RIVM report 728001029/2004

Bottom-up approaches for defining future climate mitigation commitments

M.G.J. den Elzen*
M.M. Berk

* Corresponding author: E-mail: michel.den.elzen@rivm.nl; tel +31 30 2744584; fax: +31 30 2744464

This research was performed within the framework of the Netherlands Research Programme Climate Change (NRP-CC) Options for post 2012 Climate Policies and International Agreements, and also with the support of the Dutch Ministry of Environment as part of the International Climate Change Policy Project (M/728001 Internationaal Klimaatbeleid)

RIVM, P.O. Box 1, 3720 BA Bilthoven, telephone: +31 30 274 91 11; fax: +31 30 274 29 71

Acknowledgements

This study was performed within the framework of the Netherlands Research Programme on Climate Change (NRP-CC) Options for 2012 Climate Policies and International Agreements, with the support of the Dutch Ministry of Environment in the framework of International Climate Change Policy Support project (M/728001 Internationaal Klimaatbeleid). In particular, we would like to express our thanks to the project team of the NRP-CC Options for 2012 Climate Policies and International Agreements, especially Joyeeta Gupta (IVM) and Marcel Kok (RIVM), who provided us with critical and useful comments in the preliminary reporting stages of our work. We would also like to thank our RIVM colleagues, in particular Bas Eickhout and Paul Lucas, for their comments and contributions. Any errors in the report are the responsibility of the authors.

Rapport in het kort

Dit rapport beschrijft de resultaten van een aantal in de literatuur geopperde alternatieve, bottom-up benaderingen om verplichtingen vorm te geven, i.e. technologie en performance standaards, technologieonderzoek en ontwikkelingsafspraken, sectorale verplichtingen, S-CDM (Sectoraal CDM) en SD-PAMs (Sustainable Development Policies & Measures), en analyseert de sterke en zwakke punten van de benaderingen. Daarnaast analyseert dit rapport in meer detail een bottom-up benadering voor de definitie van nationale emissie doelstellingen, de zogenaamde mondiale Triptych approach, en vergelijkt deze benadering met meer top-down benaderingen (Multi-stage (MS) en Contraction and Convergence(C&C)) op basis van een kwantitatieve en kwalitatieve analyse. Dit leidt tot de conclusie dat bottom-up benaderingen waardevolle componenten kunnen zijn van een toekomstig klimaatregime, maar dat ze geen volledig of volwaardig alternatief kunnen vormen voor kwantitatieve verplichtingen (emissieplafonds), daar ze minder zekerheid geven over de milieueffectiviteit van klimaatbeleid. In vergelijking met Multi-stage en de C&C top-down benaderingen biedt de mondiale Triptych benadering de mogelijkheid van vroege deelname van de ontwikkelingslanden zonder het risico van “hot air”, zoals onder C&C, en vermijdt de noodzaak om de niet-Annex I op te splitsen zoals bij Multi-Stage. Echter, door de complexiteit en data-intensiviteit van de Triptych benadering zijn er substantiële implementatieproblemen te verwachten in de minst ontwikkelde ontwikkelingslanden als gevolg van hun gebrekkige institutionele en technische capaciteiten. Het lijkt beter om deze landen in eerste instantie uit te sluiten, en hen te enthousiasmeren voor het op zich nemen van niet-bindende kwantitatieve verplichtingen.

Abstract

This report analyses a number of alternative, bottom-up approaches, i.e. technology and performance standards; technology Research and Development agreements, sectoral targets (national /transnational), sector based CDM, and sustainable development policies and measures (SD-PAMs). Included are technology and performance standards; technology, research and development agreements, sectoral targets (national /transnational), and sector-based (CDM), and sustainable development policies and measures (SD-PAMs). A more bottom-up approach for defining national emission targets, the so-called Triptych approach is also explored and compared with more top-down types of approaches (Multi-Stage and Contraction & Convergence) based on a quantitative and qualitative analysis. While bottom-up approaches are concluded as being valuable components of a future climate regime, they, in themselves, they do not seem to offer a real alternative to emission reduction and limitation targets, as they provide little certainty about the overall environmental effectiveness of climate policies. In comparison with Multi-stage and the C&C approaches, the global Triptych approach offers the opportunity of early participation by developing countries without the risk of creating large amounts of surplus emissions as in C&C; in using the approach we also avoid the need for dividing up the non-Annex I countries as in Multi-Stage. However, there will be substantial implementation problems related to the institutional and technical capabilities required. Thus it would seem better to exclude the least developing countries and have them first participate in some of the alternative bottom-up approaches.

