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THE MULTI-SECTOR CONVERGENCE APPROACH

A flexible framework for negotiating global rules for national greenhouse gas emissions mitigation targets

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Abstract

This Working Paper presents a new sector-based framework for negotiating binding emission targets after the first budget period as defined in the Kyoto Protocol. The framework offers a flexible tool to negotiators for agreeing upon emission assignments at the aggregate level of the signatory Parties concerned, for identifying country-specific concerns at the sector level, and for rolling over emission limitation targets from one period into the next one.

CONTENTS

TOCSUMMARY 5

1. INTRODUCTION 6

2. LESSONS FROM EARLIER BURDEN SHARING PROPOSALS 9
   2.1 Findings from phase one of the burden sharing project 9
   2.2 Review of the Triptych approach 10
   2.3 Some inferences for the design of a new framework 11

3. THE MULTI-SECTOR CONVERGENCE APPROACH 13
   3.1 Introduction 13
   3.2 The distinction of different sectors 13
   3.3 The setting of global sector emission standards 15
   3.4 The determination of national pre-adjustment emission mitigation targets 16
   3.5 Adjustment for allowance factors 16
   3.6 Graduation threshold and adjustment period 18
   3.7 Summary 19

4. SOME NUMERICAL ILLUSTRATIONS 21
   4.1 Introduction 21
   4.2 Selection of exemplary countries 21
   4.3 Sector and national GHG emissions in the base year 22
   4.4 Emissions standards in the convergence year 24
   4.5 National pre-adjustment emission mitigation targets 25
   4.6 The inclusion of allowance factors 26
      4.6.1 Introduction 26
      4.6.2 Climate 28
      4.6.3 Population density 29
      4.6.4 Transition economies 30
      4.6.5 Renewable energy resources 30
   4.7 The participation of non-Annex I countries 30

5. CONCLUSIONS 33

REFERENCES 35

SUMMARY

This report presents an approach, called the Multi-Sector Convergence (MSC) framework, to generate comprehensive sets of national targets for greenhouse gas (GHG) mitigation. The MSC framework is aimed at facilitating international negotiations on national emission mitigation targets after the first budget period defined in the Kyoto Protocol.

The main features of the MSC approach are:
(i) Emission standards are based on the distinction of different sectors within the national economy.
(ii) The base model prescribes that the amount of per capita emission assignments will ultimately converge to the same level for all countries.
(iii) Additional allowances may be conceded to countries facing specific circumstances that warrant higher emission needs than countries with more favourable specific emission mitigating circumstances, all other factors being the same.

The MSC approach encompasses the following stages:
1. the distinction of different sectors,
2. the setting of global sector emission norms,
3. the determination of pre-adjustment national emission mitigation targets,
4. adjustment for allowance factors, yielding the ultimate national emission assignments.

Major considerations underlying the design of the MSC framework are:
- The framework is flexible in terms of structure and input parameter values.
- The framework is comprehensive to the maximum extent possible with regard to inclusion of the distinct greenhouse gases specified by the Kyoto Protocol and in terms of global coverage.
- A sectoral bottom-up approach is opted for in defining standards for per capita emission needs.Distinct structures of the national economies constitute a significant factor in determining the possibilities of the adjustment process in terms of mitigation burden and speed. Some sectors have a slower turnover rate of GHG-emitting infrastructures than others. Furthermore, certain sectors might be considered to provide more essential services to fulfil basic human needs than others.
- Convergence of emissions per capita is a key point of embarkation.
- Given the large uncertainties surrounding the Climate Change issue and inertia in the adjustment process towards meeting targets consistent with sustainable emission levels from the climate perspective, the framework should include ample negotiation space for convergence year(s) and convergence level(s).
- The framework should make due allowance for major country-specific emission factors.
- The share of emission allowances on account of country-specific emission factors in the ultimate national emission assignments should be very transparent.
- Countries with relatively low per capita emission levels - which are almost invariably at the same time countries with low (average) living standards - should have the right to economic development without any emission limitation constraints up to some defined point, the so-called graduation threshold.
- Low-emission countries with emissions exceeding the graduation threshold in some future emission accounting (budget) period will be granted a pre-set adjustment period. After this period has lapsed, they are due to take on commitments to meet the targets consistent with the prevailing global emission mitigation regime.

1. INTRODUCTION

The issue of fair differentiation of national GHG emission mitigation targets is possibly the most difficult one to resolve under the Framework Convention on Climate Change. Since the Kyoto Conference of December 1997, this issue has received little attention as quantified emission limits and reduction commitments have been agreed upon for the first budget period (2008-2012) for the Annex I countries.[1] Since Kyoto, a large part of the discussion has focused on guidelines, modalities, principles and rules for the flexible instruments, i.e. Emissions Trading, Joint Implementation and Clean Development Mechanism.

However, there are various arguments why the issue of burden differentiation will very likely return in the near future. First, under the Kyoto Protocol only the Annex I countries took commitments while most of the developing countries did not yet accept such commitments. Their participation is required at some moment in time in order to meet the ultimate objective of the UNFCCC. Second, the Kyoto Protocol only covers quantified emission limitation and reduction commitments for the first budget period.[2] In the longer term further reductions are required. It is expected that burden differentiation will again get prime attention in the international climate negotiations within a few years.

Before Kyoto, various proposals were made on how to differentiate emission burdens between countries (for an overview see Torvanger and Godal, 1999). At the Conference of the Parties meeting in Bonn (COP-5), only one of these earlier proposals - the so-called Brazilian proposal - was briefly mentioned. At this occasion, various countries expressed their interest to further continue exploring rules and principles for burden sharing.

Sceptics may claim that the issue of determining national GHG mitigation targets can not be solved by simple rules or equations. However, the point is that burden sharing rules[3] are not intended to replace negotiations. The process will always be steered by negotiations. Still, burden sharing rules can be of great value. They can support negotiations by adding structure. Burden sharing rules can be a tool to show the consequences in terms of quantitative emission limits and reduction objectives of different agreements. As such, burden sharing rules can facilitate actual negotiations. Participation of parties in the negotiation process is an important factor to achieve an agreement. Therefore, consulting different kinds of actors during the design, selection and adjustment phases of burden sharing is considered crucial.

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1 In fact, the Kyoto Protocol speaks of ‘Annex B countries’ rather than ‘Annex I countries’. Whereas the former category refers to countries mentioned in Annex B of the Kyoto Protocol, the latter category concerns countries listed in Annex I of the UNFCCC. Annex B includes all countries recorded in Annex I, except Belarus and Turkey that did not accept an emission abatement target at the Kyoto Conference. Unless stated otherwise, this report will speak of Annex I countries, implying those countries – except Belarus and Turkey – that have accepted an official commitment to limit their GHG emissions.

2 In the current language used at international climate change negotiations an *emission reduction* target relates to a targeted decline of emissions per period, an *emission limitation* target refers to a targeted limitation of the increase in emissions per period. *Emission mitigation* refers to incremental efforts to realise reduced growth or faster decline of emissions per period as compared to the baseline situation in which no such efforts would be undertaken. Emission mitigation targets encompass both limitation and reduction targets.

3 In this report *burden sharing rules* refer to rules for determining (proposed) national mitigation targets. It is acknowledged that, strictly speaking, these targets as such and the possible economic burden of meeting them constitute two related but distinct issues. In fact, the present Working Paper deals with the former and Working Paper no. 6 deals with the latter issue.

Since Kyoto, the set of elements to be considered in burden sharing has changed somewhat:

- The Kyoto Protocol also covers emissions of other greenhouse gases (CH_4, N_2O, HFCs, PFCs and SF_6) and part of the sinks of carbon dioxide that occur via land use changes. The pre-Kyoto proposals on burden sharing covered only CO_2 emissions in most cases. New burden sharing proposals need to cover the other greenhouse gas emissions and sinks.
- Further, the Kyoto Protocol includes the three flexible instruments Emissions Trading (ET), Joint Implementation (JI) and Clean Development Mechanism (CDM). These instruments enable Annex I countries to reduce the costs of meeting their emission mitigation commitments by means of transactions abroad. However, they also have burden sharing consequences. Such consequences need to be taken into account in the design of new burden sharing rules. While designing burden sharing rules one needs to have an idea how much the flexible instruments will be used and what their cost consequences might be.

One way to divide proposed burden sharing rules is between allocation-based rules and outcome-based rules. Allocation-based rules define equitable burden sharing in terms of principles for the distribution of emission rights. Outcome-based rules define equitable burden sharing in terms of the (projected) final outcome, i.e. the (projected) net welfare impacts of the implementation of mitigation policies. Moreover, some even distinguish process-based rules, defining equitable burden sharing in terms of the process for arriving at a distribution of emission burdens.[4] For outcome-based burden sharing rules, models are needed, e.g. to calculate the cost impacts for different countries.

On the one hand, it is believed that outcome-based BSRs are unlikely to garner a critical mass of support among climate-change negotiators, given the highly speculative content of the outcomes of the underlying model exercises. Comparison of short-term forecasts by well-known institutes like the IMF or OECD of macroeconomic variables such as GDP or aggregate investments with realisations learns that this type of variables cannot be predicted within small confidence intervals. Systematic error margins in forecasts are compounded when the forecasting horizon is extended. It does not seem likely that it is possible to agree on one single model approach to make such forecasts. Every model is a simplification of reality and there is no agreement how reality can best be modelled. If convincing allocation-based rules can be designed these will be intrinsically more appealing.

On the other hand, negotiators may wish to have a good understanding of the cost implications of alternative burden sharing rules. Although outcome-based BSRs may seem unlikely to garner the broad support needed, cost considerations are due to play a major role in the evaluation of proposed allocation-based rules. Hence, allocation-based burden sharing rules should be readily amenable to changes considered fair by the relevant negotiators based on information they receive and consider credible on cost implications for the country they represent. The cost implication issue will be taken up in the final Working Paper (No. 6) of the present project.

A major advantage of allocation-based burden sharing rules is that a large part of the data needed can directly be measured or monitored. Models are not needed. This makes it possible that discussion can be aimed at perceptions, arguments and weights, as the numerical base is not or much less under debate. Operational burden sharing rules need to involve only indicators that already are, or can be made, readily available for most or all countries.

Several analyses of burden sharing rules (Carraro and Goria, 1999; Torvanger and Godal, 1999) suggest that a promising approach for the design of burden sharing rules is to follow a sector-based approach. A key reason may well be that such an approach allows countries to see their specific situation reflected in a burden sharing rule. Moreover, early in the process of determining national GHG emission mitigation targets stakeholders at sector levels may be consulted.

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4 This classification of burden sharing rules or rather burden sharing criteria is quoted in Carraro and Goria (1999) from Rose et al. (1998).

