As can be seen in Table 5.6 the potential to reduce emissions by lowering travel speed while keeping the total capacity constant is quite substantial. But it is quite difficult to quantify costs. Of course they are reduced due to decreased fuel consumption and lower investment costs. On the other hand they rise due to increased number of employees required on the ships. Lowering speed is equal to increase stocks and results consequently in higher costs for fixed capital. The significance of the latter aspect depends heavily on the kind of goods transported.

Table 5.7 provides an overview on other operational measures, that may qualify as CDM-project.

Table 5.7
CO_2 reduction potential by operational and design measures

Measures	Fuel/CO2 saving potential	Combined [1)]	Total [1)]
	Operational planning / Speed selection		
Fleet planning/lower speeds	5 - 40%		
"Just in time" routing	1 - 5%	1 - 40%	
Weather routing	2 - 4%		
	Miscellaneous measures		
Constant RPM	0 - 2%		
Optimal trim	0 - 1%		
Minimum ballast	0 - 1%	0 - 5%	1 - 40%
Optimal propeller pitch	0 - 2%		
Optimal rudder	0 - 0.3%		
	Reduced time in port		
Optimal cargo handling	1 - 5%	1 - 7%	
Optimal berthing, mooring and anchoring	1 - 2%		

1) Where potential for reduction from individual measures are documented by different sources, potential for combination of measures is based on estimates only.

Source: IMO (2000a, p. 15).

4. Conclusions

The contribution of international maritime transport to anthropogenic climate change is just beginning to be perceived as an important issue. Ongoing research and political pressure can be expected to raise the importance of this issue in the near future. An early recognition of the potential implications of climate change to the shipping industry could help to reduce the adaptation costs - as an industry with a vulnerability towards changing climate conditions and as a polluting industry without any reduction commitments. Given the growing attention to air pollution emissions from vessels and the potential high costs of reductions, the shipping industry might look to experiences from other industries which have already implemented efficient environmental standards.

SO_2 and NO_X emissions are currently the most important environmental problems in the shipping industry. Even without any direct technical reduction option for CO_2, instruments could easily try to address the different forms of pollution together. GHG reductions could easily be integrated into the criteria for "green" or "clean" ships under the Green Award in Sweden. Comprehensive calculations for numerous measures for reducing sulfur and nitrogen oxides show the cost-effectiveness of reducing emissions from ships (Kågeson 1999).

Shipping might be the most complex area for climate policy due to several factors. First, extreme competition has led to flagging-out and thus widespread substandard shipping. This makes implementation of climate policy instruments very difficult. Free riding is easy due to the global dimension of shipping and ease of avoiding fuel taxes. However, the growing share of shipping in global GHG emissions and the total absence of any action makes the introduction of measures necessary. The IMO study is grossly lacking in this respect. The optimal strategy would be for IMO to agree on a global shipping emissions target that would be comparable to targets of industrialized countries under the Kyoto Protocol. The target would be allocated to shipowners, and they could engage in Joint Implementation and international emissions trading. If IMO is not able to agree to such a target, CDM-type projects could still be implemented. However, the same requirements regarding baseline determination and additionality check which have been discussed in Chapter 2 would have be considered.

A minimum measure would be that governments pressure the industry to enter into voluntary agreements. Domestic measures are also possible. For example countries with major competitive ports could try to differentiate port fees according to the emissions intensity of the ships.

Chapter 6

Multi-Period Emissions Trading in the Electricity Sector - Winners and Losers

Sven Bode

Contents

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Abstract

In the context of controlling greenhouse gas emissions, the directive on a Europe-wide trading scheme may be perceived as one of the most important milestones in recent years. Prior to its start, however, a number of very specific design features have to be agreed upon. Regarding the allocation of allowances, a distribution (almost) free of charge seems to be the most likely choice. An aspect that has interestingly attracted little attention in the past is the question of how to allocate emission rights over time. The following paper analyses different allocation options in multi-period emissions trading that are currently discussed in the European context. The options are applied for the electricity sector which is simulated over two periods. The paper distinguishes between a market effect of emissions trading and compliance costs for meeting the emission reduction obligation. The market effect results from a price increase which is due to the fact that opportunity costs for using allowances must be considered. It turns out that the electricity sector as a whole gains from the introduction of the instrument due to the increase of the electricity price. With regard to the different allocation options, it is found that utilities have different preferences depending on the fuel used.

1. Introduction

In the context of environmental regulation emissions trading has gained acceptance and support in the past (Stavins 2003). With regard to the fight against global warming, tradable greenhouse gas (GHG) emission entitlements have first been introduced on state level in the Kyoto-Protocol in 1997. Subsequently, it was implemented on entity level in the UK and Denmark. The most important example, however, may be the directive on a Europe-wide emissions trading scheme adopted in 2003 (EU 2003). According this directive certain installations, i.e. major immobile sources of GHGs, are obliged to participate in a cap and trade scheme from January 1, 2005. The allocation of emission entitlements, in the European context called allowances, is perceived as a very important issue from the companies' point of view. Two main approaches have been focussed on during the discussion between governments and participants, namely an allocation based on emissions in a reference year and the use of an emission benchmark (PWC 2003). With both options allowances are distributed free of charge. Interestingly, the question on how to design the allocation over time, i.e. in subsequent periods, has only attracted little attention. The impact of different alternative allocation options on the single installations has only rarely been addressed so far (for example Burtraw et al. 2001 and 2002). Apart from that, existing literature, which is briefly reviewed below, generally either concentrates on the sector level or provides a pure analytical discussion. During the negotiations of the national allocation plans within the EU Member States this issue has either been overlooked or has not been discussed in public so far. Nevertheless, this question has to be answered in some way – possibly without knowing the exact implications.

Against this background this article deals with the analysis of the impact of different allocation options on installations in the electricity sector. Electricity generation has been chosen as it is a major source of GHG emissions in Europe and plays an important role in the planned trading scheme. The focus is on the relative impacts of the allocation on different power generation technologies rather than on absolute effects of the allocation on this sector compared to other sectors covered by a trading scheme. It thus addresses equity issues within the electricity sector and does not discuss efficiency aspects.

The analysis is based on a simulation of an artificial but realistic electricity market. As the focus is on the impacts of the allocation, only a few technical issues are considered. Transmission losses, for example, are fully neglected. The analysis is limited to a short-term perspective only. On the one hand, this is due to the fact that politically a short term perspective is likely to influence current legislation the most. On the other hand the path for auctioning the allowances is already slightly paved in the European scheme. With a 100 percent auctioning, however, the problems discussed below, do not exist anymore.[65]

The paper first discusses the impact of emissions trading on firms from a theoretical perspective. Section three reviews different options for allocation allowances free of charge. Multi-period emissions trading in the electricity sector is analysed in detail in section four. Section five concludes.

2. Emission Trading and its Impact on Firms

Emission trading is a market based instrument that allows a cost-efficient achievement of an emission target through the equalisation of marginal abatement cost. Participants in the trading scheme are not prescribed any specific abatement options. The only obligation they face is to surrender as much emission allowances at the end of a period as they released emissions into the atmosphere in this period. Therefore, they can decide whether to abate emissions in-house or to buy allowances[66] on the market. The decision to buy allowances is driven by

65 The price increase and the resulting additional producer rents, which are discussed below, would persist. With a 100 % auctioning, no rule for allocating the allowances (and thus the scarce resource) would be required. The scarcity rent would be collected by the government as in the case of a CO_2 tax.

66 The term emission right and allowance are used interchangeably.

the question of whether internal marginal abatement costs[67] are lower than the allowance price.

The implementation of an emissions trading schemes requires a number of decisions to be taken with regard to the design, as for example the compliance period, the units traded, monitoring rules, liability etc. (for a more detailed discussion see AGE 2001, AGO 1999, Boemare et al. 2002, CCAP 1999, CCAP 2002, WBCSD 2001, p. 8, UNEP and UNCTAD 2002). Another important aspect is the allocation of the allowances. Generally, allowances may either be provided free of charge or only be issued to participants for a fee. For trading at the company level, economists have argued in favour of a fee-based allocation or more precisely an auction. Distributing the allowances for free would result in extra revenue for the recipients of the allowances and in reduced efficiency on a macro-economic level (Cramton and Kerr 2002, FIELD 2000 p. 31, Speck 1999, Woerdman 2000 p. 620). A more detailed analysis follows below. However, it has been argued that this question can only be answered when comparing the concrete design of an auction[68] and a free of charge scheme respectively (for example Bohm 2002). Burtraw et al. (2001) compare three different allocation options for the electricity sector in the US and find that the costs to society are about one-half with auctioning compared to the two free of charge options.[69]

On the other hand, emitters ask for an allocation free of charge arguing that the additional financial burden of paying the fees would be too high. They have until now generally succeeded. The directive on GHG trading in the EU prescribes [70]

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67 Costs resulting from in-house abatement are referred as abatement costs in this paper. Compliance costs by contrast are the sum of abatement costs and expenses from buying or selling allowances on the market.

68 For example “How is the revenue from the auction recycled?”

69 The authors use the revenue from the auction in the least efficient way discussed in literature, namely the direct redistribution to households.

70 For their position during the legislation process see COM (2001), p. 2.

an allocation almost free of charge [71] and Stavins (2003) reports the same for the relevant non-GHG trading schemes in the US.

The argument of the additional financial costs is, however, only partly true. One also has to look at the other side of the coin. It is reasonable to assume that allowances are scarce, at least at the start of the scheme. Otherwise there would be no reason to introduce the instrument apart from obfuscation of a do-nothing strategy. In this case there will be a price for allowances. Thus, although allowances are allocated for free, their use for production involves an opportunity cost; they could have been sold in the case of non-production. According to cost theory, producers will consequently raise the product prices according to the product's emission intensity and the costs for emitting carbon.