Contents

Samenvatting

Wanneer na 2012 ontwikkelingslanden ook verplichtingen op zich zouden nemen, is de benadering zoals momenteel onder het Kyoto Protocol met kwantitatieve verplichtingen (absolute emissieplafonds) waarschijnlijk niet meer algemeen aanvaardbaar voor alle landen. Ten gevolge van de toenemende diversiteit van de betrokken landen, lijken alternatieve bottom-up benaderingen meer voor de hand liggend. In dit rapport bekijken we een aantal in de literatuur geopperde alternatieve bottom-up benaderingen om inspanningen vorm te geven, i.e. technologie en performancestandaards, technologieonderzoek en ontwikkelingsafspraken, sectorale verplichtingen (nationaal/ transnationaal), S-CDM (Sectoraal CDM), SD-PAMs (Sustainable Development Policies and Measures) en Relatieve emissieplafonds, en proberen we de sterke en zwakke kanten van de verschillende benaderingen aan te geven.

Daarnaast analyseert dit rapport in meer detail een bottom-up benadering voor de definitie van nationale emissiedoelstellingen, de zogenaamde mondiale Triptych-benadering, en vergelijkt het rapport de resulterende emissiereducties en kosten van deze benadering met die van meer top-down-achtige benaderingen (Multi-Stage en Contraction & Convergence (C&C)). Naast de kwantitatieve analyse is op basis van een multi-criteria analyse (milieucriteria, politieke criteria, economische criteria, institutioneel-technische criteria en algemene beleidscriteria) ook een kwalitatieve beoordeling gemaakt.

Het rapport concludeert dat bottom-up benaderingen waardevolle componenten kunnen vormen van een toekomstig klimaatregime, maar dat ze geen echt alternatief vormen voor kwantitatieve verplichtingen (emissieplafonds), omdat ze minder zekerheid bieden over de milieueffectiviteit van klimaatbeleid. In vergelijking met de Multi-Stage en de C&C benadering biedt de mondiale Triptych-benadering de mogelijkheid van vroege deelname van de ontwikkelingslanden zonder het risico van “hot air”, zoals onder C&C. Het vermijdt de noodzaak om de niet-Annex I op te splitsen zoals bij Multi-Stage. Echter, door de complexiteit en data-intensiviteit van de Triptych benadering zijn er substantiële implementatieproblemen te verwachten voor de minst ontwikkelde ontwikkelingslanden als gevolg van hun gebrekkige institutionele en technische capaciteiten. Het lijkt beter om deze landen in eerste instantie vrij te stellen, en hen te stimuleren deel te nemen op basis van bepaalde bottom-up benaderingen.

Summary

If future climate change commitments were to be extended to other countries, the approach adopted under the Kyoto Protocol with fixed national emission targets probably is no longer general acceptable for all countries. Considering the increasing diversity of countries concerned, approaches defining commitments in a more bottom-up way may be more appropriate. In this report then we will look at a number of alternative, bottom-up approaches for defining and differentiating commitments and try to identify their strengths and weaknesses. Included approaches are technology and performance standards; technology, research and development agreements, sectoral targets (national /transnational), and sector-based CDM (S-CDM), and sustainable development policies and measures (SD-PAMs).