This report will introduce a framework for negotiating burden differentiation among countries at the global level. First, some lessons drawn from earlier burden sharing proposals are discussed, relevant for the design of new burden sharing rules (Chapter 2). Subsequently, Chapter 3 introduces a flexible sector-based framework for negotiating burden sharing rules - resulting in national emission mitigation targets - while Chapter 4 presents some numerical illustrations of this framework. Conclusions are given in Chapter 5.

2. LESSONS FROM EARLIER BURDEN SHARING PROPOSALS

2.1 Findings from phase one of the burden sharing project

Earlier burden sharing proposals - both before and after the assignment of the Kyoto Protocol - have been examined in Project Working Paper No. 2 (Ringius, Torvanger and Underdal, 1999). Some major findings are epitomised below.

CICERO has identified and analysed the main general principles of fairness. A first distinction is between equality, equity and exemption. Equal obligation has a firm normative basis if all parties involved are equal in all relevant aspects. If this is not the case, equity comes into play. A range of key principles exists to distribute obligations equitably. If the range of variance is so great that equity rules still lead to unfair burdens upon the poorest parties, exemption of obligations is the option that remains.

> *Lesson for the design of new burden sharing rules: equity is the level to aim at in this study. Too few countries are equal enough to legitimise equal obligations. Further, if exemption would be the 'rule' it would not make sense to construct burden sharing rules.*

Principles of equity can be distributed in four groups (Ringius, Torvanger and Underdal, 1999):
1. Principle of need
2. Principle of capacity
3. Principle of contribution
4. Principle of guilt.

It was found that burden sharing rules should not be incompatible with the principle of need. Several examples of need-based burden sharing rules exist. Most of them follow a top-down approach. These rules suggest a step towards convergence of the greenhouse gas emission levels per capita. Only the Triptych proposal includes more bottom-up elements as it calculates the allowed emission for a certain time period following a sector approach.

But what does the principle of need imply in terms of operational indicators? It implies that all human beings are granted emission allowances needed to secure basic human needs. The rules for allocating emission permits for basic human needs might be different from the rules to allocate emissions for the production and use of luxury goods. If such an approach is pursued, a first question that has to be solved is that a distinction needs to be made between what is a basic need and what is a luxury good.

To make the principle of need operational, a step needs to be made to express general equity considerations in terms of real life indicators. The translation of the need principle to concrete indicators will be ruled by pragmatic considerations, as a multitude of factors affect the level of emissions and one can not include all of them and still have a simple and transparent burden-sharing rule. Thus, in designing a need-based burden sharing rule it will be endeavoured to include those factors that are considered most important.

An approach that considers aggregate emissions from a bottom-up sector perspective is a logical choice: the need to emit is linked to the provision of services, taking place in distinct sectors. Moreover, a sector approach also allows one to relatively easily integrate other concerns, such as country-specific aspects which importantly affect the capacity to bear the burden of emission mitigation (prevailing welfare levels, availability of cheap mitigation options, differences in emission needs to provide the same level of a certain service, etc.).

Future climate agreements need commitments from countries that together represent the major part of current and future greenhouse gas emissions. Although, in line with the Climate Convention, high-income countries should take the lead through initial unilateral mitigation actions, new, more comprehensive burden sharing approaches are called for that will make it feasible for medium- and low-income countries to assume commitments commensurate with their welfare situation.

Any burden sharing rule should have due consideration for inertia (lead times) in behaviour, institutions, capital and infrastructure related to activities that determine the level of greenhouse gas emissions. Many of the mitigation options that are expected to have a large impact require investments. Evidently, inertia aspects manifest themselves quite differently in distinct economic sectors.

2.2 Review of the Triptych approach

Before starting up sector BSR design activities, it is useful to review the determination of emission allowances in the Triptych approach.[5] It should be stressed that the Triptych approach was originally intended as a burden sharing application for a group of economically relatively homogeneous countries, being Member States of the European Union. For any Triptych approach to become successful for world-wide application, adjustment is necessary to make it more flexible in accounting for the wide diversity of country-specific circumstances among the various nations of the world.

The major characteristics of the Triptych approach include:

- Based on fuel input, CO_2 emissions by the power sector are calculated for the base year (1990), using standard IPCC default values.
- For the electric power sector, a norm is used for volume changes: power generation per capita is allowed to increase at a rate of 1% per year. In order to arrive at an aggregate sector emission level, norms are formulated for the fuel-input mix. By the year 2010, non-gas fossil-fuel shares should be reduced to 30%, while the share of CHP (cogeneration) should have gone up to 15%. In addition, the share of renewables should have increased to 8%. Gas should account for the remaining share. Renewable-based and nuclear-based power generation is assumed to be totally emission-free. For power generation based on coal, oil, and gas, standard IPCC emission values are imputed, while CHP-based power generation emissions are assumed to be 70% of power generation based on gas. Subsequently, the sector emission reduction norm can be calculated.
- For energy-intensive industrial sectors, a fixed reduction factor is taken for CO_2 emissions for all countries. To make the norms not overly complicated, no allowance was made for structural developments regarding sector composition and initial differences in energy efficiency.
- The domestic sector is defined to comprise households, services, light industry, agriculture and transportation. For this sector, per capita emission allowances should converge towards an equal level in some distant year, e.g. 2030. Adjustment for climate differences with respect to space heating was applied. Interim allowances are derived by linear interpolation.
- It should be stressed that countries would only be bound to the overall aggregate reduction norm. Overshoots at sector level are permitted, if these are fully compensated by emission reductions above the norm for other sectors.

[5] See Blok, Phylipsen, and Bode (1997), and Phylipsen, Groenenberg, and Blok (1998).

The attractiveness of the Triptych approach for the given purpose - setting medium term emission targets for a group of fairly homogeneous countries - relates to its relative simplicity and transparency on the one hand and a sector bottom-up approach which permitted to take account of some broad country-specific ‘emission needs’ aspects on the other hand.

This report addresses the issue of country/region emission assignments at a global level and over a longer-term time frame. Evidently, accounting fairly for country-specific circumstances at a global level including ‘developmental emission needs’ demands more elaboration and flexibility than the Triptych approach offers. Nonetheless, Triptych has proven the usefulness of bottom-up sector approaches. Among its outstanding features are its relative simplicity and transparency.

2.3 Some inferences for the design of a new framework

The Climate Change issue can be looked at from many perspectives. One major feature motivating worldwide action is the risk of human-induced drastic climate change to mankind. Should drastic Climate Change become reality, initially certain world regions may well be less adversely affected than other regions. Some regions might even gain initially. However, through social tensions by way of migratory movements, social conflicts may be transmitted to initially less badly affected regions, while climate may change further, turning initial local gains into eventual substantial losses. Hence, all countries might ultimately be less well off, although with large - but hard to predict - differences. Therefore, the precautionary motive suggests that containment of global GHG emissions to more sustainable levels from the perspective of the international climate system will be ultimately beneficial for all countries. On the one hand a regime to achieve this has to be quite comprehensive. On the other hand, emission needs comprise an overriding principle for which such a regime should account. Moreover, location-specific factors and adjustment problems (e.g. related to infrastructural inertia) make for widely divergent emission patterns and per capita emission requirements among countries, even if living standards would be comparable.

These considerations make convergence of per capita emissions an attractive point of departure. Yet, at the same time, the Climate Change issue is surrounded by very large uncertainties that may or may not be reduced in future. Moreover, location-specific factors and adjustment problems have to be duly taken into account. Hence, a very flexible approach is called for in negotiations on national GHG mitigation targets.

Paramount considerations for introducing flexibility are:

- *Level and time path of allowable global GHG emission levels*. Given the large uncertainties, ample negotiation space for convergence year(s) and convergence level(s) should be built in.
- *Allowance for low-emission countries.* Countries with relatively low per capita emission levels - which are almost invariably at the same time countries with low (average) living standards - should have the right to economic development and associated emissions (up to some defined point) without incurring the additional cost of emission mitigation.
- *Adjustment for rigidities and other major concerns at sectoral level*. Distinct structures of the national economies constitute a significant factor in determining the possibilities of the adjustment process in terms of mitigation burden and speed. Some sectors have a slower turnover rate of GHG-emitting infrastructures than others. Furthermore, certain sectors might be considered to provide more essential services to fulfil basic human needs than others.

- *Allowance for constant location-specific factors.* Per capita emissions in areas with extremely cold or hot climates will be appreciably higher than the ones in temperate climates, other factors being equal. The same applies to sparsely populated areas as compared to densely populated areas. Also the resource base for harnessing the renewable energy potential importantly affects the cost of low-emission energy.
- *Allowance for changeable location-specific factors.* Some countries are faced with severe economic transition problems. These countries may negotiate assigned emission levels that gives some leeway to solve these problems.

3. THE MULTI-SECTOR CONVERGENCE APPROACH

3.1 Introduction

In this chapter, a sector-based approach will be introduced for setting national targets regarding GHG emission mitigation. This approach is called the *Multi-Sector Convergence* (MSC) approach. The major distinguishing characteristics of the MSC approach are that (i) it is based on the distinction of different sectors within the national economy, (ii) the MSC base model prescribes that the amount of per capita emission assignments will ultimately converge to the same level for all countries, (iii) additional allowances may be conceded to countries facing specific circumstances that warrant higher emission needs than countries with more favourable specific emission mitigating circumstances, all other factors being the same.

In the previous chapters, it has been argued why this study opts for a flexible, sector-based burden sharing approach. Reasons in favour of this choice include:
- A large part of the data needed can directly be measured or monitored.
- For determining the emission (mitigation) assignments, no a priori macroeconomic modelling exercises are needed.
- A direct link can be made between sector emission norms and meeting specific needs.
- An early consultation with sector representatives would improve the feasibility of setting targets and, at the same time, stimulate commitment on the part of sector agents.
- Apart from emission needs, allowance can be made for other sensitive, country-specific aspects.
- The approach can be implemented in a flexible way in the sense that the resulting national (or regional) emission targets will be proposed as binding assignments, whereas the distinct envisaged sector emission standards are not.
- The resulting national targets can be aggregated to global GHG emission targets. In turn, the impact of the latter on the stabilisation level of atmospheric concentrations (ppm) can be assessed. If deemed necessary, parameter values of the MSC approach can be re-calibrated in an iterative way to reconcile considerations of Climate Change with the ones of economic costs of and political feasibility.

The MSC approach outlined in this chapter includes the following stages:
1. The distinction of different sectors.
2. The setting of global sector emission norms.
3. The determination of national emission mitigation targets.
4. The inclusion of allowance factors.

Stages one to three yield results for the MSC base model (i.e. results before adjustment for major country-specific emission factors). The last stage leads to the determination of post-adjustment emission allowances. These steps will be further explained below in Sections 3.2 up to 3.5. The final result of this process contains the national emission (mitigation) targets after adjustment for allowance factors. Some numerical examples to illustrate the MSC approach will be presented in the next chapter.