The effect on the market can be studied in comparison to a per unit tax (for general example see Pashigian 1995, pp. 313-316; for the specific comparison Goulder 2002). Assume a competitive market for a certain product and denote the demand curve for the product by D and the supply prior to the implementation of the trading scheme by S_1 (see Figure 6.1). The equilibrium price p^* and the corresponding quantity q^* arise from the intersection of the two curves. Furthermore, assume that a competitive allowance market emerges. The CO_2 price is then determined by the overall emissions budget and the individual participants' abatement costs. All participants face the same CO_2 price which translates into opportunity costs within the firms' cost and price strategy. In the case all producers have the same emission intensity per unit of output, the additional opportunity costs for CO_2 emissions result in an upwards shift of the supply curve (see S_2 in Figure 6.1). This shift in turn results in a new equilibrium with the equilibrium quantity $q^\#$. Consumers now face the price $p^\#$. In the case a per unit (CO_2) tax had been introduced, the producers would face the price $p^\sim$ and the government would receive a transfer from consumers and producers equal to the rectangles b and c. The triangles e and f are the deadweight losses that result from

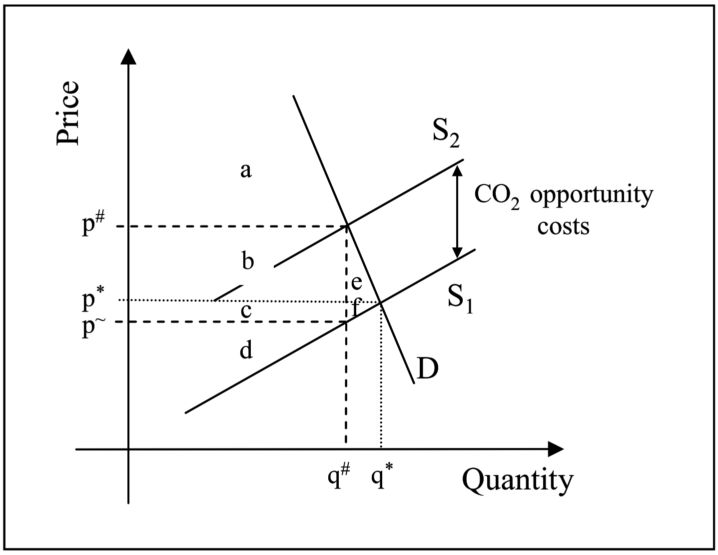
71 More precisely: At least 95% of allowances have to be allocated free of charge for the initial period 2005-2008 and at least 90% for the subsequent period (EU 2003).

the reduction of output. In the case of emissions trading the price increase is due to the fact that producers take opportunity costs into account. As a consequence they can receive additional revenues. The magnitude of the latter depends on the slope of the supply and that of the demand curve. If price elasticity of demand is low, revenues increase strongly. To prevent producers from benefiting too much, partial auctioning of the allowances would be sufficient. Goulder (2002) analysed this issue for the US fossil fuel industries and finds that only about 13 percent of allowances need to be distributed free of charge in order to avoid losses of profit for these industries. Regarding the EU trading scheme, current legislation already provides the possibility for such a change.[72]

As mentioned above, transferring these revenues to the government with subsequent tax reductions can reduce total costs of the regulation to society. Apart from these economic aspects Parry (2002) points out that the higher revenues result in increased equity values which lead to more income for shareholders. As "…stock ownership is skewed towards the rich…" (Parry 2002, p. 7) there is a strong case for auctioning also on distributional grounds.

72 See previous footnote.

Figure 6.1
Impact of a per unit tax or consideration of opportunity costs of emitting CO_2 by producers



While some emitters theoretically may get surplus allowances, most emitters will have to invest in either in-house abatement or to purchase emission rights on the market as total emissions are to be reduced. As a consequence the majority of emitters will face at least some compliance costs. Summarising these two aspects, i.e. the market effect and the compliance costs, one can see that the total financial impact on an individual installation can be calculated by subtracting the compliance costs from the additional revenues resulting from the price increase.

With regard to the allocation discussed in the next section one should note that, with the assumptions made above, the market effect is not linked to the allocation and vice versa. The price increase always takes place, either due to the opportunity costs as discussed above or due to real costs in the case (parts of) the permits are auctioned. Depending on the CO_2 costs, the merit order curve, which is introduced below, may change and some installations may be driven out of the market – regardless of the initial allocation. The latter only affects the participants' compliance costs and thus their liquidity.

3. Options for Allocating under a "Free of Charge" Scheme

While the theoretical analysis of the change in the producer rent has generally been done on the sector level, the allocation of the allowances free of charge is a matter to be dealt with at the installation level. A wide basket of options for this allocation exists (AGE 2001, AGO 1999, Boemare et al. 2002, CCAP 1999, CCAP 2002, Holmes et al. 2000, MIES, 2000, Nera 2002, NZME 1998). In the existing schemes in Denmark or the US and in the current discussion (PWC 2003), however, the following two approaches have been favoured:

- an allocation based on emission in a certain period (what is referred to as emission based allocation below)
- the use of a benchmark, i.e. specific emission factor.

The latter has to be multiplied with the reference figure of the benchmark in order to get an absolute emission figure. Formulae are given below. However, as Bode (2003) showed, the use of a general, i.e. non-installation specific, emission benchmark together with an absolute cap as foreseen by the emission targets of the Kyoto Protocol, results in an allocation in proportion to output only. This is also referred to as generation benchmark. The line of argumentation is given in the annex. Thus, there is no need to put any effort on the determination of an emission benchmark[73]. Furthermore, one should be aware that an output-based allocation provides an incentive to increase output (Fischer 2001). However, in this short-term analysis it is assumed that the output is only determined by the producers' marginal production costs.[74]

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73 In the context of the design of the allocation plan in Germany there has, for example, been an intensive discussion on the determination of emission benchmarks. Should it be product specific (i.e. electricity only)? Should it be fuel specific (lignite, coal etc.)? Or plant specific (gas turbine, steam turbine etc.)? For non-electricity products this seems even more difficult. Given the fact that the emission benchmark becomes a generation benchmark, this discussion is not necessary.

74 Efforts to increase market share by, for example additional marketing measures, may be effective only in the mid-term.

A number of analyses concerning free of charge allocation schemes exists. The majority (exceptions are mentioned below), however, is either a pure analytical exercise or concentrates on the sector or society level. They do not explicitly analyse the individual electricity generator's perspective, at least with regard to the options politically discussed in Europe. Apart from the level analysed, literature may also be distinguished regarding of whether is addresses efficiency and / or equity issues.

Böhringer et al. (2003) for example analytically analyse an emission and an output based allocation in order to analyse the trade-off between a compensation of energy intensive industry for the adverse impacts from regulation and economic efficiency. They conduct a comparative static CGE analysis and find that the trade-off depends strongly on the allowance price on the international market. With regard to the concrete allocation scheme the first and the second best design depends on the fact whether the system studied is open or closed.

Other studies focus more on the electricity sector without explicitly referring to efficiency. The Balmorel project (Balmorel 2001) resulted in a detailed model of the electricity and the combined heat and power market in the Baltic Sea region. It provides a long-term analysis of the price for heat and power until 2030. The price increase found is explained by the restructuring of the supply system and increases in fuel prices. Costs for emissions are not mentioned. Emission trading is only assumed for deriving an aggregate abatement cost curve for this region. No different allocation schemes are studied. Hauch (2003) focuses on electricity trade and CO_2 reduction in the northern European power market. He finds that trade in electricity in addition to allowances trading can reduce compliance costs and that the burden sharing agreement in the EU implies different costs for different Member States. The investigation is restricted to country level. Munksgaard et al. (2002) analyse the impact of internalising external costs in the northern European power market using the same model as the previous author. They show how cross-border trade and prices are affected in different scenarios such as under a coordinated and a national approach. In order to regulate the power sector a tax is applied and the authors point out that the model is appropriate for long-term analyses. UBS (2003) provides an analysis of the German electricity market until 2010. Apart from three different allocation schemes they also consider other issues as the phase out of nuclear energy and the aging of plants etc. so that a clear understanding of the impact of the allocation is not possible. The focus is then on the change of the asset value of two major German utilities (RWE and Eon) rather than on efficiency.

As mentioned above, Burtraw et al. (2001) study the electricity market in the US regarding both efficiency and equity. In a paper that follows (Burtraw et al. 2002) the authors introduce "the auction paradox" according to which generators as whole would be better off under an auction than with a generation performance standard[75] as electricity prices are higher in the former case. The concrete distributional effects depend on the fuel use in the power plant analysed and the fact whether or not a plant is entering the market. They compare two different allocation options free of charge[76], namely grandfathering and a generation performance standard. While both consider generation as the metric for allocating the allowances, they differ in the reference period. The former uses a constant base year (and is thus equivalent to the "generation benchmark constant" in this paper) whereas the latter uses an updated one (which is equal to the "generation benchmark updating")[77]. However, they do not consider any emission based allocation as it is discussed in the Europe. From the European discussion, it seems also somewhat strange that they allocate allowances to non-hydro renewable installations – at least for the performance standard approach.[78]

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75 The generation performance standard corresponds to the output-based allocation used in this paper.

76 Additionally, a revenue raising auction is analysed.

77 At least it seems to be equivalent. They author only state that according to grandfathering allowances are allocated "…on the basis of a historic measure such as emissions or generation." (Burtraw et al. 2002, p. 52) The context, however, suggest that generation is chosen.

78 It remains unclear whether allowances are allocated to non-hydro renewable installation under the grandfathering approach, too. In a sensitivity analysis allowances are even allocated to hydro and nuclear installations.

Against this background, the impact of different allocation options in multi-period emissions trading for the electricity sector, or more precisely on single installations as prescribed in the EU directive on emissions trading, is analysed in the next section.

4. Multi-Period Emissions Trading in the Electricity Sector

The electricity sector generally accounts for a high percentage of CO_2 emissions from fossil fuel combustion. This is why it has been the major focus of regulating GHG emissions. As power generation usually takes place in big plants, i.e. large immobile sources, lots of features of regulation (incl. monitoring) are especially suited for emissions trading.