This report also explores a more bottom-up approach for defining national emission targets, the so-called Triptych approach. In a quantitative analysis the regional emissions reductions and abatement costs resulting from the Triptych approach are compared with those of more top-down approaches (Multi-Stage and Contraction & Convergence (C&C)). In addition, we performed a qualitative multi-criteria evaluation of the Triptych approach and the two top-down approaches, taking into account environmental, economic, political and technical and institutional considerations. While bottom-up approaches are concluded as being valuable components of a future climate regime, we conclude that they do not seem to offer a real alternative to a climate regime defining quantified emission reduction and limitation targets, as they provide little certainty about the overall environmental effectiveness of climate policies. However, they offer particularly interesting opportunities for additional components of a future climate regime and for defining contributions of developing countries to mitigation and for enhancing the integration of climate policies in other areas of policy making, promoting sustainable development.

In comparison with Multi-stage and the C&C approaches, the global Triptych approach offers the opportunity of early participation by developing countries without the risk of creating large amounts of surplus emissions as in C&C; in using the approach we also avoid the need for dividing up the non-Annex I countries as in Multi-Stage. However, there will be substantial implementation problems related to the institutional and technical capabilities required. It therefore would seem better to exclude the least developing countries and have them first participate in some of the alternative bottom-up approaches.

1 Introduction

1.1 Rationale

In 1997, during the Third Conference of Parties (CoP3) in Kyoto, agreement was reached on binding quantitative emission targets for the Annex I countries, which would lead to a reduction in CO_2-equivalent emissions of 5.2% in the 2008-2012 period compared with base-year levels (UNFCCC, 1998). This current climate regime can be characterised as a top-down regime, imposing greenhouse gas emission targets on a country level and leaving the details of implementation to the countries themselves, even though certain mechanisms to increase cost-effectiveness have been introduced - notably international emissions trading and the Clean Development Mechanism.

Future commitments could well be rather different from those made under the Kyoto Protocol for the 2008-2012 period. There are two main reasons for this. First, to enhance the effectiveness of the climate regimes, there is a need to broaden the group of countries taking on (quantified) emission reduction or limitation commitments beyond the group of developed countries. The increase in the diversity of the group of countries in terms of their economic, technical and institutional capabilities will make it more difficult to agree on the same type of commitments. Second, there are also signals from some developed countries on the appropriateness of post-Kyoto regimes being based on the targets and timetables adopted under the Kyoto Protocol. The US decided not to ratify the Kyoto Protocol and instead adopted an alternative, domestic, approach based on voluntary, relative emission targets, and the promotion of research and development on new technologies.[1] In Japan, the Ministry of Industry and Trade (METI) also indicated considering other types of commitments than fixed binding targets and timetables, although this is still under discussion (METI, 2004).

Both prior and subsequent to the negotiations on the Kyoto Protocol there were many proposals for differentiating mitigation commitments among countries. These came from both academic circles and from Parties to the UNFCCC (including Banuri *et al.* (1996); Reiner and Jacoby (1997); Jacoby *et al.* (1997; 1999), Rose *et al.* (1998); Ringius *et al.* (1998); Torvanger and Godal (1999), Berk *et al.* (2002), Depledge (2000); Philibert (2001); Babiker and Eckhaus (2002); Baumert *et al.* (2002); Evans (2002); den Elzen (2002); OECD/IEA (2002); Aldy *et al.* (2003a); Höhne *et al.* (2003), Müller *et al.* (2003); Philibert *et al.* (2003) and the German Advisory Council on Global Change (WBGU, 2003). Many of the approaches proposed or explored for defining future climate-change commitments, particularly from European scholars, have been top-down: i.e. allocating emission targets on the basis of criteria and rules for allocating emission allowances. See examples in Evans (2002); Höhne *et al.* (2003), den Elzen (2002) and the German Advisory Council on Global Change (WBGU, 2003). These proposals focus mainly on the differentiation aspects of future action. In contrast, other proposals, particularly from US scholars, focus much more on bottom-up approaches – that is, where the emission reduction effort is not pre-defined but results from the policies and measures agreed upon. Here the focus is more on the type of commitments to be adopted than on the differentiation and stringency of efforts, as for example in Aldy *et al.* (2003a). This division in the literature reflects differences in political context. The European Council (1996) adopted as its long-term climate objective, a global-mean temperature change that would not exceed 2 degrees Celsius with respect to the pre-industrial level, and focusing on deducting its implications for short-term action. In contrast,