3.2 The distinction of different sectors

The first stage of the proposed sector-based framework for negotiating burden sharing rules is to distinguish a relevant set of socio-economic sectors. The precise division between sectors should be an appropriate compromise between various concerns, i.e.:

- Distinct sectors should account for a significant share in total, human-induced GHG emissions.
- The sectors should not be overly heterogeneous with respect to intra-sector GHG-emission characteristics.
- Reliable data should be available on indicators of the distinct sectors for a large number of countries.
- The number of sectors should be large enough to guarantee maximum comprehensiveness, but small enough to preserve simplicity and clarity.

In line with the above-mentioned considerations, the following sectors - and related GHG emissions - will be distinguished for the time being, given the present state of data availability:

1. Power
- GHG emissions related to power generation, excluding emissions related to power use in industry.

2. Households
- All energy-related GHG emissions by households, except for emissions related to electricity use.

3. Transportation
- All energy-related GHG emissions by the transportation sector, except for emissions related to electricity use.

4. Industry
- GHG emissions related to power generation, brought about by power use in industry.
- Other energy-related GHG emissions by the industrial sector.
- Non-energy GHG emissions of high GWP (Global Warming Potential) gases in industrial processes (notably in the cement industry).

5. Services
- All energy-related GHG emissions by services and agriculture, except for emissions related to electricity use.

6. Agriculture
- Non-energy-related GHG emissions from crop production (mainly methane from paddy growing).
- Non-energy-related GHG emissions from livestock (notably methane, some nitrous oxide).

7. Waste
- Non-energy-related GHG emissions from waste treatment (mainly from landfills: especially methane, some nitrous oxide).

All energy-related GHG emissions are encompassed by the first five sectors. Data availability problems necessitated the inclusion of GHG emissions from electricity use in the sectors Households and Services in the sector Power. As factors determining GHG emissions from industrial processes are similar to the ones determining energy-related industrial GHG emissions, emissions from industrial processes have been categorised under *Industry*. The sector *Services* in fact encompasses energy-related GHG emissions by services and agriculture, except for emissions related to electricity use. As services accounts for the lion's share of these emissions, we have labelled the sector concerned as *Services*. The last two sectors - Agriculture and Waste - account for (the bulk of) non-energy-related GHG emissions.

Together, the seven sectors distinguished above account for the vast majority of GHGs covered by the Kyoto Protocol. The main exceptions are GHG emissions due to land use changes and emissions of HFCs, SF_6 and PFCs. The major reasons for these exceptions are (1) lack of available, reliable data at the sector and/or national level for a large number of countries and (2) for land use changes: current uncertainty on future arrangements as to whether and, if so, how sinks will be accounted for in the determination of allowable emission levels. Improvement in the availability of data and future agreements on the role of sinks in the determination of allowable emission levels may give rise to the introduction of an alternative choice of sectors and further improvement in the coverage of global GHG emissions. In fact, the flexibility of the MSC approach lends itself well towards doing so: in principle, land use changes can be readily included in the MSC framework.

3.3 The setting of global sector emission standards

For each sector, several aspects have been considered in order to establish at the global level non-binding sector emission standards - expressed in per capita terms - in both a base year, a convergence year and intermediate target years (see below). These aspects or considerations include:
1. main subsectors or end uses and major sector-related GHGs,
2. considerations at subsector level, including the character of the needs met in association with the emissions ('basic needs' versus 'non-basic' needs),
3. main factors explaining variances in sector emission levels among countries,
4. global activity and non-policy-induced decarbonisation trends, and other major driving factors for emissions at the sector level,
5. typical turnover periods of capital goods of the sector considered, which 'lock in' emission reduction potentials for a certain period,
6. impact of an assumed level of Climate Change policy efforts on decarbonisation trends at sector level taking into account sector-specific rigidities (such as the ones mentioned under point e),
7. major allowance factors, i.e. country-specific circumstances resulting in variances of sector emissions among countries that are virtually impossible to influence by the governments concerned.

With the exception of item f (see Section 3.5 hereafter), these aspects have been considered in order to establish global sector emission standards. For the base year (2010), these standards have been set equal to the world average sector GHG emissions per capita in that year. Subsequently, an annual mitigation (reduction or limitation) norm per sector has been set - expressed in a percentage per year - in order to derive sector emission standards in the years thereafter, notably in a convergence year (e.g. 2100) and in some intermediate target years (for instance, 2015, representing the second budget period). Finally, per capita emission standards at the sector level have been added up to obtain the global per capita emission standard at the aggregated level.[6]

Countries with emission levels in a certain base year higher than the global per capita total emission standard (GTES) in that year will be designated as *high-emission countries*, while countries with lower emissions than this standard will be called *low-emission countries*. We assume that international agreement will be reached that signatory countries to the UNFCCC exceeding the GTES will have to graduate into the league of countries accepting future emission mitigation targets. This assumption of convenience can be readily replaced by another 'graduation' assumption. The graduation issue is further discussed in Section 3.6.

[6] A numerical example will be presented in the next chapter.

3.4 The determination of national pre-adjustment emission mitigation targets

The next step in designing a sector-based burden sharing framework concerns the determination of emission limitation targets for each country in certain target years such as 2015 or 2050 in accordance with the MSC base model. Starting point for each country is its sector levels of *per capita* emissions in the base year (2010).[7] In the years thereafter, these levels are supposed to converge to the global (*per capita*) sector emission standards of the convergence year derived in the previous Section. Non-binding (*per capita*) sector emission levels for each country in intermediate target years are obtained by geometric interpolation between the actual national sector emission levels in the base year and the global sector emission standards of the convergence year.[8] Finally, these non-binding sector emission levels are added up and multiplied by total population in order to determine national emission mitigation targets for the countries and years concerned. These commitments can be expressed either in absolute terms - i.e. in amounts of emission assignments for a certain budget period - or as a reduction/limitation rate, i.e. as a percentage by which emissions in a certain budget period has to be reduced/limited compared to a base year or a previous budget period.

3.5 Adjustment for allowance factors

The framework for negotiating national GHG emission mitigation targets can be fine-tuned by including so-called allowance factors. These factors can be defined as country-specific circumstances resulting in variances of sector emissions among countries that are virtually impossible to influence by the governments concerned, at least in the short and medium run. Hence, under certain conditions such allowance factors may provide grounds for justification and agreement at the international negotiation table to concede certain *additional allowances* to the national emission mitigation targets derived in the previous Section in countries that are faced with less favourable country-specific circumstances.[9] Additional allowances may be negotiated to be either temporary - i.e. only for specific target years - or for all target years, including the convergence year. Allowance factors may impact differently on per capita emissions for the distinct sectors. Yet, it is proposed to include allowance factors at the national level so that the impact of the allowance for country-specific emission factors on the total emission budget becomes fully transparent.

Some examples of possible allowance factors include:

- *Climate*
  Due to climate factors and resulting differences in in-doors heating and cooling conditioning, emission levels between countries may vary significantly, notably in the power, household and other sectors of the economy. These factors may be accounted for by granting countries with relatively high needs for space conditioning an additional amount of emission assignments.

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7 For Annex-I countries, the sector levels of per capita emissions in the year 2010 are based on the actual sector emission levels in the year 1990 adjusted by the (national) emission mitigation rates laid down in the Kyoto Protocol. For non-Annex-I countries, the sector levels of per capita emissions in the year 2010 are based on the actual sector emission levels in the year 1990 adjusted by the projected regional growth rates according to the A1 SRES- scenario of the IPCC.

8 It should be noted that whereas the normative, sector emission standards of the convergence year are, in principle, the same for each country, the actual sector emission levels in the base year - and, hence, in intermediate target years - are different for each country (see numerical examples included in Chapter 4).

9 Although, from a negotiation strategy perspective, we have opted to include allowance additions only, the alternative of including allowance deductions as well with a neutral impact on the global emission budget has the advantage of potentially higher robustness of global emission mitigation objectives. Including only allowance additions in the MSC framework, implies stronger reliance on feedback iterations after comparing first-round aggregate results with desired global emission limits.

- *Population density*
  A low population density compared to some world standard will, on average, result in a higher level of per capita GHG emissions, mainly because of higher efficiency losses in the power sector, higher transport needs, and higher energy needs in the household sector (for instance, to warm houses in scarcely populated areas), if differences in other circumstances would be negligible. Therefore, it seems justified to assign an extra amount of GHG emissions to scarcely populated countries.

- *Agriculture*
  Some countries are highly dependent on *rice cropping* in order to meet the basic food needs of their population. Rice cropping by means of irrigation or natural flooding, however, is the most important source of GHG emissions - notably of CH_4 - in the food crop sector. Hence, rice cropping may be included as an allowance factor for the countries concerned, according to the area of their irrigated paddy fields. To a certain extent, *animal husbandry* also provides basic food needs. An alternative way of making allowance for the basic needs character of certain products of the agricultural sector and the required non-energy GHG emissions to produce these products is to introduce relatively lenient GHG emission standards for agriculture.

- *Transition economies*
  Some countries are facing specific problematic circumstances because their economy is in a state of transition, either from a centrally planned to a market-led economy or from a rapidly developing, industrialising state to a more developed and moderately growing services economy. These circumstances may justify *temporary*, additional amounts of emission assignments during the transition period. The same - evidently also on a temporary basis - might be considered for *fossil-fuel exporting countries*, i.e. countries that face the difficult transition towards a more diversified economic base with reduced dependence on fossil fuel exports and use. However, this kind of compensation would only be useful if oil exporting countries would accept an emission limitation commitment. Moreover, as recently recommended by a joint study of ECN and Clingendael, it could also be considered to compensate oil exporting countries by creating a special fund managed by the IMF and World Bank (Van der Linden et al. 1999). Resources on behalf of this fund can be generated by raising taxes on oil consumption of Annex I countries or by providing other financial means to this fund. These resources can be used as balance-of-payments support (IMF) or to restructure oil exporting economies during their transition period.

- *Renewable energy resources*
  Some countries are poorly endowed with renewable energy resources (hydro power potential, wind resources, solar energy), whereas other countries possess vast resources of renewable energy. These differences in renewable energy resources - resulting in large variances in GHG emissions of power generation - may justify country-specific additional allowances for the former renewable-energy-recources-poor group of countries.

In addition, other allowance factors may be considered. For instance, the above-average presence of export-oriented industries is sometimes suggested as an allowance factor as countries concerned are faced by additional amounts of GHG emissions. However, as the flexible mechanisms of the Kyoto Protocol may enable the Annex I countries to meet their domestic emission commitments by means of foreign transactions, it seems more obvious that export-oriented countries use part of their foreign revenues to obtain additional amounts of emission assignments by means of the flexible instruments (Emissions Trading, Joint Implementation and/or the Clean Development Mechanism). This way, relative (world) prices of high-carbon-intensity products will increase (with respect to low-carbon-intensity goods). As the world demand for high-carbon-intensive products might be negatively affected by this internalisation of cost to the global environment without significantly affecting the incidence of comparative advantages in the manufacturing of these products, this is an efficient way of including environmental concerns in the world economy.[10] In conclusion, whether an allowance factor is justified depends not only on the incidence of country-specific circumstances but also on the institutional setting of granting and trading emission assignments.