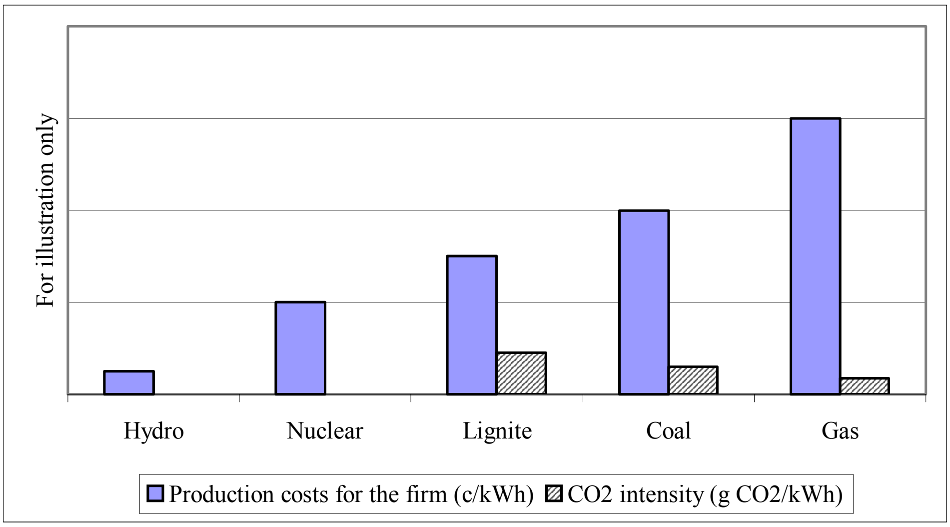
The electricity sector and market both have special characteristics which are described below. It is important to understand these features as they are responsible for the effects shown below.

4.1 Some Explanatory Remarks - Supply and Demand Side Characteristics

The electricity market has special characteristics. The product is homogenous whereas a number of options exist for the production, which involve different quantities of GHG emissions per unit produced. Lignite fired power plants incur the highest specific emissions. Apart from the fuel used, the efficiency of the power plant is also relevant. In the lower range, there are a number of zero emission technologies as for example nuclear power plants or renewable energies. Storage of electricity is possible, though much more complicated and expensive, when compared to other goods.

It goes without saying that both short-term and long-term marginal production costs also differ. Figure 6.2 gives a schematic overview for different production techniques and their characteristics as it can be seen in western European countries. As the paper focuses on the short-term implications and as the short-term market economics are determined by marginal costs (UBS 2003, p. 29), only short-term marginal costs[79] are considered.

Figure 6.2
Schematic production costs and CO_2 intensities for different production techniques (figures are given in Table 6.1)



Apart from the economic and emission-related aspects, there are other differences between the technologies. Most important for this paper is the operational flexibility. While gas fired plants, for example, can be started and stopped quite easily, lignite fired or nuclear power plants require more time for both processes. Thus they are differently suited for satisfying peak load demand which is discussed below.

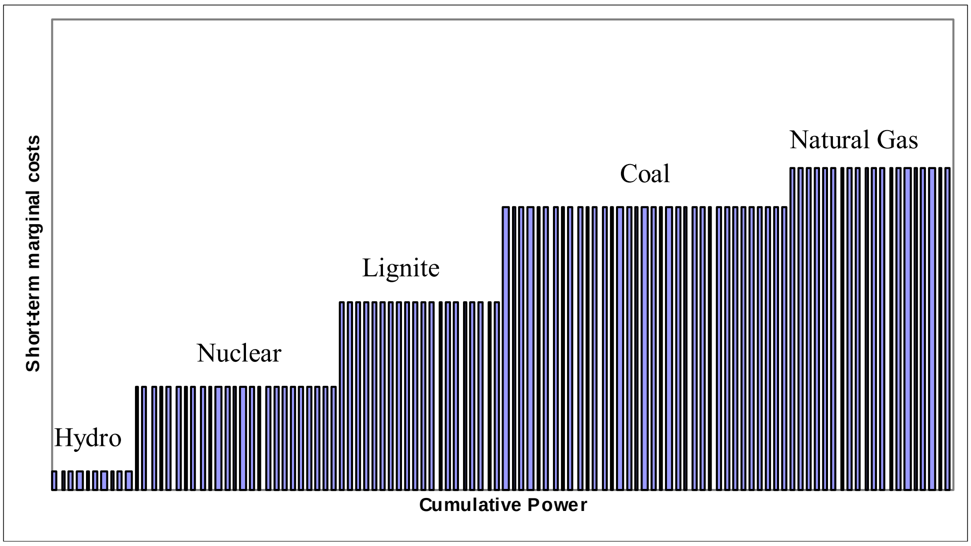
The main characteristic for the demand side is the variation throughout the day as depicted in Figure 6.5 in the data section below. Demand in modern societies is

79 Most important parts of short-term marginal production costs are fuel costs and operation and maintenance (e.g. fuel handling) Balmorel (2001, p. 20).

low during the night when most of the people sleep and peaks about noon. Furthermore, there are changes in the demand curve depending on the season.

When supply and demand match in functioning markets, system economics will determine that the lowest marginal cost plant will be operated first (UBS 2003, p. 32). Thus, a merit order curve as shown in Figure 6.3 develops. As demand changes over the day, the equilibrium price, which is determined by the marginal plant, also changes during the day. Peak load prices are much higher than base load prices.

Figure 6.3
Schematic depiction of short-term marginal electricity production costs depending on the fuel used (no CO_2 costs included)

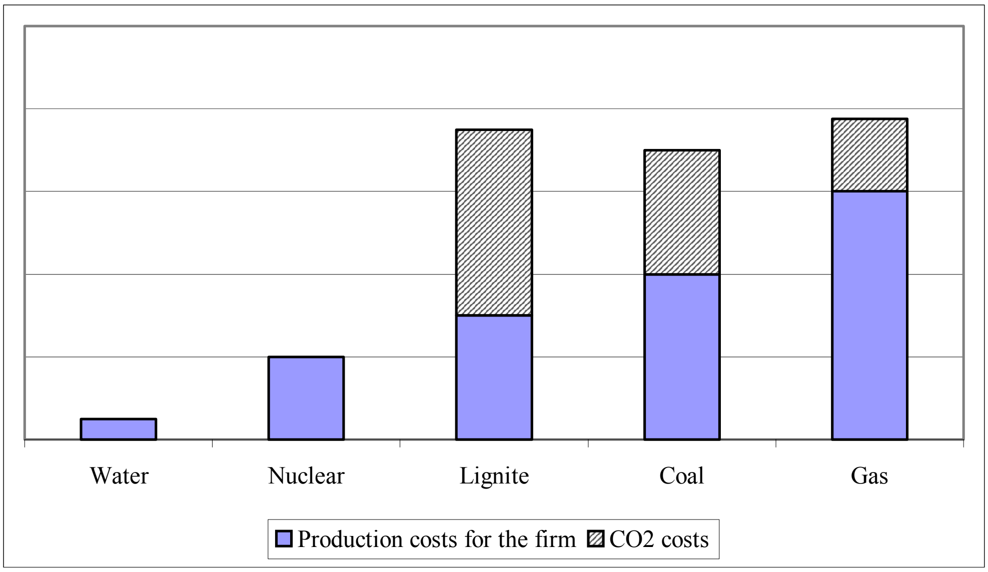


As mentioned above it is important to understand and remember these special characteristics of the electricity sector and market. If, for example, demand would be completely elastic the outcome would change dramatically as it would not be possible to pass on the additional costs to the customer in a way it is assumed here (see Figure 6.1). On the demand side, the heterogeneity of the production processes allows for the large different effects which will be shown below. This would change with one homogenous production options.

4.2 The Impact of CO_2 Costs

Even though CO_2 emissions imply external costs[80] they are rarely included in the current production costs due to lack of appropriate regulation. However, in the case this is done, production costs rises depending on the emission intensity and the costs of an allowance. Depending on the additional costs, the merit order curve may change (see Figure 6.4) and as a consequence the equilibrium price may also change. Some installations may be driven out of the market even though being fully economically viable if emissions face no costs.

Figure 6.4
Exemplary change in merit order due to impact of additional CO_2 costs



In this context it should be noted that primary the objective of emissions trading is not to drive coal and lignite fired power plant out of the market as stated by UBS (2003). It is rather to meet a given target cost-efficiently. This driving out may be a result but not an objective of the instrument. If for example operators of a high emission intensive plant manage to establish "pure" production costs at a certain

80 See for example COM (2003).

level so that total costs (incl. CO_2 costs) are lower than those of competing less emission intensive plants, the instrument could still be judged to be successful in the sense that the total emission target is met.

4.3 The Model

To analyse the impact of different allocation options in multi-period emission trading in the electricity sector a power market is simulated. Effects outside the power sector, as for example effects on the labour market, are not considered.

The Market[81]

Two periods (years) are studied. The market is perfectly competitive. The supply side consists of i = 1, 2, …N installations which are run by either water, uranium, lignite, coal or gas.

The individual supply curve for hour t is as follows:

$$S^i_{t,r} = (c^i_r + k^i_r) q^i_{t,r} \qquad \text{if } (c^i_r + k^i_r) \leq p_{t,r} \tag{1a}$$

$$S_{i,t} = 0 \qquad \text{if } (c^i_r + k^i_r) > p_{t,r} \tag{1b}$$

$$\text{s.t. } q^i_{t,r} \leq q^i_{\max} \tag{2}$$

with $k^i_r = e^i p^{CO_2}_r$

Where $S^i_{t,r}$ = supply of installation i in hour t in period r (MW), which results in a corresponding production of (MWh), c^i_r = short term marginal costs of installation i in period r (Euro/MWh), k^i_r = specific CO_2 costs for installation i in period r (Euro/MWh), $q^i_{t,r}$ = power of installation i in hour t in period r (MW), $p_{t,r}$ = electricity price in hour t and period r (Euro/MWh), e^i = emission intensity of installation i (t CO_2/MWh), $p^{CO_2}_r$ = costs of CO_2 allowances in period r, which is equal to the market price (Euro/t CO_2), $q^i_{\max}$ = nameplate power of installation i (MW).