[1] Although it remains unclear if any future American administration would actually propose intensity targets for future climate commitments.

climate change policy in the USA is mainly debated from an economic perspective with a focus on cost-benefit analysis and avoiding negative economic impacts from climate policies.[2]

Notwithstanding these different foci in the academic debate between mainly European and American scholars in the negotiations on the Kyoto Protocol, this difference has been less clear-cut. In fact, in the early negotiations on the Kyoto Protocol it was the EU that was much in favour of adopting (binding) common policies and measures, while the USA preferred more flexible targets and a timetable approach. One bottom-up type of approach – to the differentiation of commitment – is the so-called Triptych approach (Blok *et al.*, 1997). This approach, which has played as special role in the EU was successfully applied under the Dutch EU presidency during the preparations for the Kyoto Protocol negotiations. It was used for both determining the negotiation position of the EU and for assessing a possible internal differentiation of efforts. Since then, several academics have explored a global application of this approach for defining post-Kyoto commitments (Groenenberg, 2002). this Triptych approach combines features of bottom-up approaches to defining commitments with more top-down approaches to defining national commitments. It is particularly interesting to compare it with typical top-down approaches to differentiating commitments.

1.2 Aim and outline of the report

Here we will review and evaluate the strengths and weaknesses of various proposals for bottom-up approaches to define and differentiate future mitigation commitments. We will also evaluate the implications of a global application of the Triptych approach, and compare its outcomes with those of top-down approaches, addressing the following research questions:

1. What bottom-up approaches have been proposed in the literature and in policy circles, and what are their strengths and weaknesses?
2. How do the results of globally applying the Triptych approach compare with top-down approaches for differentiation of post-Kyoto commitments?
3. How does the Triptych approach score on various policy-relevant criteria compared with other approaches?
4. What may the contribution be of bottom-up approaches to future climate policy regime?

To answer these questions we will start by defining precisely what we mean by bottom-up approaches, considering that in the context of future climate change regimes different definitions are used. This will be followed by an overview of some bottom-up approaches for defining and distributing future climate change commitments proposed in the literature and policy circles. We particularly discuss commitments on a sectoral or technology basis, research and development agreements, sectoral targets, and new proposals on the Clean Development Mechanism (Chapter 2). We will then describe a global application of the Triptych approach (Chapter 3) followed by a quantitative implementation and evaluation of the implications of the Triptych approach in terms of the allocating emission reductions. The FAIR 2.0 model (Framework to Assess International Regimes for the distribution of commitments) is described in Chapter 4 of Den Elzen and Lucas, 2003) (www.rivm.nl/fair). We will also compare the results of the Triptych approach with other approaches, notably the Contraction & Convergence and Multi-Stage approaches. And finally, we will evaluate the various approaches on the basis of the various policy criteria

[2] Interestingly, in the negotiations on the Kyoto Protocol this difference has been less clear cut. In fact, in the early negotiations on the Kyoto Protocol it was the EU that was much in favour of adopting (binding) common policies and measures, while the US preferred a more flexible targets and time tables approach.

(Chapter 5). We conclude with some overall observations related to the above-mentioned research questions (Chapter 6).

Part of this report will also be published as part of the report “Beyond Climate Options for broadening climate policy”, which present the overall results from the project Options for 2012 Climate Policies and International Agreements.

2 Proposals for bottom-up approaches to defining climate change commitments

2.1 Definitions of bottom-up approaches

Since the literature on climate commitments is not always consistent in defining the term, “bottom-up approach”, we would like to clarify here our what we consider “bottom-up approaches” to defining mitigation commitments to be before reviewing the proposals. We have chosen to do this by presenting three different interpretations of the bottom-up approach to climate regimes: the approach to regime development, the approach to types of commitments and the approach for differentiating national targets.