3.6 Graduation threshold and adjustment period

In Section 3.3, the assumption has been set out that so-called low-emission countries will be exempted from taking on emission mitigation commitments. In the MSC framework, it is assumed that such countries will eventually graduate towards taking on emission mitigation commitments when exceeding a certain per capita emission threshold. This *graduation threshold* indicates the - to be negotiated - per capita realised emission level at which non-Annex-I countries, signatory to the FCCC, will have to assume mitigation commitments. In the numerical example to be explained in the next chapter, the graduation threshold will be put at the GTES level (global total emission standard on a per capita basis, already explained in Section 3.3).

Granted five-year budget periods with reference years 2010, 2015, 2020, etc. as mid-years, we may assume that for each country that is signatory to the FCCC realised emissions in a certain budget period will be determined and verified ex post by the following reference year at the latest. Hence, the national emissions in the first budget period, 2008-2012, are assumed to be determined and verified by the year 2015 at the latest.

Now assume a certain non-Annex-I country has generated average annual (per capita) emissions during the first budget period exceeding the graduation threshold. Assuming this country will be notified to take on emission mitigation commitments in year 2015, the earliest budget period in which this country can conceivably take on emission limitation commitments is the third budget period, 2018-2023. Yet it is conceivable that a longer adjustment period will be agreed upon, e.g. an additional five year adjustment period. This is depicted in Figure 3.1.

In conclusion, in the MSC approach the *adjustment period* after which a signatory non-Annex I country exceeding the graduation threshold, will have to adopt the targeted emission mitigation is an additional flexible parameter which value is to be determined by international negotiations.

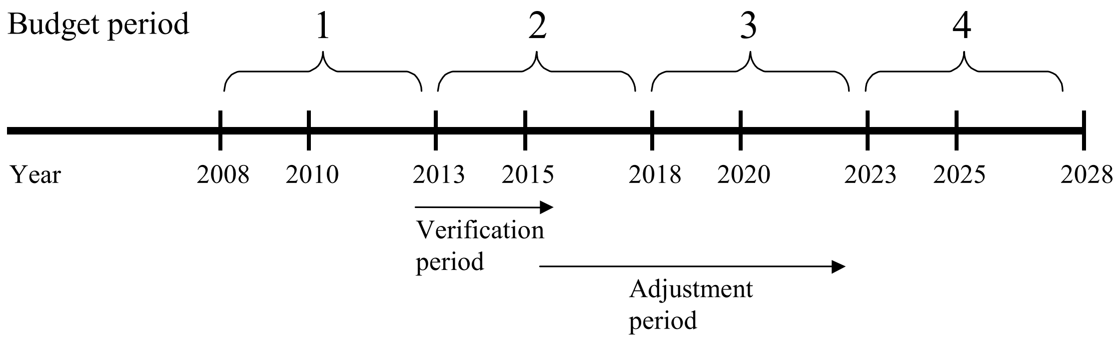


Figure 3.1 *Example of an adjustment period, including verification and notification, of 15 years*

[10] This assumes a high extent of comprehensiveness of the mitigation regime and, consequently, no major 'carbon leakage' to non-Annex I countries.

3.7 Summary

The MSC framework can be summarised by means of a 'flow chart', presented in Figure 3.2. In order to make the chart not overly complicated, this chart pertains to the so-called high-emission countries, presumably having committed themselves to the MSC mitigation regime. Figure 3.2. gives an outline of most steps to be taken and depicts the iterative character of the MSC approach.

Let us explain the flow chart in Figure 3.2. The flow chart assumes that the determination of the sectors to be included (stage 1 explained in Section 3.2) has already taken place. Steps 1-6 will have to be taken in stage 2, the setting of global sector emission standards. The following steps have to be taken:

- establish (total) sector emissions at national level in the base year for all countries (step 1),
- establish sector emissions at the global level in the base year (step 2),
- establish per capita sector emissions at the global level in the base year (step 3),
- set the per capita sector emission limitation rates that determine non-binding sector emission standards at the global level given projected sectoral emission trends at an assumed global level of Climate Change mitigation policy efforts (step 4),
- set the convergence year and the per capita sector emission standards in the convergence year (step 5).

Stage 3, the determination of national emission mitigation targets, involves the following steps:

- determine the national per capita sector emissions in the base year (step 6),
- determine the implied per capita sector emission limitation rates at the national level (step 7),
- determine the (non-binding) per capita sector emission standards in the target year at the national level (step 8),
- aggregation of these per capita sector emission standards and multiplication by the projected population number in the target year yield the proposed pre-adjustment national assignments in the target year (step 9).

Stage 4, the inclusion of allowance factors, runs as follows:

- determine the allowance factors to be included, and for each factor its indicator, the country indicator values of the allowance indicators concerned and the rule to determine the level of additional allowances per country (step 10),
- determine the post-adjustment national assignments in the target year (step 11).

For assessing the Climate Change impact and impact on the national economies further steps need to be made:

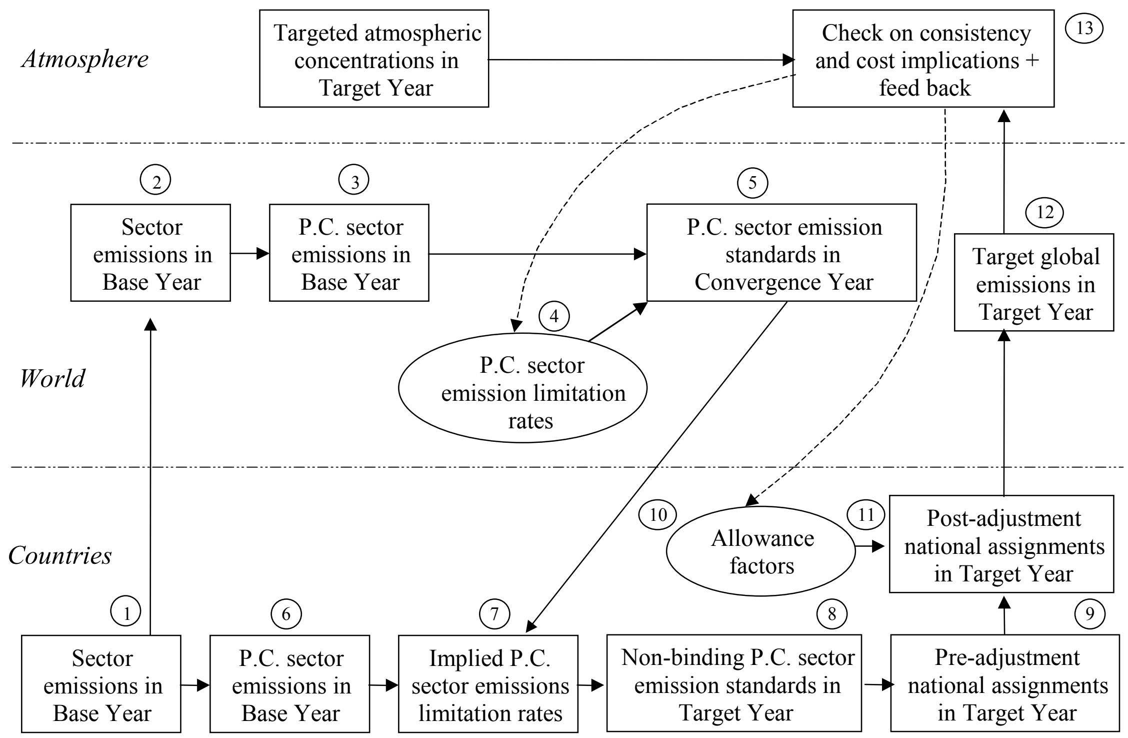
- based on the target national assignments (for countries with mitigation commitments) and baseline emission projections (for countries without commitments), target global emissions can be obtained by aggregation (step 12),
- results generated by steps 11 and 12 have to be weighted on their potential impact on Climate Change (e.g. by projecting atmospheric carbon-equivalent concentrations in ppm) and macroeconomic impacts at the national level ('Are the national mitigation cost burdens and other macroeconomic impacts 'politically feasible?').

If the outcomes of a certain run with the MSC framework model are not considered satisfactory from the Climate Change perspective (or, alternatively, from the perspective of the expected economic impacts), negotiators can iteratively define new input parameter values considered fair and mutually consistent. The iterations are to be continued until results are obtained on which broad-based agreement on a comprehensive set of national mitigation targets can be reached. Notably the following negotiation parameters may be reconsidered for plugging in alternative values:

- the convergence year,

- per capita sector emission mitigation rates at global level (asuming more/less Climate Change mitigation policy efforts),
- allowance factors: deletion or inclusion of more factors, the rules for determining allowance additions for each factor e.g. the maximum percentage rate of additional allowance over the MSC base model allowable emissions,
- the graduation threshold.
- the adjustment period towards graduation,
- the accounting rule for possible surplus emission credits of low-emission countries.

The list above shows the main negotiation parameters but is far from exhaustive. Yet it brings out the great flexibility of the MSC framework. The next chapter presents a numerical example that may provide further insight into the MSC approach.



Note: P.C. = Per Capita

Figure 3.2 *A flow chart of the main steps of feedback loops in the Multi-Sector Convergence approach*

4. SOME NUMERICAL ILLUSTRATIONS[11]

4.1 Introduction

This chapter will present some numerical illustrations of the Multi-Sector Convergence framework for negotiating national GHG mitigation targets outlined in the previous chapter. [12] This approach will particularly be illustrated for a selection of nine countries and regions introduced in Section 4.2. Subsequently, Section 4.3 will provide data on GHG emissions of these countries/regions in the base year 1990. The setting of sector and national emission standards in the convergence year will be illustrated in Section 4.4, while Section 4.5 will show the determination of national emission limitation targets. The introduction of allowance factors is clarified in Section 4.6. Finally, Section 4.7 will pay specific attention to the discussion whether and how non-Annex I countries could participate in the GHG emission mitigation framework.