Adding up the individual supply curves we get the cumulative supply:

$$S_{t,r} = \sum_i S^i_{t,r} \tag{3}$$

Where $S_{t,r}$ = cumulative supply in hour t and period r (MW)

Demand in this short-term study is assumed to be inelastic.[82] Modern societies depend on electricity and substitutes are hard to find and hard to be implemented in the short-run. People will continue to switch on their fridges to cool their food in the near future even if prices increase. Bower et al. (2001, p. 998) assume an inelastic demand for electricity prices below 125 Euro / MWh which is already very high. The inelastic, exogenously given demand is denoted by $D_{t,r}$.

As the short-term market is analysed, supply and demand are balanced hourly as for example in Bower et al. (2001). As no storage option is considered we get the equilibrium for each hour directly as follows:

$$S_{t,r} = D_{t,r}$$

Only one market is being considered. No distinction between industrial and private consumers is made. Furthermore, neither transmission fees nor taxes are considered.

The Allocation

The allocation of allowances is restricted to CO_2 emitting plants.[83] Two different allocation options are applied: an emission based and a generation benchmark

81 Specific characteristics are provided in the data section that follows.

82 Fischer (2001) and show that rebating revenues from environmental regulation based on the firms' output can provide an incentive to increase output for three different policy instruments. This may result in sub-optimal abatement behaviour compared to the social optimum. Burtraw et al. (2002) show the same for the electricity sector and the generation performance standard mentioned above. However, with the assumption of inelastic demand this does not apply in this analysis.

83 This does not seem to be obviously. Burtraw et al. (2002) allocate allowance to non-hydro renewable sources, too.

based approach.[84] Furthermore, both approaches are distinguished regarding the design over time. More precisely, a constant and an updating approach are proposed. A constant allocation means that emissions rights in both periods are allocated on the basis of (the same) data of the reference period. On the other hand, the distribution is always based on the data of the previous period in an updating allocation. The allowances are given to the installation for the whole year and are also calculated on this level. Thus, in total we get four different allocation possibilities for a single installation i that translate into formula as follows:

Emission based constant

$$A_r^i = \frac{\sum_t e_{t,0}^i q_{t,0}^i}{\sum_i \sum_t e_{t,0}^i q_{t,0}^i} * A_r \quad (5)$$

Emission based updating

$$A_r^i = \frac{\sum_t e_{t,r-1}^i q_{t,r-1}^i}{\sum_i \sum_t e_{t,r-1}^i q_{t,r-1}^i} * A_r \quad (6)$$

Generation benchmark constant

$$A_r^i = \frac{\sum_t q_{t,0}^i}{\sum_i \sum_t q_{t,0}^i} * A_r \quad (7)$$

Generation benchmark updating

$$A_r^i = \frac{\sum_t q_{t,r-1}^i}{\sum_i \sum_t q_{t,r-1}^i} * A_r \quad (8)$$

where A_r^i = allocation to installation i in period r, A_r = total quantity of allowances to be distributed in period r

Emission Abatement

A total budget of allowance for the all plants is set which is 5% below the emissions in the reference year for the first and 10% for the second period respectively. Emission abatement options and costs differ widely among installations. Apart from the fuel applied, the age and retrofit measures taken in

84 Remember the relation between an emission benchmark and generation benchmark in trade system with an absolute cap as shown in the annex.

the past are important factors. However, as the focus is on the multi-period allocation and the market effect, no concrete abatement costs are considered when calculating the profit below. An arbitrary assignment of different mitigation options to the single plant has not been judged reasonable. Rather the same costs - the carbon price on the allowance market – are used for all installations. This implies a worst case scenario as the market price is the highest cost a firm will have to bear. In the case its abatement costs are below the market price, compliance costs would be lower. The firm can abate more than necessary to meet its target and sell allowances on the market. This worst case scenario would be a realistic analysis in the case the sector as a whole would buy emission rights from cheaper abatement options from outside the sector, as for example by investing in CDM projects.

At a first glance the assumption of a fixed total allowance budget and a fixed allowance price may seem strange. In general one would expect the price to be an outcome of the model. However, one has to keep in mind that the allocation can be (and in the European context is) done one the sector level. This provides the opportunity to consider special aspects of different sectors as for example the exposure to international competition. The allowance market, however, may comprise other sectors from one or more states as in the European Union. In this case a single sector in one state can be considered as price taker.

The Overall Financial Impact

Finally, the financial impact consisting of the market effect and the compliance costs can be calculated for one period as follows:

$$P_r^i = \sum_t (p_{t,r} - c_r^i) q_{t,r}^i - (e^i q_{t,r}^i - A_r^i) p_r^{CO_2} \qquad (9)$$

Where P_r^i = profit of installation i in period r (EUR)

The second product on the r.h.s. of the equation constitutes of the compliance costs discussed above.

The Data

On the supply side 110 power plants have been introduced. Table 6.1 gives an overview on type, capacity, specific emissions and costs. The latter are constant over the two periods.

Table 6.1
Portfolio of power plants used in the simulation*)

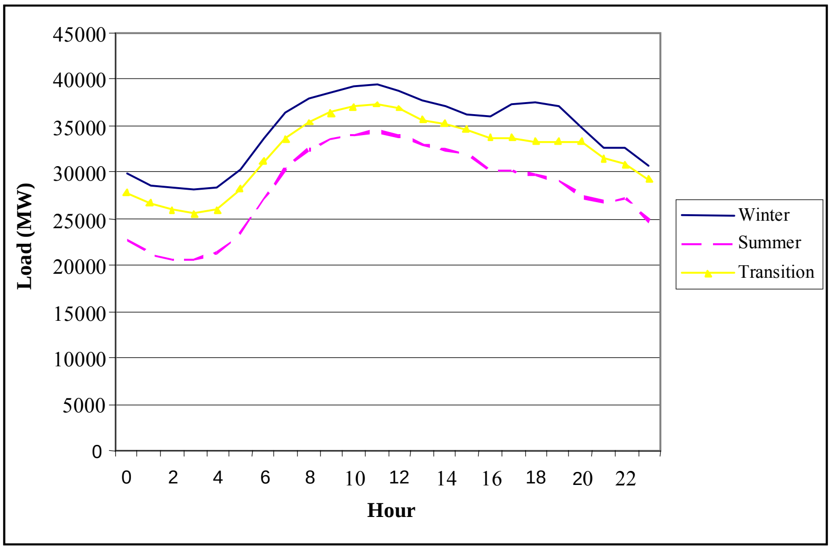
				Short-term marginal costs for the producer (EUR/MWh)	
Type of plant	Number	Net-capacity (MW)	CO_2 intensity (kg CO_2/MWh)	Literature **)	Used in the simulation
Hydro	10	100	0	0 - 4,4	2
Nuclear	25	800	0	0 - 15	5
Lignite	20	350	1000	10 - 21	12
Coal	35	300	800	5 - 22	15
Natural Gas	20	150	350	10 - 37	20

*) Based on Balmorel (2001), Bower et al. (2001), Rowland et al. (2003), Leyva et al. (2003), UBS (2003), UCTE (2002).

**) Differences can be explained by different definitions. Lowest figures only comprise fuel costs whereas higher ones contain all costs of keeping the plant running. Not all studies provide cost data for each type of plant. Regardless of absolute differences, all studies but one result in the same merit order curve as depicted in Figure 6.3.

On the demand side three seasons are distinguished: Summer, winter and transition (see Figure 6.5). The two former comprise 90 days each and the later 180. The trend is based on UCTE (2002). Thus, total annual energy demand amounts to 275 TWh. Maximum demand is 39479 MW in the winter between 11 and 12 am. As the focus in on the allocation and market effect, the same annual demand is assumed for all years.

Figure 6.5
Load curves as used in the simulation



There are a lot of studies dealing with the carbon prices for different kinds of trading schemes. An overview of model results is given by Springer (2003). Prices for Annex B trading only CO_2 are reported to range from 3 to 71 US$/t CO_2. Allowance prices for the EU trading scheme are currently about 12 EUR / t CO_2 (Point Carbon 2004) and CER from CDM projects, which are likely to be eligible within the EU scheme sell at about 5 EUR. Thus, two different carbon prices are studied, 5 and 20 EUR/ t CO_2.

The total allowance budget is set in such a way, that emissions decline compared to the reference period by 5% in the first and by 10% in the second period.

4.4 Results

In order to be able to better compare the different allocation schemes a reference scenario with two periods and no carbon costs has been studied. A discount rate of zero has been applied.[85] To give a first idea of the impact of the model assumptions, Table 6.2 shows the change of the merit order and the resulting change in electricity generation for different plant types. As can be seen, with the assumptions made, there are no changes with a carbon price for CO_2 of 5 EUR/t. However, with a carbon price of 20 EUR/t the total production alters. As one would have expected there are no changes for the emission-free plants, i.e. hydro and nuclear plants. Regarding the CO_2-emitting installations, one can see that production is shifted from the emission intensive to the less intensive.

Table 6.2
Electricity generation with different carbon costs cumulated over two periods

Type of plant	Production of all plants; carbon costs: 0 EUR/t CO_2 (GWh)	Production of all plants; carbon costs: 5 EUR/t CO_2 (GWh)	Production of all plants; carbon costs: 20 EUR/t CO_2 (GWh)
Hydro	17280	17280	17280
Nuclear	345463	345463	345463
Lignite	110196	110196	12423
Coal	76634	76634	125391
Gas	427	427	49443
Total	550000	550000	550000

As mentioned in the analytical section above there will be a price effect that affects all plants regardless of the emission intensity. Only the compliance costs vary as a function of fuel. Table 6.3 and 6.4 show the results in detail. The row "total change" shows the market effect only. It describes the change regarding the variable gross margin (i.e. revenues minus costs where carbon costs are not considered here). For a given allowance price it is always the same. The row "Compliance Costs" on the other hand describes the compliance costs for meeting the emission target (see also equation 9). The net-effect can be determined by subtracting the compliances costs from the absolute change.