1. Bottom-up approach to regime development: multilateral versus coalition approach

One definition refers to the development characteristics of the climate regime. Here, a fully multilateral regime based on an extension of the UNFCCC and Kyoto Protocol (UN approach) is considered a top-down approach, while a bottom-up approach consists of regimes based on coalitions of like-minded parties (“coalitions of the willing”) or regimes at the regional level (Egenhofer and Fujiwara., 2003). This bottom-up approach is is often promoted as more efficient than the UNFCCC approach and also associated with a so-called pledge-based approach towards defining commitments: i.e. the contribution of the coalition parties consists of pledges made by participating countries, reflecting each country’s’ “willingness to pay”, and is not pre-determined by any conceived need for action or burden-sharing rules.

2. Bottom-up approach based on types of commitments: commitments defined by a set of (common) policies and measures

Another more common definition of bottom-up approaches to defining mitigation commitments is related to the characteristics of the commitments adopted. Here a distinction is made between:

Output commitments – are, for example, limits on the emissions of greenhouse gases that may not be exceeded. These are known as commitments related to *results achieved.*

Input commitments – are, for example, agreements about Policies And Measures (PAMs) that must be implemented. These are known as commitments related to *conduct* (Aldy *et al.*, 2003a; Bodansky, 2003; OECD/IEA, 2002). Approaches focusing on this type of commitments can then be considered as bottom-up in nature.

Such bottom-up commitments can be defined both at the national and sectoral levels. The literature documents various proposals for defining commitments in other ways than national emission targets. These include:

- technology and performance standards e.g. energy-efficiency standards (e.g. Barrett, 2001; Edmonds and Wise, 1998;1999; Tol, 2002);
- technology, research and development incentives (e.g. Barrett, 2001; Edmonds and Wise, 1999, Buchner *et al.* (2003);
- sectoral targets and sectoral CDM (e.g. Samaniego and Figueres (2002);

- financial measures, including subsidies and government-funded investments (e.g. Schelling, 2002);
- taxes (e.g. Cooper, 2001; Nordhaus, 2002);
- Sustainable Development Policies And Measures (SD-PAMs) (Winkler *et al*., 2002).

3. Bottom-up approach for distributing national targets

In some studies bottom-up approaches to defining mitigation commitments refer to climate regimes where national (emission) targets are not determined and differentiated among countries on the basis of rules for the allocation of an overall emission reduction burden or allowed emissions. Rather, the national efforts to emission control are added up . In these approaches national emission targets commitments are defined on the basis of a bottom-up assessment of feasible and acceptable measures, taking into account different national circumstances related to economic structure and potential for technical change. Examples of such bottom-up approaches are the (global) Triptych approach (Groenenberg, 2002), and the Multi-sector convergence approach (Sijm *et al.*, 2001).

In defining future climate commitments here we will focus on definitions 2 and 3, starting with an evaluation of proposals for bottom-up types of commitments. Next, we will look at Triptych approach as a typical example of a bottom-up approach for defining national emission targets.

2.2 Proposals for defining climate change commitments outside national emission objectives

In this section we will describe and evaluate the following proposals for defining climate change commitments in terms other than national emission objectives:

- technology and performance standards;
- technology Research and Development agreements;
- sectoral targets (national /transnational);
- sector based CDM, and;
- sustainable Development Policies and Measures (SD-PAMs).

Technology and performance standards

Instead of focusing on emissions, international commitments can also relate to the use of common technology standards, like energy efficiency standards for appliances, residential insulation levels, or the prescribed use of low or zero-carbon technologies, such as a minimum share of renewable energy in energy production. These commitments could also set minimum standards for the energy efficiency of industrial production processes.

This approach is particularly favoured by Barrett (2001), who considers it an alternative to the targets and timetable approach adopted under the Kyoto Protocol. The technology standards approach should challenge the poor incentives for compliance and participation in the Kyoto Protocol. It should also be largely self-enforcing because, if enough countries adopt the standards, other countries and their industries will tend to follow common standards to ensure market excess, economies of scale in production and network effects. Common technology standards should also help in realising an international level-playing field and provide incentives for investments in climate-friendly technologies. As a successful example of the use of technology standards, Barrett refers particularly to the control of oil pollution from ships by the use of technology standards for oil tankers within the MARPOL[3] convention. Shipping companies will be more prone to adopt these standards to ensure access to harbours. Another example is the regulation of noise standards for aeroplanes induced by airports in response to local noise problems. The proposal also includes agreements for common funding of climate-friendly research and development (R&D) (see below).