4.2 Selection of exemplary countries

As noted above, the MSC approach will be illustrated for a selected sample of countries and regions.[13] These countries/regions can be considered to represent a wide variety of interests and concerns on the world climate change negotiation table. The countries, in ascending order of per capita GNP in 1998, are:

- Tanzania: a low-income African developing country with relatively small endowments of fossil energy resources.
- India: the world's second most populous country; a low-income Asian developing country with relatively small endowments of fossil energy resources with the notable exception of coal.
- China: the world's most populous country, a low-income Asian developing country with a remarkably fast growing economy over the last two decades but relatively poorly endowed with fossil energy resources with the notable exception of coal.
- Iran: a middle-income Asian developing country with large endowments of fossil fuel energy resources; member of OPEC.
- Russia: the country with the largest economy in transition, a middle-income country endowed with large fossil resources but presently coping with the consequences of an economy in transition and a declining population.
- Brazil: the largest Latin-American country, a middle-income country with moderate fossil fuel endowments.
- EU-15: the most populous developed-region party of the FCCC.
- USA: the country with the world's largest economy in terms of total GNP.
- Japan: the richest country - in per capita terms - among the world's largest economies.

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[11] An interactive Multi-Sector Convergence tool will become available soon: Internet website http://www.ecn.nl/unit_bs/kyoto/burden/main.html

[12] Data regarding GHG emissions in absolute terms presented in this chapter have been compiled with great care. Yet these data ought to be treated with caution as some differences with not completely consistent officially published data. Nevertheless, the data used are deemed to be reliable enough for application of the MSC framework on the basis of a set of assumptions on the input parameter values. The upshot will be sets of suggested national emission mitigation targets, either in relative terms or as a percentage of emissions in a certain base year.

[13] It should be noted that the sample of selected countries/regions could be extended to any country or region for which the necessary data are available. The project has developed a database to apply the burden sharing framework to more than 50 countries and 3 regions (EU, Annex I and non-Annex I region).

Table 4.1 presents some data regarding population, GNP and GHG emissions of the selected countries. It shows that these countries account for 58 percent of world population (1997), 79 percent of world GNP (1998) and 75 percent of global GHG emissions in the year 1990.

Table 4.1 *Population, GNP and GHG emission data of selected countries*

	Population [million] 1997	GNP [billion US$] 1998	GNP/cap [US$] 1998	GHG emission [$MtCO_{2eq.}$][a] 1990	GHG/cap [$kgCO_{2eq}$.][a] 1990	Index [GNP/cap] 1998	Index [GHG/cap] 1990
Tanzania	31	7	210	21	813	4	16
India	962	421	430	1481	1741	9	35
China	1227	929	750	3497	3027	15	60
Iran	61	110	1770	251	4236	36	84
Russia	147	338	2300	2960	20163	47	401
Brazil	164	758	4570	509	3437	93	68
EU-15	375	8280	22010	4175	11431	450	226
USA	268	7923	29340	5903	23230	600	462
Japan	126	4090	32380	1175	9511	662	190
Total selection	3349	22856	6738	19949	6375	138	127
World	*5820*	28862	4890	26552	5027	100	100
Selection as % of world	*57.5*	79.2		75.1			

a) Excluding estimated emissions from land use changes.

4.3 Sector and national GHG emissions in the base year

This section will provide some data of GHG emissions at the sector and national level, notably of the selected countries introduced in the previous section. As noted in Chapter 3, these data include the three major GHGs covered by the Kyoto Protocol (CO_2, CH_4 and N_2O) but exclude the three minor GHGs (HFCs, SF_6 and PFCs) as well as emissions from land use changes ('sinks').[14]

First of all, Table 4.2 presents an overview of GHG emissions in the base year 1990 by sector and greenhouse gas. Of all three major GHGs, CO_2 accounts - on average - for 81 percent of global emissions in 1990, whereas the shares of CH_4 and N_2O amount to 15 and 4 percent, respectively. At the national level, however, the distribution of GHG emissions may show quite different patterns as illustrated in Figure 4.1 for Tanzania and Japan.

At the sector level, global GHG emissions in 1990 can be largely ascribed to industry (36.5 percent), followed by power (18.2 percent), agriculture (15.7 percent) and transportation (13.5 percent). Again, this distribution of GHG emissions by sector shows significant differences between countries. For instance, GHG emissions in Japan can be mainly attributed to industry (48.2 percent) and hardly to agriculture (only 1.8 percent), whereas in Tanzania the comparative shares of these sectors are quite the opposite, i.e. 3.0 and 77.3 percent respectively.

The bottom-line of Table 4.2 presents data on total GHG emissions. In 1990, total and average global emissions amounted to 26,552 $MtCO_{2eq}$ and 5.0 tonne $CO_{2\ eq}$. per capita, respectively (see also Table 4.1). As expected, per capita emission levels show large differences among countries, depending - to some degree - on their level of GNP per capita. For instance, per capita emissions in the USA are about 32 times higher than in Tanzania. The major exceptions to the relationship between GNP and GHG emissions are Russia (i.e. relatively high GHG emissions) as well as Brazil and Japan (i.e. relatively low GHG emissions, see Table 4.1 - last two columns - and Figure 4.2).

[14] In 1990, the three major GHGs accounted for 99 percent of all global emissions - excluding sinks - covered by the Kyoto Protocol. In 2010, the share of these gases will be some 98 percent (Ybema et al. 1999; Sijm et al., 2000).

Table 4.2 *Emissions in selected countries by sector and GHG (1990)*[a]

	Unit	Tanzania	India	China	Iran	Russia	Brazil	EU-15	USA	Japan	World
CO_2	% of total	9.3	42.5	69.1	76.1	79.3	45.1	79.9	83.5	95.7	73.6
CH_4	% of total	69.5	49.1	25.5	20.0	18.3	46.2	11.1	10.6	2.8	22.4
N_2O	% of total	21.1	8.4	5.4	3.9	2.3	8.6	9.0	6.0	1.5	4.0
Total GHG	*$MtCO_{2eq}$*	*21*	*1481*	*3497*	*251*	*2990*	*509*	*4175*	*5903*	*1175*	*26552*
Power	% of total	4.4	15.1	10.8	13.7	30.4	1.0	20.1	23.2	15.8	18.2
Industry	% of total	3.0	23.7	49.6	22.9	45.6	24.6	32.9	29.8	48.2	36.5
Transport	% of total	3.5	5.2	3.8	8.0	5.7	14.8	17.1	26.0	18.0	13.5
Households	% of total	1.7	2.9	10.4	4.2	3.1	3.1	10.1	5.4	6.1	6.2
Services	% of total	0.0	0.1	4.2	33.7	8.2	2.6	6.3	4.6	8.3	5.9
Agriculture	% of total	77.3	47.3	18.8	11.2	5.6	48.2	9.6	7.3	1.8	15.7
Waste	% of total	10.1	5.8	2.3	6.3	1.4	5.7	4.0	3.7	1.9	3.9
Total GHG	*$MtCO_{2eq}$*	*21*	*1481*	*3497*	*251*	*2990*	*509*	*4175*	*5903*	*1175*	*26552*

[a] Including CO_2, CH_4 and N_2O but excluding estimated emissions from land use changes.

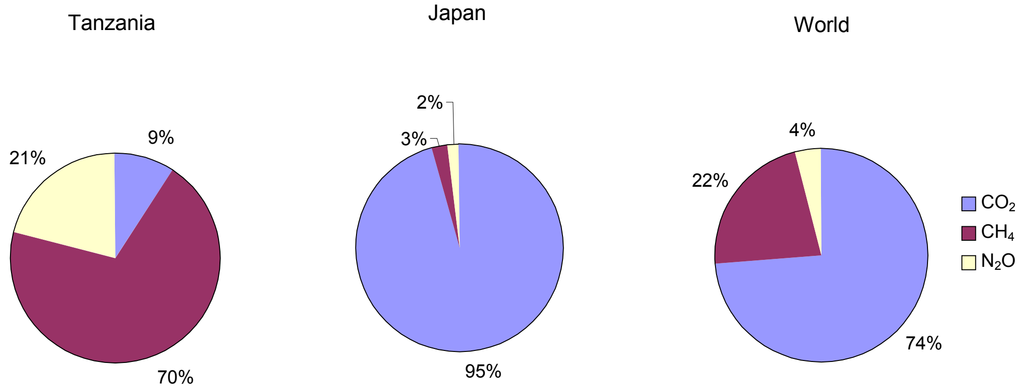

Figure 4.1 *Distribution of GHG emissions by gas*

Table 4.3 *Assumptions on deriving the world GHG mitigation rate per sector (in annual % of change)*

	Assumed future per capita activity trend	Assumed future baseline decarbonisation trend	Assumed climate change policy-induced additional reduction	Total reduction or mitigation rate [a]
Power	1.5	0.8	1.3	-0.6
Industry	1.0	0.4	1.3	-0.7
Transport	1.5	0.2	1.3	0.0
Households	0.8	0.4	1.3	-0.9
Services	1.0	0.4	1.3	-0.7
Agriculture	0.2	0.1	0.1	0.0
Waste	1.0	0.8	1.3	-1.1

[a] Rounded to nearest decimal.

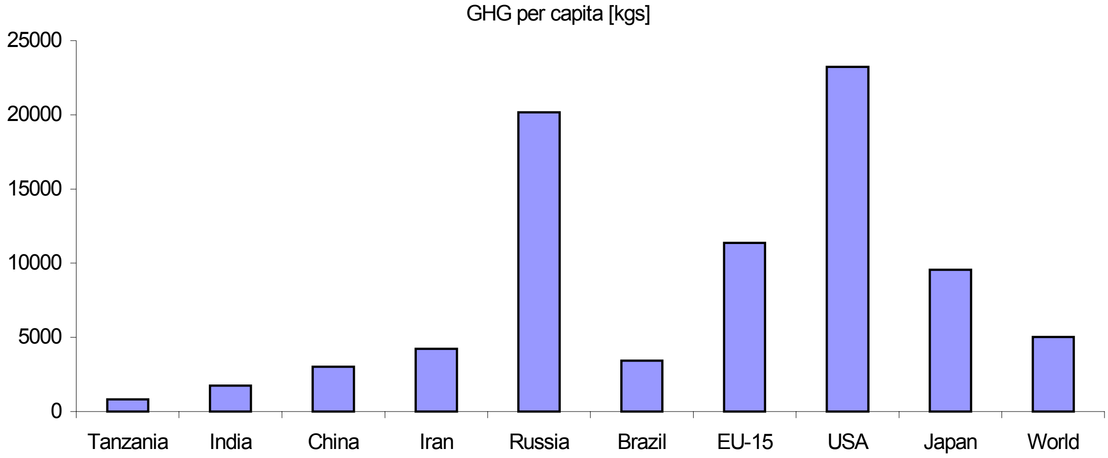

Figure 4.2 *GHG emissions per capita in selected countries (1990) [kgs]*

Table 4.4 *Derivation of global per capita emission standards in the convergence year* [a]

Sector	Base year BY	GHG/cap 2010 [$kgCO_{2eq}$] $GSES_{by}$	Mitigation norm [% per annum] GSEMN [b]	Convergence [year] CY	GHG/cap CY [$kgCO_{2eq}$] $GSES_{cy}$
Power	2010	1036	-0,6	2100	591
Industry	2010	2081	-0,9	2100	915
Transport	2010	772	0,0	2100	758
Households	2010	354	-0,7	2100	186
Services	2010	337	-0,7	2100	177
Agriculture	2010	895	0,0	2100	895
Waste	2010	224	-1,1	2100	82
Total	*2010*	*5700*		*2100*	*3606*

a) Including CO_2, CH_4 and N_2O but excluding estimated emissions from land use changes.
b) Rounded to nearest decimal (See Table 4.3).