85 Discounting is often a point of conflict especially when it comes to a discussion of the "right" discount rate. As both profits and losses generally have to be discounted, a discount rate of zero was judged to be appropriate in this context.

As can be seen, the total changes are always the same, i.e. the electricity sector as a whole benefits from the introduction of the scheme. In contrast, plant-type specific changes depend on the allocation rule. Remember that the absolute figures are a consequence of the assumptions stated above as for example a completely inelastic demand in the short-term market. Thus, it should be interpreted more qualitatively.[86]

As mentioned above, different allocation rules do have distributional effects on certain plant types that depend on the costs for emitting CO_2. Non-emitting plants always face the same changes. They earn only windfall profits due to the introduction of the trading scheme.[87] As carbon costs of 5 EUR/t CO_2 do not have an impact on the total production of certain types of plants (i.e. hydro, lignite etc.), there is no difference between a constant and updating approach for the same class of allocation, i.e. the emission-based and the generation benchmark approach. However, there is a difference between the classes.

It is conspicuous that gas-fired power plants realise negative compliance costs with a generation benchmark allocation. As has been mentioned above, a generation benchmark allocation only refers to output and not to emissions. Obviously, gas-fired plants receive more allowances than they need to be compliant.

The picture changes slightly with higher emission costs. As could be seen in Table 6.2 lignite fired plants lose market shares. This is why they can sell surplus allowances that in turn result in negative compliance costs. Contrary to the case with low costs, there are now differences between the constant and the updating approach within the two allocation classes. The concrete impact depends on whether the plants' production increases or decreases. As this influences the value of the installation, the expected owners' preferences differ accordingly. An overview is given in Table 6.5.

86 The gas-fired power plants do not realise any gross margin because the model itself does not fully represent heterogeneity in technology and costs that exist in industry.

87 More precisely they earn windfall profits as long as the marginal plant is a fossil-fuelled one.

Table 6.3
Model results over two periods for the four different allocation rules and a carbon price of 5 EUR/ t CO_2
(all figures in Mill. EUR)

	Reference scenario (no CO_2 costs)		Emission based constant		Emission based updating		Generation benchmark constant		Generation benchmark updating	
Type of plant	Total variable gross margin [1)]	Absolute change [2)]	Compliance costs [3)]	Net effect [4)]	Compliance costs	Net effect	Compliance. costs	Net effect	Compliance costs	Net effect
Hydro	214	69	0	69	0	69	0	69	0	69
Nuclear	3251	1390	0	1390	0	1390	0	1390	0	1390
Lignite	309	445	224	221	224	221	251	194	251	194
Coal	38	290	125	165	125	165	98	191	98	191
Gas	0	1	0	0	0	0	0	1	0	1
Total	3812	2194	349	1845	349	1845	349	1845	349	1845

1) $\sum_r \sum_t (p_{t,r} - c_r^i) q_{t,r}^i$ (see also equation 9) 2) Compared to reference scenario 3) $\sum_r \sum_t (e^i q_{t,r}^i - A_r^i) p_r^{CO_2}$ (see also equation 9) 4) "Absolute change" minus "Compliance costs"

Table 6.4
Model results over two periods for the four different allocation rules and a carbon price of 20 EUR/ t CO_2
(all figures Mill EUR)

	Reference scenario (no CO2 costs)		Emission based constant		Emission based updating		Generation benchmark constant		Generation benchmark updating	
Type of plant	Total variable gross margin [1)]	Absolute change [2)]	Compliance costs [3)]	Net effect [4)]	Compliance costs	Net effect	Compliance. costs	Net effect	Compliance costs	Net effect
Hydro	214	280	0	280	0	280	0	280	0	280
Nuclear	3251	5602	0	5602	0	5602	0	5602	0	5602
Lignite	309	-60	-1059	999	-517	457	-950	890	-433	373
Coal	38	2025	1279	746	872	1153	1173	852	915	1110
Gas	0	557	357	201	222	336	354	203	94	463
Total	3812	8404	576	7827	576	7827	576	7827	576	7827

1) $\sum_r \sum_t (p_{t,r} - c_r^i) q_{t,r}^i$ (see also equation 9) 2) Compared to reference scenario 3) $\sum_r \sum_t (e^i q_{t,r}^i - A_r^i) p_r^{CO_2}$ (see also equation 9) 4) "Absolute change" minus "Compliance costs"

Table 6.5
Owner's preference for different types of plants for different allocation rule as a function of the carbon costs

		Carbon costs (EUR / t CO_2)	
Type of plant	Preference	5	20
Hydro		indifferent	indifferent
Nuclear		indifferent	indifferent
Lignite	1.	Emission based	Emission based constant
	2.		Generation benchmark constant
	3.	Generation benchmark	Emission based updating
	4.		Generation Benchmark updating
Coal	1.	Generation benchmark	Emission based updating
	2.		Generation benchmark updating
	3.	Emission based	Generation benchmark constant
	4.		Emission based constant
Gas	1.	Generation benchmark	Generation benchmark updating
	2.		Emission based updating
	3.	Emission based	Generation benchmark constant
	4.		Emission based constant

As can be seen in Table 6.5, the preferences vary strongly among the different fossil-fuelled plants. With the carbon prices studied, the lignite-fired power plant operators would always prefer the emission based constant approach, whereas the gas-fuelled plant operators would prefer the updating generation benchmark as basis for the allocation. Operators whose plants use coal do not have a clear preference. Plant operators may take these results in mind when lobbying for a certain design of the trading scheme. On the other hand, politicians may use it when framing their general energy policy.

5. Conclusion

Emission trading offers the opportunity to limit GHG emissions into the atmosphere cost-efficiently. This is one reason why the EU decided to implement a Europe-wide trading scheme for major sources such as combustion plants with a thermal power larger than 20 MW. Thus, the majority of the electricity sector must participate. However, many detailed design issues have not been decided yet. The question of how to allocate emission allowance over time is one of them.

This paper has analysed this point using the electricity sector as an example. Using a stylised power market, four different allocation options have been used to analyse the resulting impact on different types of plants. It turned out that the electricity sector as a whole is likely to benefit from the introduction of the trading scheme as long as the allowances are distributed free of charge. The results, however, must be interpreted with caution as some simplified assumptions were made. If, for example, the assumption of the inelastic demand was released, the additional costs from emitting CO_2 would not translate in a corresponding increase of the electricity price. Thus, the change in the variable gross margin would be smaller. Additionally, the incentive to increase output with an output-based allocation as described by Fischer (2001) and Burtraw et al. (2002) would have to be considered.

Non-emitting facilities such as hydro or nuclear plants are indifferent with regard to the allocation rule. They always realise windfall profits as long as the marginal plant is fossil-fuelled. With regard to the later group of plants, it was shown that the preferences depend on the fossil fuel used as well as on the carbon costs. The result may serve decision makers in industry and policy during the negotiations on the design of the scheme.

Future work will use more specific data on both, supply and demand side. Furthermore, the time period may be extended to allow new plants to enter the market. A more detailed distinction on installation level between abatement costs and compliance costs is also of interest though such data may be hard to collect.

Annex

How does a benchmark based allocation work?

In this analysis the term "benchmark" is used in the sense of a specific emission factor, i.e. $\frac{emissions}{output}$.[88]

The allocation based on a general benchmark could be calculated as follows

$$A_r^i = s_{r-j} q_{r-j}^i \quad (10)$$

where A_r^i = allocation to installation i in period r, $s_{r\text{-}j}$ = benchmark in period r-j, q_{r-j}^i = output of installation i in period r-j

An alignment between a bottom-up (benchmark) approach and a top-down constraint as set by the Kyoto targets requires the consideration of the constraint given in inequality (6). A straightforward approach would be the introduction of a period-specific correction factor c_r as discussed for example in PwC (2003) and AGE (2001)

$$c_r = \frac{A_t}{\sum_i A_r^i} \quad (11)$$

Taking into account this factor, (10) changes to

$$A_r^i = s_{r-j} q_{r-j}^i c_r \quad \Leftrightarrow A_r^i = s_{r-j} q_{r-j}^i \frac{A_r}{\sum_i A_r^i} \quad \Leftrightarrow A_r^i = s_{r-j} q_{r-j}^i \frac{A_r}{\sum_i s_{r-j} q_{r-j}^i}$$

$$\Leftrightarrow A_r^i = \frac{q_{r-j}^i}{\sum_i q_{r-j}^i} A_r \quad (12)$$

A_r = total quantity of allowances to be distributed in period r

88 Theoretically, any benchmark as, for example, labour productivity or turnover could be used for allocation. For an emission benchmark, other reference figures than the output could also be used.

As one can see, a benchmark based allocation which takes into account the national budget (e.g. the Kyoto Commitment), results in an individual allocation which is only proportional to a participant's output in a certain period and not at all related to emission intensities. This might be somewhat surprising as the intention of the use of a benchmark is generally to consider the specific emissions.[89]

89 Compliance costs may of course differ.

Chapter 7

Conclusion

Sven Bode

Contents

1. Summary of Results

Climate is changing and there is increasing evidence that this is due to the excessive release of anthropogenic greenhouse gas emissions into the atmosphere. As a consequence of this unnatural change, severe adverse impacts on natural and human systems are expected. The first forerunners are already experienced today.

As a consequence, the international community took action and agreed on the United Nations Framework Convention on Climate Change and adopted the Kyoto-Protocol to this Convention. Although the latter has not entered into force until today due to the lacking ratification of at least Russia or the US, it still is the most advanced international agreement on climate change.