A more specific proposal for an international agreement on international technology standards was made by Edmonds (1999) and Edmonds and Wise (1999). They propose an agreement that would require any new fossil-fuel electric power plant or synthetic fuels plant installed in industrialized countries after 2020 to capture and sequester its CO_2 emissions. Developing countries would be required to do the same when their per capita income rises to the average 2020 income level for industrialized countries in purchasing power parity (PPP[4]) terms.

Tol (2002) proposes an alternative technology protocol based on Best Available Technologies (BAT) standards. The protocol would specify both the speed at which these BAT standards would progress; inferior technologies would also need to converge to that, and – as in Edmonds' proposal – would only apply to countries sufficiently rich to adopt these standards. The progress of BAT standards would be subject to repetitive negotiations. Such an approach would have the advantage that the costs of emission reductions would be more predictable and be robust enough to withstand economic variability. Another advantage is the emphasis this protocol places on improving technology (a positive aspect) rather than reducing emission (a negative aspect).

At the national level, technology and performance standards, particularly mandatory energy-performance standards (MEPS) for household appliances and insulation standards for buildings, have helped to induce consumers to use more-efficient technologies (OECD, 2003). For these sectors, standards have proved more effective than price instruments. However, the use of technology standards for industrial processes is much more controversial. Technology standards, both national and international, have a number of drawbacks, particularly for heavy industry and energy production (Grubb *et al.*, 2001; OECD, 2003; Bodansky, 2003). Drawbacks are that:

- since governments do not accurately know which technologies are the most cost-effective, technology standards may be more costly than market-based instruments; moreover, they do not provide an incentive for further improving performance-regulated technologies beyond the standard (like a carbon tax would do);
- while technology standards may create conditions for exploiting economies of scale, they can also result in lock-in effects to technologies that may prove to be less promising on the long term, and hinder future innovation;
- national circumstances may affect the feasibility of meeting certain standards, such as options for switching to other energy resources, and thus carry unbalanced cost implications for industries in different countries;

[3] The International Convention for the Prevention of Pollution from Ships (MARPOL). The Convention was adopted on 2 November 1973 at IMO and covered pollution by oil, chemicals, harmful substances in packaged form, sewage and garbage. It includes regulations aimed at preventing and minimizing pollution from ships - both accidental pollution and that from routine operations, layedd down in various protocols. (see: www.imo.org)

[4] GDP levels of different countries are normally compared on the basis of conversion to a common currency using Market Exchange Rates (MER). However, this is known to underestimate the real income levels of low-income countries. Therefore, an alternative conversion has been developed on the basis of purchasing power parity (PPP). Here, we have usually used PPP-based GDP estimates; however, MER-based estimates for comparison are used where required.

- regulation of specific technologies may be very sensitive to political influence by the interest groups affected (e.g. the fossil-fuel industry, which opposes the phasing out of coal-based energy production);
- the use of technology standards to sufficiently reduce the level of greenhouse gas (GHG) emissions may require a too large and complex set of agreements to be negotiable;
- while the non-discriminatory use of product standards has been generally accepted under World Trade Organization (WTO) trade rules, the use of process-related (industrial production) standards in regulating trade is much more controversial and likely to result in trade conflicts with third parties. Developing countries, in particular, are likely to resist production standards out of fear of being used as a tool of protectionism, with a consequent loss of competitiveness among their industries.

Müller *et al.* (2001) thus concluded that “an approach based purely on technology standards may be unworkable, and at best that it would be a poor and ineffective – and potentially highly inequitable – substitute for an international regime that focuses upon the actual problem, namely greenhouse gas emissions.”