4.4 Emissions standards in the convergence year

A possible approach for the determination of global per capita emission standards at the sector and aggregated level is illustrated in Tables 4.3 and 4.4. Table 4.3 shows the derivation of *global sector emission mitigation norms*. These norms indicate the normative % change per year in global sector emissions per capita, presupposing a comprehensive global emission mitigation policy framework. For power generation the applied norm is a per capita global emission reduction of -0.6% per year. This norm is based on the following assumptions on future developments:

- power generation per capita is assumed to increase by 1.5% per year,
- the quantity of GHG emitted per kWh of power produced is assumed to decrease by 0.8% per year,
- the international climate change negotiations and resulting policies are assumed to lead to a further reduction in carbon emissions by 1.3% per year.

These figures serve to illustrate the MSC methodology. In-depth analysis of recent sector trends, consultations with sector representatives and international negotiations should improve the realistic value of the underlying assumptions.

Based on the (annual) global sector emission mitigation norms, global sector emission standards (GSESs) for the assumed convergence year (2100) can be derived: see Table 4.4.

The GSESs depend on the following parameters:

- *The base year (BY).* In the example included in Table 4.4, the base year is set at 2010. If desired, however, another year might be chosen.
- *The global per capita sector emission standards in the base year ($GSES_{by}$).* In Table 4.4, these standards have been set equal to the projected world average GHG emissions at the sector/national level in 2010. However, they could be fixed at the average level of any region or groups of countries, for instance the average emission levels of the EU or all Annex I countries.
- *The convergence year (CY).* This parameter refers to the year in which countries with actual national emission levels above the convergence national emission standard should have brought down these levels to this standard. In Table 4.4, the convergence year is set at 2100. However, it could also be 2050 or any other year in the (far) future. Moreover, although in the present example the convergence year is set the same for each sector and country, it could be varied by sector/country.
- *The global per capita sector emission mitigation norm (GSEMN).* This variable concerns the annual mitigation rate of the emission standards in the years following the base year. The GSEMN can not only vary by sector but also by variant considered within the Multi-Sector Convergence framework.

Together, these four parameters determine the global per capita emission standards at sector and aggregated levels in the convergence year ($GSES_{cy}$) as shown in the last column of Table 4.4. In the convergence year, the global sector emission standards are assumed to hold at the national level as well. In order to obtain the global total emission standard in the convergence year in per capita terms ($GTES_{cy}$) - *which applies to all countries* - the $GSES_{cy}$ sector standards should be added up.

4.5 National pre-adjustment emission mitigation targets

Actual emissions levels of the selected sample of countries in the year 1990 have been recorded in Table 4.2, whereas normative emissions standards for all countries in the convergence year 2100 have been derived in Table 4.4. As explained in Section 3.4, non-binding sector emission standards for each country in intermediate years - for instance, 2015, representing the second budget period - are obtained by geometric interpolation between the actual sector emission levels in the base year and the global sector emission standards of the convergence year. These non-binding sector emission standards are multiplied by total population and, subsequently, added up in order to determine national emission mitigation targets for the countries and years concerned.

Results of this procedure *assuming immediate participation of low-emission countries (i.e. making no allowance for exemption of low-emission countries)* are summarised in Table 4.5 for the selected sample of countries in the years 2010, 2015, 2020, 2050 and 2100. This table shows, for instance, that Tanzania is allowed to increase its total GHG emissions from 21 Mt in 1990 to 67 Mt in 2010 and even to 397 Mt in 2100. This significant increase is due to the combination of two effects, i.e. (i) a substantial rise in allowable emissions per capita - up to the world average standards - is multiplied by (ii) a rapidly growing population. On the other hand, Russia is obliged to reduce its total GHG emissions from almost 3,000 Mt in 1990 to some 350 Mt in 2100 as a result of (I) a substantial lower emission assignment per capita in 2100, combined by (II) a steadily declining population.

In order to enhance the comparability of national emission mitigation targets between the selected countries and budget periods, the lower part of Table 4.5 expresses these targets in terms of reduction/limitation percentages. According to the multi-sector convergence approach, the rates of emission reductions regarding the second budget period are quite substantial, varying from +13.9 percent for Tanzania to -12.7 percent for Russia. In cumulative terms, Russia has to reduce its GHG emissions by 89 percent over the years 2010-2100 compared to 52 percent for Japan. On the other hand, non-Annex I countries such as Tanzania or India are allowed to increase their GHG emissions over the period 2010-2100 by 495 and 55 percent, respectively.

Table 4.5 *Pre-adjustment emission mitigation targets for selected countries: immediate participation case (2015-2100)*[a]

Unit	Year/period	Tanzania	India	China	Iran	Russia	Brazil	EU-15	USA	Japan	World
GHG/cap	1990	813	1741	3027	4236	20163	3437	11431	23230	9511	5027
[kgCO_{2eq}/cap]	2010	1514	3263	6504	8214	21198	8627	10259	18368	8693	5700
	2015	1520	3240	6216	7651	18890	8109	9599	16680	8155	5394
	2020	1530	3220	5947	7154	16857	7630	8989	15156	7657	5132
	2050	1737	3181	4689	5129	8824	5431	6177	8633	5383	4173
	2100	3606	3606	3606	3606	3606	3606	3606	3606	3606	3606
Total GHG	1990	21	1481	3497	251	2990	509	4175	5903	1175	26552
[MtCO_{2eq}]	2010	67	3760	8878	807	2990	1637	3852	5490	1104	39275
	2015	76	3926	8759	838	2610	1619	3588	5185	1026	39301
	2020	86	4095	8616	857	2272	1591	3340	4884	948	39372
	2050	152	4923	7026	804	1032	1369	2054	3090	731	38950
	2100	397	5839	4897	619	346	986	989	1277	536	35908
Change	1990-2010	221.8	153.8	153.8	221.8	0.0	221.8	-7.7	-7.0	-6.0	47.9
[%]	2010-2015	13.9	4.4	-1.3	3.8	-12.7	-1.1	-6.8	-5.6	-7.1	0.1
	2015-2020	13.2	4.3	-1.6	2.3	-13.0	-1.7	-6.9	-5.8	-7.6	0.2
	2010-2050	128.7	30.9	-20.9	-0.4	-65.5	-16.4	-46.7	-43.7	-33.8	-0.8
	2010-2100	495.3	55.3	-44.8	-23.3	-88.4	-39.8	-74.5	-76.7	-51.5	-8.6

a) Including CO_2. CH_4 and N_2O but excluding estimated emissions from land use changes.

Table 4.6 presents emission limitation targets for the full sample of countries and regions included in the database of the present research project on burden sharing. Besides 17 non-Annex I countries and three regional groupings of countries, it covers all Annex I countries of the UNFCCC.[15] The average reduction rate agreed by the Annex I countries as part of the Kyoto Protocol is about five percent for the first budget period, whereas the comparative figure according to the multi-sector convergence approach is projected to be about eight percent for the second and third budget periods.

4.6 The inclusion of allowance factors

4.6.1 Introduction

As discussed in Section 3.5, the MSC framework for negotiating global rules for national GHG emission mitigation targets can be fine-tuned by including country-specific allowance factors. This section will provide some examples of operational rules and/or numerical illustrations of such allowance factors. It should be stressed, that these examples are largely presented for illustrative purposes only and that they can be changed - i.e. adjusted, elaborated, removed or extended by other examples - during the Climate Change negotiation process on the issue of emission mitigation targets. Additional research is needed to further elaborate upon the examples of allowance factors suggested below or to develop new ones.

[15] As explained in footnote 1, all countries listed in Annex I of the UNFCCC have accepted an emission limitation target at the Kyoto Conference of 1997, except Belarus and Turkey. Hence, the latter two countries are not listed on the so-called ‘Annex B list’ of the Kyoto Protocol.

Table 4.6 *National pre-adjustment emission mitigation targets for the full database of countries: immediate participation case [%]*

	Per budget period[a]			Cumulative[b]	
	First (2008-12)	Second (2013-17)	Third (2018-22)	2010-2050	2010-2100
Australia	8.0	-5.2	-5.3	-41.5	-76.1
Austria	-13.0	-5.8	-6.0	-41.4	-65.5
Belarus	-19.0	-7.4	-7.7	-47.8	-75.1
Belgium	-7.5	-7.8	-7.7	-50.6	-78.5
Bulgaria	-8.0	-11.0	-10.8	-58.4	-82.7
Canada	-6.0	-5.3	-5.4	-41.7	-74.9
Czech Republic	-8.0	-11.5	-11.7	-62.9	-85.5
Denmark	-21.0	-6.4	-6.2	-44.9	-74.7
Estonia	-8.0	-15.9	-16.0	-72.7	-91.2
Finland	0.0	-7.6	-7.6	-51.6	-80.3
France	0.0	-5.2	-5.3	-40.9	-70.2
Germany	-21.0	-7.6	-7.8	-50.3	-77.5
Greece	25.0	-8.5	-8.7	-52.1	-79.4
Hungary	-6.0	-8.7	-8.6	-49.1	-71.9
Iceland	10.0	-4.3	-3.9	-40.6	-67.0
Ireland	13.0	-7.8	-8.4	-55.1	-84.2
Italy	-6.5	-7.6	-7.9	-46.8	-72.3
Japan	-6.0	-7.1	-7.6	-33.8	-51.5
Latvia	-8.0	-9.7	-10.0	-56.6	-83.0
Lithuania	-8.0	-8.8	-8.9	-53.9	-80.2
Luxembourg	28.0	-13.8	-13.9	-71.6	-92.7
Netherlands	-6.0	-7.2	-7.2	-49.1	-77.8
New Zealand	0.0	-5.1	-4.9	-38.9	-70.1
Norway	1.0	-6.4	-6.3	-47.2	-73.4
Poland	-6.0	-6.6	-6.9	-47.7	-75.0
Portugal	23.9	-7.0	-6.9	-44.4	-70.3
Romania	-8.0	-7.7	-8.0	-48.5	-73.4
Russia	0.0	-12.7	-13.0	-65.5	-88.4
Slovakia	-8.0	-7.3	-7.6	-50.3	-77.9
Spain	15.0	-6.4	-6.8	-43.9	-71.5
Sweden	4.0	-3.5	-3.3	-34.8	-64.4
Switzerland	-8.0	-5.4	-5.3	-38.2	-58.9
Turkey	54.0	3.3	2.8	20.9	24.8
Ukraine	0.0	-11.8	-12.0	-62.7	-86.8
United Kingdom	-12.5	-6.2	-6.1	-45.3	-74.7
United States	-7.0	-5.6	-5.8	-43.7	-76.7
Bangladesh	153.8	4.8	3.5	34.6	143.9
Bolivia	221.8	4.8	4.0	13.4	4.9
Brazil	221.8	-1.1	-1.7	-16.4	-39.8
China	153.8	-1.3	-1.6	-20.9	-44.8
Egypt	221.8	3.9	3.8	36.2	59.5
India	153.8	4.4	4.3	30.9	55.3
Indonesia	153.8	4.7	4.3	34.6	57.0
Kazakhstan	-19.4	-4.4	-4.9	-31.6	-54.8
Kuwait	221.8	-10.0	-10.7	-64.1	-89.6
Mexico	221.8	-2.0	-2.6	-23.6	-57.3
Iran	221.8	3.8	2.3	-0.4	-23.3
Nigeria	221.8	17.3	16.4	171.9	490.6
Saudi Arabia	221.8	1.2	0.3	-27.6	-66.4
South Africa	221.8	-2.2	-3.0	-26.1	-60.7
South Korea	153.8	-8.7	-8.4	-50.4	-81.1
Tanzania	221.8	13.9	13.2	128.7	495.3
Yemen	221.8	19.4	18.7	151.6	341.2
Total	47.9	-3.2	-3.2	-24.3	-40.1
EU-15	-7.7	-6.8	-6.9	-46.7	-74.5
Annex 1	-5.1	-7.8	-7.9	-49.2	-77.1
Non-Annex 1	152.6	5.9	5.4	35.0	42.2
World	47.9	0.1	0.2	-0.8	-8.6