Though the Kyoto Protocol is quite advanced in terms of specification of rules, a number of issues are still unresolved or undecided. These issues are mostly related to the allocation of GHG emission entitlements among Parties to the Convention and across time. Against this background the present study tried to answer the following five questions:

1. How must the rules for the determination of emission reductions by renewable energy projects in developing countries be set in order to avoid the crediting of non-additional emissions reductions and to avoid adverse incentives regarding cost efficiency of the international climate policy regime?
2. How can the burden of limiting GHG emissions be shared among states in such a way that the two justice principles *responsibility* (for climate change) and *equity of rights* are combined while at the same time offering flexibility regarding the time of fulfilling the resulting obligation for each Party?
3. How can the European Union, the leader in international climate policy, continue its burden sharing after 2012 and what are the consequences of different approaches regarding the costs and the negotiation process among member states?

4. How can the emissions from international maritime transport, which are currently not part of any Parties' GHG emission inventory, be addressed by and integrated into the international reduction efforts?
5. What are the implications of different approaches to allocate GHG emission entitlements to the participants of multi-period emissions trading schemes?

During the analysis of the first question in Chapter 2, the following general dilemma emerged. On the one hand, strict rules for issuance of certified emission reductions (CERs) generated through CDM-projects are necessary in order to avoid the crediting of non-additional emission reductions.[90] Fake credits may be beneficial to investors, but would worsen the environmental integrity of the clean development mechanism. On the other hand a stiff investment additionality threshold[91] would make these projects become more attractive than other projects which are economically viable *without* supplement income from the sale of CERs. This may provide incentives for investors to decide in favour of projects which are not cost-efficient from the macro-economical point of view.

For renewable energies (RE) two other aspects must be considered in this context. Firstly, the yield of RE-projects generally depends on the site where the device is installed. Secondly, electricity is often traded across borders while emission reductions are calculated in a national context only. Together, these two aspects may create an incentive to invest at unfavourable sites. To give an example, there may be an incentive to install wind turbines at sites with low wind speed but high computed emission reductions. This point was studied in more detail by simulating two concrete options: an investment in a wind turbine and in a photovoltaic module. The theoretical findings are found to be relevant for realistic projects.

90 This is why the corresponding discussion is referring to the "additionality" requirement.

91 I. e. a threshold which only allows the issuance of CERs to additional and thus non-economical projects.

To overcome this adverse incentive, two suggestions were made. Firstly, the quantification of reductions should be based on the electrical grid the RE device is connected to and not on the basis of national statistics. Secondly, a fuzzy investment additionality approach was introduced according to which CERs are issued as a function of the IRR of the project in question. By so doing the undesired incentive can clearly be weakened.

The investigation of the second question starts with a review of different justice principles. When trying to apply these principles in the context of the allocation of GHG emissions entitlements, as in other contexts, the problem arises that there is no *one and only* principle which is supported by all Parties involved in the international climate negotiations. Views are particularly opposed between industrialised and developing countries.

Regarding the high number of possible allocation schemes, two approaches which are worthwhile to be mentioned, are the so-called Contraction and Convergence approach and the Brazilian Proposal. The first one is supported by a number of stakeholders and is mainly based on the principle of equity of rights. The second approach is based on the principle of responsibility and has formally entered the international climate negotiations. In the course of the analysis in Chapter 3, these two principle have been combined in such a way that the average emissions per capita are the same for all people on earth from a certain year in the past to the future. The outcome is an allocation which may be perceived as fair though it may lack political support from industrialised countries. Most of them would receive a few, even negative, emission entitlements due to their accumulated historical contribution to climate change.

Another interesting feature of the combination proposed is the great flexibility the approach offers. Parties would be allowed to start contributing to limiting global GHG emissions whenever they like. However, the later they start, the more negative the “emission entitlement account” will be in subsequent periods.

Sharing the burden of limiting GHG emissions is, however, not only an issue between industrialised and developing countries; it is also a potential source of conflict within the former group. This is why different burden sharing options, among which the one proposed in Chapter 3, are studied for a long-term European emission target in Chapter 4. As the EU will have new members after 2012, the year the current burden sharing agreement ends, the states joining the EU on May 1 2004, as well as Romania and Bulgaria, have been included.

The analysis of the cost implications of the different approaches for the member states reveals that costs may differ strongly at least for some member states. Others, however, may be almost indifferent regarding the different options as cost differences are small, especially when put into relation to GDP. Given these distributional implications, an indicator was developed which describes each member state‘s expected interest in the negotiations on the burden sharing in Brussels. By choosing a “relevance threshold”, conclusions on the complexity to be expected during these negotiations may be drawn.

Like GHG emissions from developing countries, emissions from international aviation and international maritime transportation are also uncapped, i.e. there is no quantitative limit for them. This is quite unsatisfactory as all these sources show rapidly increasing GHG emissions. Against this background, GHG emissions from international shipping are discussed in Chapter 5.

The discussion of options to allocate these emissions to Parties of the Convention shows that different alternatives exist in theory which are, however, inadequate in practice. This is either for political, environmental or technical/economic reasons. Annex-B Parties, for example, have already been and are likely to continue to be reluctant to have these emissions included into their emission inventory on the basis of bunker fuel sold in their ports. This would put an additional burden on them. In contrast to that, non-Annex-B countries do not mind using bunker fuels sold in their ports or other rules[92] as a basis as they currently do not have an emission target. If emissions were allocated that way, environmental integrity would not be secured. Other options as for example the application of the polluter-

92 As for example the tonnage registered in their shipping registers.

pays-principle seem tempting, however, transaction costs for assigning specific emissions to a specific, responsible person are prohibitive.

An analysis of the possible instruments which could be introduced to address this problem shows once again the trade-off among different criteria as for example environmental effectiveness, cost efficiency, dynamic efficiency, institutional complexity or conformity with existing regulation. It is concluded that the most promising strategic option for the International Maritime Organisation, the body through which this sector shall be addressed according to the Kyoto-Protocol, is to accept an overall cap for emissions from international maritime transportation and to subsequently allocate the resulting budget of emission entitlements to the individual shipping companies or ships. For a prompt start of emission reductions in this uncapped sector, a CDM-type mechanism is proposed. However, the same aspects regarding undesirable incentives and environmental integrity as discussed in Chapter 2 would have to be kept in mind.

When talking about the allocation of allowances in GHG emissions trading schemes, one has to keep in mind that real trading schemes are multi-period games. This is to say that emission entitlements are allocated to the participants at the beginning of a period and that they have to surrender entitlements equal to their emissions at the end or the beginning of the next period. If the entitlements are distributed free of charge as it is the case for most existing and planned trading schemes, the question arises of how to allocate emissions in the subsequent periods.

As existing and planned schemes mostly propose either an emission based or benchmark based allocation, these two options are studied in detail. The options are specified in such a way that entitlements are either allocated on the basis of initial, i.e. constant reference figures over all periods or on the basis of rolling reference figures, that is to say figures that are updated each period. As governments generally do not behave in a cost-minimising manner, the electricity sector, a major source of GHGs, has been used as an example instead. A realistic power market with more than 100 power plants is simulated over two periods.

It turns out that there is no impact of different allocation rules on the electricity market. This is due to the fact that producing and thus emitting greenhouse gases always involves the same costs for the company which is the price on the carbon market. From the company's point of view, it is unimportant whether the emission allowance was purchased or received free of charge. In the latter case, the opportunity costs of using the allowances must be considered.

What differs are the compliance costs for the different installations. Compliance costs are defined as the sum of the costs for reducing emissions in-house and for purchasing or selling allowances on the market. It was found that the installations' preference regarding the different allocation options depends on the emission intensity of the fuel used and the price on the carbon market. These findings may be helpful when determining national energy policies and the national allocation plans for allowances as for example in the context of the upcoming EU emissions trading scheme.

2. Limitations of the Study and Implications for Future Research

It goes without saying that a study as the one presented cannot address all crucial issues of the current international climate policy regime.

An important example of these neglected points, which is worthwhile to be mentioned, is adaptation to the adverse impacts of climate change. This is already important today and it may even become more important than mitigation in the future for both research and policy making. Much research is required in this field.

With regard to this study and especially to Chapter 2, 3 and 5, the question of how CDM projects, which are already implemented, should be treated in case the host country accepts an absolute emission target needs to be answered. As the first non-Annex I country (Kazakhstan) expressed its interest to join Annex I, this question must be resolved soon.

Another aspect which has been mentioned, but which could not be resolved, is the need to find mechanisms to bridge the gap between the opposing views of industrialised and developing countries with regard to the contribution to limiting GHG emissions. This is why the burden sharing rule proposed in Chapter 3 may be considered as interesting academic exercise only. It may, however, also serve as a new analytical starting point for the international climate negotiations. Something similar is true for the analysis of the cost implications from allocating GHG entitlement based on different justice principles within the EU as presented in Chapter 4. From an economist's point of view, auctioning the emission rights as mentioned in Chapter 6 may be the option of choice. However, it goes without saying that there is currently no political support for such an approach, especially for an allocation on the state level. For a more likely allocation on an entity level, the question of how to use the revenue from the auction would need to be answered first.

This leads to a broader framework which may not have been sufficiently kept in mind throughout this study - the political economy of climate policy. There is a number of powerful stakeholders which benefit more from a lax climate policy regime than from a stringent one: Project developers and host countries of the CDM (Chapter 2), high emitting industrialised countries (Chapter 3), poor high emitting countries within the EU which are likely to demand at least side payments for stringent targets (Chapter 4), the international shipping industry (Chapter 5) and the energy intensive industry which currently lobbies heavily in the context of the so-called national allocation plan under the EU-directive on emissions trading (Chapter 6). Given this distribution of power, even promising proposals to advance the international climate policy may fail in reality – at the expense of environmental integrity. Then, the role of adaptation will become crucial one day.

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Annex

This chapter provides data used in the previous chapter which was not explicitly presented in the interest of brevity and which is not directly accessible via the references mentioned. It is, in other words, data which has been calculated as for example by interpolation. The respective equation has always been presented in the respective chapter.