a) Percentage reduction of GHG emissions in the period considered compared to the previous period. For the first budget period, this reduction is compared to the emission level in the base year 1990.

b) Percentage reduction of GHG emissions in the last year mentioned compared to the year 2010.

4.6.2 Climate

Differences in climate conditions may result in differences in GHG emissions per capita. Climate differences can be expressed by the number of heating degree-days, defined as the number of days that require indoor heating multiplied by the number of heating degrees concerned.[16] Differences in heating degree-days among countries may allow for an additional amount of GHG emissions. Countries with an above-average number of degree-days would be eligible for a certain additional emission allowance. Once reliable data will become available, the index to be used may relate to their average number of heating degree-days. An index $I_{climate}$ may be designed with a base value 100 for countries with average country-specific emission conditions: the world average number of heating degree-days and values below 100 for countries with less favourable country-specific conditions with respect to the allowance factor Climate. This may be done in the following way:

Given the variables

$I_{climate,b}$	: index base value of allowance factor 'climate'
HDD_n	: annual number of heating degree-days for country n
HDD_{av}	: average annual number of heating degree-days for all countries concerned
$a_{climate,n}$	: additional allowance regarding 'climate' for country n, in % of pre-adjustment emission allowance
$m_{climate}$	: maximum additional allowance regarding 'climate'
$A_{climate,n}$	: additional allowance regarding 'climate' for country n, in $MtCO_2$ eq.
E_n^{pa}	: pre-adjustment emission allowance for country n in per capita terms (tCO_2 eq.)
P_n	: population of country n (millions),

the additional allowance for country n regarding allowance factor 'climate' can be derived by application of the following rules:

$$I_{climate,b} = 100$$

$$I_{climate,n} = (HDD_{av} / HDD_n) \times 100$$

$$a_{climate,n} \begin{cases} = (1 - I_{climate,n} / 100) \times m_{climate} & \text{, if } I_{climate,n} < 100 \\ = 0 & \text{otherwise} \end{cases}$$

$$A_{climate,n} = a_{climate,n} \times E_n^{pa} \times P_n$$

A major problem to put into operation the rules stated above is lack of data on the number of heating degree-days for a large number of countries. This problem can be relieved by restricting the allowance factor concerned to only those countries which have accepted an official commitment to limit their GHG emissions (i.e. the Annex I countries). A fictive, illustrative example of heating degree-days as an allowance factor is presented in Table 4.7. It shows, for instance, that country D has a number of 4000 heating degree-days a year. Based on a maximum allowance factor of 10% (in terms of the pre-adjustment total emission allowance) and using the formulas expressed above, this results in a total additional amount of emission assignments of 0.7 $MtCO_2$ eq. for country D.

[16] A similar rule can be designed for cooling degree-days (or, alternatively, a rule for a combination of heating and cooling degree-days).

Table 4.7 *Fictive example of heating degree-days as an emission allowance factor*

Country	HDD_n	$I_{climate,n}$	$a_{climate,n}$	E^{pa}_n	P_n	$A_{climate,n}$
			[%][a)]	[tCO_{2eq}]	[million]	[$MtCO_{2eq}$]
A	1000	300	0.0	5.02	15	0.0
B	2000	150	0.0	7.01	10	0.0
C	3000	100	0.0	9.00	38	0.0
D	4000	75	2.5	11.0	22	6.1
E	5000	60	4.0	8.0	53	17.0

a) $m_{climate}$ has been set at 10%.

Another problem is that the concepts of (average) heating degree days and cooling degree days are less meaningful for countries with fast differences in climate within the country. For establishing adjustments for allowance factors for very large countries covering e.g. widely different climate zones, it might be considered to determine these adjustments in per capita terms at appropriate sub-national/regional levels using population weights for aggregation. This might especially hold for giant countries such as Russia, China or the US (with even non-contagious regions such as Alaska).

4.6.3 Population density

Differences in population density among countries and resulting differences in GHG emissions can be accounted for in a similar vein by including an allowance factor 'population density' in a similar way as the allowance factor 'climate'. The index $I_{popdens,n}$ for country n can be obtained by taking the ratio of population density in country n to the mean population density in the countries considered and multiplying by 100. A similar approach as with allowance factor 'climate' can then be pursued.

Given that

$I_{popdens,n}$	:	index value of allowance factor 'population density' for country n
$I_{popdens,b}$	:	index base value of allowance factor 'population density'
PD_n	:	population density for country n (#inhabitants/km^2)
PD_{av}	:	average population density for all countries concerned (#inhabitants/km^2)
$a_{popdens,,n}$	:	additional allowance regarding 'population density' for country n (in % of pre-adjustment emission allowance)
$m_{popdens}$	:	maximum additional allowance regarding 'population density'
$a_{popdens,n}$	:	additional allowance regarding 'population density' for country n (in $MtCO_{2eq}$.)
E^{pa}_n	:	pre-adjustment emission allowance for country n in per capita terms (tCO_{2eq}.)
P_n	:	population of country n (millions),

the additional allowance for country n regarding allowance factor 'population density' can be derived by application of the following rules:

$$I_{popdens,b} = 100$$

$$I_{popdens,n} = (PD_n / PD_{av}) \times 100$$

$$a_{popdens,n} \begin{cases} = (1 - I_{popdens,,n} / 100) \times m_{popdens}, & \text{if } I_{popdens,n} < 100 \\ = 0 & \text{otherwise} \end{cases}$$

$$A_{popdens,n} = a_{popdens,n} \times E^{pa}_n \times P_n$$

A numerical example of population density as an allowance factor is presented in Table 4.8. It is assumed that this allowance factor applies only to countries with population densities below world average.

Table 4.8 *Example of population density as an emission allowance factor*

Country	PD_n	$I_{popdens,n}$ a)	$a_{popdens,n}$ [%]b)	E_n^{pa} [tCO_{2eq}]	P_n [millions]	$A_{popdens,n}$ [$MtCO_{2eq}$]
A	30	60	3.2	5.0	15	2.4
B	300	600	0.0	7.0	10	0.0
C	10	20	6.4	9.0	38	21.9
D	40	80	1.6	11.0	22	3.9
E	70	140	0.0	8.0	53	0.0

a) Taking as base value the average world population density in the year considered, set in this example at 50 inhabitants/km^2.

b) $m_{popdens}$ has been set at 8%.

4.6.4 Transition economies

It is hard to formulate a general rule - resulting in a certain allowance factor - that applies to all economies in a state of transition, either from a communist, centralised state to a capitalist, market-led economy or from a rapidly developing, industrialising state to a more developed and moderately growing services economy. However, some suggestions can be made. For instance, countries in economic transition with GHG emission above the world average emission standard may be granted a grace or exemption period during which GHG emissions are limited to a certain specified level, followed by an adjusted abatement regime in the years thereafter. These adjusted stipulations depend on both country-specific circumstances and the outcome of political negotiations during the process of allocating emission limitation targets.

4.6.5 Renewable energy resources

The share of renewables in total energy supply might be taken as a first crude point of departure for developing a suitable index for the economic potential of renewable energy resources of a country. In principle, this information is readily available. ECN has developed a more appropriate methodology for determining an indicator for renewable energy potential of a country.[17] This methodology is presently being applied to the EU member-countries (REBUS project) and to China.

4.7 The participation of non-Annex I countries

A major point of discussion is whether and how non-Annex I countries should participate in the burden sharing approach outlined above. The present, post-Kyoto situation is that non-Annex I countries are not subject to an official commitment to limit their GHG emissions. However, they are involved in international climate policies to control the greenhouse effect by means of the Clean Development Mechanism (CDM). The main objectives of this mechanism are (a) to encourage the sustainable development of non-Annex I countries by means of institutional capacity building and technology transfers, and (b) to enable Annex I countries to meet part of their Kyoto commitments cost-effectively by means of abatement projects in non-Annex I countries.

[17] Reference is made to Schaeffer et al. (1999) for a first introduction.

Although the specific guidelines, rules and procedures of CDM still have to be defined by ongoing policy negotiations as part of the annual Conference of the Parties (CoP), the post-Kyoto situation offers the following advantages:[18]

- It encourages the sustainable development of all interested non-Annex I countries as it implies a transfer from Annex I to non-Annex I countries of investment funds, knowledge and technologies regarding GHG mitigation.
- It offers net gains to non-Annex I countries by selling CDM emission credits to Annex I countries.
- It encourages particularly the participation in international GHG mitigation efforts of those non-Annex I countries that possess a large abatement potential at relatively low costs (such as China or India).
- It contributes to mitigating GHG emissions at low costs and, hence, to accepting more ambitious, higher emission limitation targets by Annex I countries.
- It does not require a reliable system of monitoring and evaluating GHG emissions at the national level, but only at the project level.

It should be stressed, however, that the above-mentioned advantages depend partly on the specific definition of the guidelines, rules and procedures of the CDM (which - as noted - is still part of ongoing policy negotiations). Compared to Joint Implementation (JI) - which enables Annex I countries to meet their Kyoto commitments through abatement projects in other Annex I countries - the Clean Development Mechanism is characterised by some specific problems regarding emission reduction validation, monitoring and verification because non-Annex I countries do not have a mitigation commitment. As a result, the risks of fake abatement projects and other kinds of 'leakages' are higher for CDM than JI since in case of JI projects both host and investing countries have an interest in correct emission monitoring and verification. Probably the best way to avoid an improper use of CDM is to formulate a list of criteria to which CDM projects must comply - in order to ensure that only genuine reduction activities are accepted to generate and trade CDM credits - accompanied by a strict GHG monitoring and evaluation system at the project level.

An alternative option to ensure the participation of non-Annex I countries is that they - just as Annex I countries - accept an official commitment to limit their national GHG emissions as determined by the MSC approach discussed above. Table 4.6 shows that the non-Annex I countries as a whole do not really have to reduce their GHG emissions as - even in the base model variant without incorporation of an adjustment period and allowance factors - they are allowed to *increase* these emissions by 42 percent over the years 2010-2100. For individual non-Annex I countries, however, emission limitation targets differ significantly. For instance, a non-Annex I countrY such as Nigeria is permitted to increase its emissions by some 172 percent over the years 2010-2100, whereas other non-Annex I countries - for instance, Kuwait -has to reduce its emissions by some 64 percent over this period (Table 4.6).

The effects (advantages/disadvantages) of this alternative option depend largely on the question whether - and to what extent - non-Annex I countries are able to trade their surplus of emission assignments to deficit (mostly Annex I) countries. If not, this option corresponds highly to the present, post-Kyoto situation outlined above, albeit some non-Annex I countries are committed to limit their emissions rather strictly in the nearby future, notably when population/economic growth is accounted for. On the other hand, if non-Annex I countries are allowed to trade their full surplus of emission assignments ('hot air'), the most likely effects will be:

- Non-Annex I countries - such as Tanzania or Nigeria - which will benefit most from Emissions Trading (ET) will accept the commitments concerned, whereas countries that will be faced by strict emission limitations - or even real reductions - will not be inclined to

[18] For details, see Sijm et al. (2000a). See also Working Paper No. 6 of the present research project (Sijm et al., 2000b).

participate. From a GHG emission limitation point of view, however, the latter group of countries is far more interesting than the former group.

- Depending on the variant of the MSC approach, allowing non-Annex I countries to trade their full ‘hot air’ surplus of emission assignments implies that the emission targets of Annex I countries will be largely undermined - notably in the second, but also in the subsequent budget periods - as they can be achieved quite simply by buying emission credits at relatively cheap terms from non-Annex I countries. The overall impact might be a large transfer of financial resources from Annex I countries to non-Annex I countries - which may also undermine the present system of development assistance - with hardly any real limitation of global GHG emissions. These effects may be mitigated by raising the emission limitation commitments of Annex I countries and/or by reducing the surplus of emission assignments that non-Annex I countries may sell (either by reducing their level of emission assignments or by stipulating that only a certain percentage - say 10 percent - of the surplus may be traded). In the first case, Annex I countries will be faced by higher abatement burdens, with higher financial transfers to non-Annex I countries. In the second case, non-Annex I countries that are most interesting from a GHG emission mitigation point of view will be even less inclined to participate in the burden sharing approach concerned.

Moreover, emissions trading between countries requires a reliable system of monitoring and evaluating GHG emissions at the national level. At present, such systems are hardly available in non-Annex I countries.[19] Therefore, regarding the participation of low-emission non-Annex I countries in global emission limitation efforts, the present (post-Kyoto) situation seems to be more preferable than the alternative option discussed above. However, with regard to the higher emission non-Annex-I countries that are signatories to the UNFCCC, it is assumed that they will have to accept future emission mitigation targets as part of the international negotiations on this issue.

For negotiating a comprehensive MSC approach with participation of the present non-Annex-I countries, the introduction of an adjustment period of acceding countries appears warranted. Reference is made to Section 3.6 in which recommendations for the design of a graduation procedure for high-emission non-Annex-I countries have been presented.

[19] Even the emission statistics of some non-Annex I countries included in the database of the present research project are questionable.

5. CONCLUSIONS

It was found that burden sharing rules should not be incompatible with the principle of need. Several examples of need-based burden sharing rules exist. Most of them follow a top-down approach. These rules suggest a step towards convergence of the greenhouse gas emission levels per capita, be it with due allowance for country-specific emission circumstances.

To make the principle of need operational, a step needs to be made to express general equity considerations in terms of real life indicators. The translation of the need principle to concrete indicators will be ruled by pragmatic considerations, as a multitude of factors affect the level of emissions and one can not include all of them and still have a simple and transparent burden sharing rule. Linking the most important factors to emissions per sector seems a logical choice as the need to emit is linked to the provision of services which, in turn, takes place in distinct sectors. Moreover, a sectoral approach will be helpful in designing national emission mitigation policies.

In this report a flexible Multi-Sector Convergence framework is introduced to facilitate Climate Change negotiators in reaching a comprehensive agreement on the allocation of national GHG emission commitments. The MSC framework is characterised by:

- A number of distinct 'emission sectors' covering all human-induced GHG emissions. Pending the availability of reliable data and further guidance from the Climate Change negotiating table, sinks/land-use changes have not yet been included but could be included at a later stage.
- Inclusion of the greenhouse gases CO_2, CH_4 and NO_2, accounting for approximately 99% of all human-induced GHG emissions.
- Convergence of national sector emissions per capita to world standards in the (negotiated) convergence year.
- The aggregation of world sector standards defines the world standard of total emissions (in per capita terms) towards which the national total emissions (again in per capita terms) will have to converge.
- The world sector standards can be set, considering the desired total world emission level and sector-specific considerations.
- Allowance factors can be included in the framework to allow for major country-specific circumstances that explain significant variations in per capita emission levels.
- Also a graduation threshold and a graduation adjustment period can be included.

Should the MSC methodology be used as a framework for international emission mitigation negotiations, it stands to reason that final negotiation results will be obtained after several iterations. E.g. should the resulting first-round adjusted global emission mitigation targets for all countries be considered too lenient, all parameter values including the ones for allowance factors should be scrutinised on the scope for further tightening.

More research is required to improve the empirical basis for the formulation of sector mitigation norms. The same holds for the development of appropriate indicators for allowance factors such as climate and the potential for renewable energy.

A distinct but related issue to the approach for determining national mitigation targets, is the operationalisation method for the flexible instruments of the Kyoto Protocol. High emission burdens are only likely to be accepted by high-emission countries when these will be achieved most cost-effectively by the Kyoto flexible instruments. High caps on the use of these instruments are poised to render significant additional emission mitigation commitments politically infeasible. Yet modest caps might be considered to encourage domestic emission mitigation efforts in high-emission countries.

REFERENCES

Blok K., G.J.M. Phylipsen and J.W. Bode (1997): *The Triptique approach: Burden differentiation of CO_2 emission reduction among European Union member states*. Utrecht University, Utrecht.

Bouwman, A.F. (1991): *Agronomic aspects of wetlands rice cultivation and associated methane emissions.* Biochemistry, 15, pp. 65-88.

Carraro, C. and A. Coria, (1999): *Integrating Climate Change Policies in the European Environment.* EFIEA Policy Report, Milan/Amsterdam.

CDIAC (2000): World Data Center, Carbon Dioxide Information Analysis Center, Oak Ridge, USA, *http;//www.cdiac.esd.oml.gov/wdca/wdcinfo.html.*

Crutzen, P.J and M.O. Andreae, (1990): *Biomass burning in the tropics: impact on atmospheric chemistry and biochemical cycles.* Science, 250, pp. 1669-1678.

Crutzen, P.J. I. Aselman, and W. Seiler (1986): *Methane production by domestic animals, wild ruminants, others herbivorous fauna and humans*. Tellus, 38B, pp. 271-284.

Gupta S. and P.M. Bhandari (1999): *An effective allocation criterion for CO_2 emissions.* Energy Policy, 27, pp. 727-736.

IEA (1997): *Indicators of Energy Use and Efficiency.* Paris.

IPCC (1997): *Greenhouse Gas Inventory Reference Manual.* Volume 3.

Pepper, W., J. Leggett, R. Swart, J. Watson, J. Edmonds, and I. Mintzer, (1992): *Emissions scenarios for the IPCC: an update*. Assumptions, methodology and results, 155p. Prepared for IPCC working group 1.

Phylipsen, G.J.M., H. Groenenberg, and K. Blok (1998*): The EU burden sharing after Kyoto - renewed Triptych calculations*. Department of Science, Technology and Society, Utrecht University.

Ringius, L., A. Torvanger and A. Underdal (2000): *Burden differentiation of greenhouse gas abatement: Fairness principles and proposals.* Working Paper No. 13, CICERO, Oslo, and ECN C--00-013, Petten.

Rose, A., B. Stevens, J. Edmonds, and M.Wise, (1998): *International Equity and Differentiation in Global Warming Policy*. Environmental and Resource Economics, Vol. 12. No. 1, pp. 25-51.

Schaeffer, G.J., M.G. Boots, J.W. Martens and M.H. Voogt (1999): *Tradable Green Certificates. A new market-based incentive scheme for renewable energy: Introduction and analysis*. ECN Report No ECN-I--99-004.

Schafer, A. and D.G. Victor (1999): *Global passenger travel: implications for carbon dioxide emissions.* Energy, 24, pp 657-679.

Sijm, J., F.T. Ormel, J.W. Martens, S. van Rooijen, M.H. Voogt, M.T. van Wees, and C. de Zoeten-Dartenset (2000): *Kyoto Mechanisms: The role of Joint Implementation, the Clean Development Mechanism and Emissions Trading in Reducing Greenhouse Gas Emissions*. ECN Report No ECN-C--00-026, Petten.

Torvanger, A. and O. Godal (1999): *A survey of differentiation methods for national greenhouse reduction targets.* Report No. 5, CICERO, Oslo, and forthcoming as report from the Nordic Council of Ministers, Copenhagen.

Ybema J.R., J.J. Battjes, J.C.Jansen, F.T.Ormel (2000*): Burden differentiation: GHG emissions, undercurrents and mitigation costs*. Report ECN-C--00-012/CICERO WP 1999: 14, Petten/Oslo.

Watson R.T., Meira Filho, L.G., Sanhueza, E., and Janetos, A. (1992): *Sources and sinks, in*: Houghton, J.T., Callendar, B.A., and Varney, S.K. (eds) Climate Change 1992. *The supplementary report to the IPCC scientific Assessment.* pp. 25-64. University Press, Cambridge.

World Bank (1998): *World Development Indicators 1998*. Washington DC.

World Bank (1999): *World Development Report 1999/2000.* Washington DC.