Additional data used in Chapter 3

Table 8.1 shows the emissions assumed for Annex I countries accepting the new approach from 2013 onwards for the years 1999 to 2008.

Table 8.2 shows the emissions assumed for countries accepting an emission target from 2022 onwards for the years 1999 to 2021

Table 8.3 shows the population assumed between 2051 and 2100 for all countries studied.

Additional data used in Chapter 4

Table 8.4 shows the emissions assumed for EU member states for the years between 1990 and 2010.

Table 8.1
CO_2 Emissions from fuel combustion assumed in Chapter 3 for certain countries for the years 1999 to 2007 (million t CO_2)

	1999	2000	2001	2002	2003	2004	2005	2006	2007
Australia	320.37	323.58	326.81	330.08	333.38	336.71	340.08	343.48	346.92
Canada	504.60	509.64	514.74	519.89	525.08	530.34	535.64	541.00	546.41
Germany	872.54	881.26	890.08	898.98	907.97	917.05	926.22	935.48	944.83
Japan	1110.29	1121.40	1132.61	1143.94	1155.38	1166.93	1178.60	1190.38	1202.29
Spain	251.09	253.60	256.13	258.69	261.28	263.89	266.53	269.20	271.89

Table 8.2
Emissions from fuel combustion assumed in Chapter 3 for certain countries for the years 1999 to 2021 (million t CO_2)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Argentina	131.01	132.32	133.64	134.98	136.33	137.69	139.07	140.46	141.86	143.28	144.71	146.16	147.62	149.10
Brazil	286.18	289.05	291.94	294.86	297.80	300.78	303.79	306.83	309.90	312.99	316.12	319.29	322.48	325.70
China	2874.69	2903.44	2932.47	2961.80	2991.42	3021.33	3051.54	3082.06	3112.88	3144.01	3175.45	3207.20	3239.28	3271.67
India	882.49	891.31	900.23	909.23	918.32	927.50	936.78	946.15	955.61	965.16	974.82	984.56	994.41	1004.35
Nigeria	43.69	44.13	44.57	45.02	45.47	45.92	46.38	46.84	47.31	47.79	48.26	48.75	49.23	49.73
Saudi Arabia	259.73	262.33	264.95	267.60	270.28	272.98	275.71	278.47	281.25	284.06	286.91	289.77	292.67	295.60
US	5487.63	5542.51	5597.93	5653.91	5710.45	5767.56	5825.23	5883.49	5942.32	6001.74	6061.76	6122.38	6183.60	6245.44
Uzbekistan	108.84	109.93	111.03	112.14	113.26	114.39	115.53	116.69	117.86	119.03	120.22	121.43	122.64	123.87

Table 8.2 continued

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Argentina	150.59	152.10	153.62	155.15	156.70	158.27	159.85	161.45	163.07	164.70
Brazil	328.96	332.25	335.57	338.93	342.32	345.74	349.20	352.69	356.22	359.78
China	3304.38	3337.43	3370.80	3404.51	3438.56	3472.94	3507.67	3542.75	3578.18	3613.96
India	1014.40	1024.54	1034.79	1045.13	1055.59	1066.14	1076.80	1087.57	1098.45	1109.43
Nigeria	50.22	50.73	51.23	51.75	52.26	52.79	53.31	53.85	54.38	54.93
Saudi Arabia	298.55	301.54	304.56	307.60	310.68	313.78	316.92	320.09	323.29	326.52
US	6307.89	6370.97	6434.68	6499.03	6564.02	6629.66	6695.96	6762.91	6830.54	6898.85
Uzbekistan	125.11	126.36	127.62	128.90	130.19	131.49	132.80	134.13	135.47	136.83

Table 8.3
Population assumed in Chapter 3 for the years 2051 to 2100 (million people)

	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064
Canada	41.35	41.39	41.42	41.45	41.47	41.49	41.50	41.50	41.50	41.50	41.49	41.47	41.46	41.43
Australia	24.34	24.36	24.37	24.38	24.40	24.41	24.42	24.43	24.43	24.44	24.45	24.45	24.46	24.46
Germany	73.39	73.06	72.74	72.41	72.09	71.76	71.44	71.11	70.78	70.46	70.14	69.82	69.49	69.18
Japan	99.78	99.06	98.34	97.64	96.95	96.28	95.62	94.98	94.35	93.74	93.15	92.57	92.01	91.47
Spain	35.54	35.35	35.16	34.97	34.78	34.60	34.41	34.22	34.03	33.84	33.66	33.47	33.28	33.10
Argentina	49.11	49.18	49.24	49.30	49.36	49.41	49.47	49.52	49.56	49.61	49.66	49.70	49.75	49.79
Brazil	230.75	230.87	230.98	231.07	231.14	231.21	231.26	231.30	231.34	231.36	231.39	231.40	231.42	231.43
China	1424.81	1421.30	1417.68	1413.95	1410.12	1406.22	1402.24	1398.20	1394.11	1389.98	1385.82	1381.65	1377.47	1373.29
India	1607.05	1613.40	1619.54	1625.46	1631.17	1636.66	1641.94	1647.02	1651.88	1656.55	1661.01	1665.28	1669.35	1673.23
Nigeria	307.34	311.12	314.87	318.59	322.28	325.94	329.55	333.13	336.67	340.16	343.61	347.01	350.35	353.65
Saudi Arabia	90.42	91.96	93.48	94.98	96.46	97.91	99.35	100.75	102.14	103.49	104.82	106.12	107.39	108.62
US	418.81	420.93	423.00	425.01	426.96	428.86	430.70	432.48	434.19	435.85	437.44	438.96	440.42	441.80
Uzbekistan	48.49	48.81	49.10	49.39	49.67	49.93	50.18	50.42	50.65	50.86	51.06	51.25	51.43	51.59

Table 8.3 continued

	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078
Canada	41.41	41.37	41.34	41.30	41.26	41.21	41.16	41.11	41.05	40.99	40.93	40.86	40.79	40.72
Australia	24.47	24.47	24.48	24.48	24.48	24.49	24.49	24.50	24.50	24.51	24.52	24.52	24.53	24.54
Germany	68.86	68.54	68.23	67.92	67.62	67.31	67.01	66.71	66.42	66.13	65.84	65.56	65.28	65.00
Japan	90.95	90.45	89.97	89.51	89.07	88.65	88.25	87.87	87.51	87.17	86.86	86.56	86.29	86.04
Spain	32.92	32.74	32.56	32.38	32.21	32.03	31.86	31.69	31.53	31.36	31.20	31.04	30.89	30.73
Argentina	49.83	49.87	49.91	49.96	50.00	50.04	50.08	50.12	50.17	50.21	50.25	50.30	50.35	50.39
Brazil	231.44	231.45	231.46	231.47	231.48	231.50	231.53	231.56	231.60	231.64	231.70	231.76	231.83	231.92
China	1369.13	1364.99	1360.88	1356.81	1352.80	1348.85	1344.97	1341.17	1337.46	1333.84	1330.33	1326.92	1323.63	1320.47
India	1676.92	1680.43	1683.75	1686.90	1689.86	1692.66	1695.29	1697.75	1700.05	1702.19	1704.18	1706.02	1707.71	1709.26
Nigeria	356.89	360.07	363.20	366.27	369.27	372.21	375.08	377.89	380.63	383.30	385.90	388.43	390.88	393.26
Saudi Arabia	109.83	111.00	112.13	113.24	114.30	115.33	116.33	117.28	118.20	119.07	119.91	120.71	121.46	122.18
US	443.13	444.38	445.56	446.67	447.70	448.67	449.56	450.38	451.13	451.80	452.40	452.92	453.37	453.74
Uzbekistan	51.74	51.88	52.01	52.12	52.22	52.31	52.39	52.45	52.51	52.55	52.57	52.59	52.60	52.59

Table 8.3 continued

	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092
Canada	40.65	40.57	40.50	40.42	40.34	40.25	40.17	40.08	40.00	39.91	39.82	39.73	39.64	39.54
Australia	24.55	24.56	24.57	24.59	24.60	24.61	24.63	24.65	24.67	24.68	24.71	24.73	24.75	24.78
Germany	64.73	64.46	64.20	63.94	63.69	63.44	63.20	62.96	62.73	62.50	62.28	62.07	61.85	61.65
Japan	85.81	85.61	85.42	85.25	85.11	84.99	84.89	84.81	84.75	84.71	84.70	84.70	84.72	84.76
Spain	30.58	30.44	30.29	30.15	30.02	29.88	29.75	29.63	29.50	29.38	29.27	29.15	29.04	28.94
Argentina	50.44	50.49	50.55	50.60	50.65	50.71	50.77	50.83	50.89	50.96	51.02	51.09	51.16	51.23
Brazil	232.01	232.12	232.24	232.38	232.52	232.69	232.86	233.06	233.26	233.49	233.73	233.98	234.25	234.54
China	1317.44	1314.55	1311.80	1309.20	1306.75	1304.46	1302.34	1300.38	1298.60	1296.99	1295.56	1294.31	1293.24	1292.36
India	1710.66	1711.93	1713.07	1714.08	1714.97	1715.73	1716.38	1716.92	1717.34	1717.66	1717.88	1718.00	1718.03	1717.96
Nigeria	395.56	397.79	399.94	402.01	404.00	405.91	407.75	409.50	411.17	412.76	414.27	415.70	417.05	418.32
Saudi Arabia	122.85	123.49	124.08	124.63	125.14	125.60	126.02	126.41	126.75	127.04	127.30	127.51	127.69	127.82
US	454.04	454.27	454.42	454.49	454.50	454.43	454.29	454.07	453.79	453.43	453.01	452.52	451.96	451.33
Uzbekistan	52.57	52.54	52.50	52.45	52.39	52.32	52.24	52.15	52.05	51.94	51.81	51.69	51.55	51.40

Table 8.3 continued

	2093	2094	2095	2096	2097	2098	2099	2100
Canada	39.45	39.36	39.26	39.17	39.08	38.98	38.89	38.80
Australia	24.80	24.83	24.86	24.89	24.92	24.96	24.99	25.03
Germany	61.45	61.25	61.06	60.88	60.70	60.53	60.36	60.20
Japan	84.82	84.90	85.00	85.12	85.25	85.40	85.57	85.76
Spain	28.84	28.74	28.64	28.55	28.47	28.38	28.30	28.23
Argentina	51.31	51.39	51.46	51.54	51.63	51.71	51.80	51.89
Brazil	234.85	235.17	235.51	235.86	236.24	236.62	237.03	237.45
China	1291.67	1291.16	1290.84	1290.72	1290.78	1291.03	1291.47	1292.10
India	1717.81	1717.58	1717.26	1716.88	1716.42	1715.89	1715.29	1714.64
Nigeria	419.50	420.61	421.64	422.59	423.46	424.25	424.96	425.60
Saudi Arabia	127.91	127.96	127.98	127.95	127.89	127.78	127.64	127.47
US	450.64	449.89	449.07	448.19	447.25	446.26	445.20	444.09
Uzbekistan	51.24	51.08	50.91	50.73	50.55	50.35	50.16	49.95

Table 8.4
Emissions assumed for EU member states for the years between 1990 and 2010 (1000t $CO_{2\ -eq}$)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Austria	78.073	82.241	75.291	76.580	77.768	80.797	84.624	84.146	83.819	82.123
Belgium	141.216	147.107	145.641	144.038	147.636	151.773	154.182	149.243	153.403	150.054
Bulgaria	*157.090*	*115.679*	*103.710*	*102.084*	*92.586*	*98.131*	*101.984*	*89.811*	*81.360*	*77.967*
*Cyprus *)*	*3.900*	*4.400*	*4.710*	*4.940*	*5.160*	*5.060*	*5.300*	*5.500*	*5.800*	*6.100*
Czech Rep.	*189.839*	*175.323*	*161.221*	*154.710*	*147.292*	*148.103*	*153.579*	*157.816*	*148.300*	*140.578*
Denmark	69.217	79.910	73.459	76.209	80.039	77.335	90.778	80.945	75.797	72.750
Estonia	*40.732*	*39.813*	*30.210*	*24.087*	*24.925*	*22.653*	*23.122*	*23.097*	*21.756*	*19.878*
Finland	77.233	75.281	72.173	72.829	79.195	76.652	82.122	81.056	78.512	77.831
France	560.775	583.739	573.892	552.304	548.945	558.052	573.851	566.525	582.082	564.074
Germany	1.211.579	1.158.262	1.104.970	1.086.585	1.065.314	1.058.861	1.077.642	1.040.112	1.015.984	982.932
Greece	104.755	104.760	106.172	106.714	109.238	110.429	114.220	119.504	124.343	123.697
Hungary	101.633	87.905	79.077	78.974	77.161	77.916	79.183	76.854	83.688	86.547
Ireland	53.420	54.461	55.284	54.983	56.707	57.583	59.249	62.030	64.124	66.256
Italy	508.629	510.208	507.441	498.038	492.169	520.385	514.671	521.598	532.608	538.627
Latvia	*31.025*	*24.871*	*20.451*	*16.802*	*15.313*	*13.382*	*12.673*	*11.935*	*12.101*	*13.614*
Lithuania	*51.548*	*48.086*	*44.624*	*41.162*	*37.700*	*34.237*	*30.775*	*27.313*	*23.851*	26.466
Luxembourg	10.883	10.455	10.303	10.595	10.257	7.792	7.851	6.851	5.919	6.029
*Malta *)*	*2.300*	*2.200*	*2.160*	*2.790*	*2.500*	*2.270*	*2.430*	*2.500*	*2.400*	*2.400*
Netherlands	210.004	217.795	216.651	219.569	220.869	223.314	232.901	220.330	225.156	216.446
Poland	*564.286*	*437.448*	*439.045*	*429.649*	*438.895*	*416.530*	*436.545*	*426.220*	*402.477*	*400.260*
Portugal	61.441	63.251	67.322	65.617	66.253	69.972	67.496	69.670	74.577	82.880
Romania	*264.879*	*179.762*	*172.168*	*167.187*	*164.026*	*169.724*	*175.422*	*181.120*	*186.819*	*192.517*
Slovak Rep.	*72.530*	*63.857*	*59.154*	*55.052*	*52.003*	*53.697*	*53.505*	*53.509*	*51.289*	*51.796*
Slovenia	*19.322*	*17.988*	*17.755*	*18.371*	*18.516*	*19.310*	*20.042*	*19.798*	*19.554*	*19.309*
Spain	287.609	294.203	303.051	291.330	306.069	319.363	311.373	332.546	343.082	371.057
Sweden	72.756	72.873	72.042	71.881	76.679	75.085	78.687	73.772	74.907	72.239
UK	744.139	744.862	721.671	701.635	697.555	687.417	709.075	684.952	683.543	646.537
EU total	5.690.813	5.396.740	5.239.648	5.124.715	5.110.770	5.135.824	5.253.283	5.168.753	5.157.250	5.090.964

*) CO_2 emissions from fuel combustion only.

Table 8.4 continued

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Austria	81.951	85.880	83.315	80.750	78.184	75.619	73.054	70.489	67.924	67.924
Belgium	149.943	150.169	147.377	144.585	141.793	139.001	136.209	133.417	130.625	130.625
Bulgaria	85.380	92.793	100.206	107.619	115.033	122.446	129.859	137.272	*144.685*	144.685
*Cyprus *)*	*6.300*	*6.200*	5.827	5.454	5.081	4.707	4.334	3.961	3.588	3.588
Czech Rep.	144.125	147.672	151.219	154.766	158.312	161.859	165.406	168.953	172.500	172.500
Denmark	68.181	69.410	67.306	65.202	63.098	60.994	58.890	56.786	54.681	54.681
Estonia	21.833	23.788	25.743	27.698	29.653	31.608	33.563	35.518	37.473	37.473
Finland	75.391	80.888	80.366	79.844	79.322	78.799	78.277	77.755	77.233	77.233
France	557.909	560.757	560.760	560.762	560.765	560.767	560.770	560.772	560.775	560.775
Germany	981.468	993.505	988.311	983.117	977.923	972.729	967.535	962.341	957.147	957.147
Greece	129.652	132.176	132.000	131.824	131.648	131.472	131.296	131.120	130.944	130.944
Hungary	87.546	88.544	89.543	90.542	91.540	92.539	93.538	94.536	95.535	95.535
Ireland	68.184	70.018	68.639	67.260	65.881	64.502	63.123	61.744	60.365	60.365
Italy	543.751	545.355	535.385	525.416	515.446	505.477	495.507	485.538	475.568	475.568
Latvia	14.506	15.399	16.291	17.183	18.076	18.968	19.860	20.753	21.645	21.645
Lithuania	29.081	31.697	34.312	36.927	39.542	42.157	44.773	47.388	50.003	50.003
Luxembourg	5.996	6.077	6.328	6.580	6.831	7.082	7.333	7.585	7.836	7.836
*Malta *)*	*2.300*	*6.200*	5.617	5.033	4.450	3.866	3.283	2.699	2.116	2.116
Netherlands	216.816	219.694	216.510	213.325	210.141	206.957	203.772	200.588	197.404	197.404
Poland	414.723	429.186	443.650	458.113	472.576	487.039	501.502	515.966	530.429	530.429
Portugal	82.256	83.823	82.995	82.168	81.340	80.513	79.685	78.858	78.030	78.030
Romania	*198.215*	*203.913*	*209.611*	*215.309*	*221.007*	*226.706*	*232.404*	*238.102*	243.800	243.800
Slovak Rep.	53.468	55.139	56.811	58.482	60.154	61.825	63.497	65.168	66.840	66.840
Slovenia	*19.065*	*18.821*	*18.577*	*18.332*	*18.088*	*17.844*	*17.600*	*17.355*	17.111	17.111
Spain	387.104	382.789	375.355	367.921	360.487	353.053	345.619	338.184	330.750	330.750
Sweden	68.949	70.485	71.225	71.965	72.706	73.446	74.186	74.926	75.666	75.666
UK	649.107	657.232	656.359	655.486	654.613	653.740	652.867	651.995	651.122	651.122
EU total	5.143.200	5.227.610	5.229.636	5.231.663	5.233.689	5.235.715	5.237.742	5.239.768	5.241.794	5.241.794

*) CO_2 emissions from fuel combustion only.

Table 8.4 continued

	2010	2011	2012
Austria	67.924	67.924	67.924
Belgium	130.625	130.625	130.625
Bulgaria	144.685	144.685	144.685
*Cyprus *)*	3.588	3.588	3.588
Czech Rep.	172.500	172.500	172.500
Denmark	54.681	54.681	54.681
Estonia	37.473	37.473	37.473
Finland	77.233	77.233	77.233
France	560.775	560.775	560.775
Germany	957.147	957.147	957.147
Greece	130.944	130.944	130.944
Hungary	95.535	95.535	95.535
Ireland	60.365	60.365	60.365
Italy	475.568	475.568	475.568
Latvia	21.645	21.645	21.645
Lithuania	50.003	50.003	50.003
Luxembourg	7.836	7.836	7.836
*Malta *)*	2.116	2.116	2.116
Netherlands	197.404	197.404	197.404
Poland	530.429	530.429	530.429
Portugal	78.030	78.030	78.030
Romania	243.800	243.800	243.800
Slovak Rep.	66.840	66.840	66.840
Slovenia	17.111	17.111	17.111
Spain	330.750	330.750	330.750
Sweden	75.666	75.666	75.666
UK	651.122	651.122	651.122
EU total	5.241.794	5.241.794	5.241.794

*) CO_2 emissions from fuel combustion only.

Curriculum Vitae

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