More generally, the negotiations on the Kyoto Protocol have shown much resistance to adopting specific commitments on policies and measures. During the negotiation of the Kyoto Protocol, the European Union pushed for the inclusion of commitments related to policies and measures. But due to strong resistance from the United States, the Protocol eventually included only an illustrative list of possible policies and measures, without requiring parties to adopt them. More recently, a proposal was made by the EU during the World Summit on Sustainable Development that all countries commit themselves to the target of realising some agreed percentage of renewable energy sources in their primary energy supply. This met opposition from both developed countries and most developing countries, which considered the target too constraining.

Technology research and development agreements

One alleged limitation of the Kyoto Protocol and its mechanisms is its short-term focus on cost-effective mitigation (e.g. Berk *et al.*, 2001; Sandén and Azar, 2004). For meeting the long-term objective of the Climate Convention for stabilising GHG concentrations, global emissions will eventually have to be sharply reduced, that is, by more than 60% (IPCC, 2001a). This poses an enormous technological challenge because of the projected increase in the world energy demand (Hoffert *et al*., 1998, 2002). It has been argued that this will require major investments in the development and application of new breakthrough technologies (Edmonds, 1999), while energy R&D investments have declined the last few decades (Margolis and Kammen, 1999; OECD, 2003). This view is also reflected in the recent technology initiatives of the Bush Administration, which focuses on R&D on a hydrogen-based energy system, combined with carbon-sequestration technologies, in collaboration with a group of developed and developing countries, called the International Hydrogen Initiative (White House, 2002; USDOE, 2002; 2004).

Barrett (2001) has proposed the idea of international technology research and development agreements as the “push” component to his proposal for agreements on international technology standards (the “pull” complement). These agreements should consist of common research efforts for the development of climate-friendly technologies, particularly in the area of electric-power production and transportation.

Countries would commit themselves to a financial contribution to these research programmes, with contributions differentiated according to both ability and willingness to pay, which could be set according to the United Nations scale of assessments. To provide incentives for participation, each country's contribution to the collaborative effort would be contingent on the total level of participation, while the fruits of the R&D efforts would be shared among the participating countries (and its industries) only (for example, through shared patents or exemption from royalties from licences). Sandén and Azar (2004) make a simpler proposal by suggesting all countries agree on implementing an R&D carbon levy of 1 US dollar per tonne of carbon. This would raise revenues corresponding to US $6 billion, i.e., almost the entire OECD public investments in energy research.

Successful international commitments to provide funding for international co-ordinated research and development are not unprecedented, as in the case of space exploration (e.g., the international space station) or research on nuclear fusion research and agriculture (Consultative Group on International Agricultural Research). While international R&D agreements would supplement the already existing international co-operation on R&D in (energy) technologies, particularly as part of the IEA's Implementation Agreements, it might help counter the trend of decreasing rates of government and private investment in energy-related R&D (OECD, 2003). Moreover, international R&D programmes can also enhance the transfer of new climate-friendly technologies to developing countries.

However, there are also some major limitations, as outlined below, to international R&D agreements as a means for controlling greenhouse gas emissions:

- For example, in agreements on technology standards, governments may not support the technologies; for this reason Sandén and Azar propose a strategy of technology diversity;
- For new, more-costly technologies to enter the market, governmental support for R&D will have to be supplemented by policies creating the market opportunities that enable large private investments in the development and applications of these new technologies. This will require either technical regulations (e.g., MEPS), mandatory shares of new technologies in production (e.g. renewables or carbon-free vehicles), niche market creation (e.g. by procurement programmes), subsidies, a carbon tax or an emission cap- and trade system;
- Without overall emission targets, large investments in new technologies may not result in real reductions in GHG emissions. While intensified international technological co-operation may reduce the emission intensity of production, it may also induce more economic growth, and in turn higher absolute emissions (Buchner *et al.*, 2003);
- A climate regime based on international R&D agreements may leave countries without the capacity to participate, like the least developed countries, empty-handed, although the growth in their emissions may be reduced due to technological spillover effects.

Overall, it seems that while technology research and development agreements may be valuable components of any future climate regime, the agreements in themselves offer no real alternative to a climate regime based on quantified emission reduction and limitation targets, particularly because their effectiveness is uncertain

Sectoral targets

Sectoral targets relate to three different types of commitments:
- national commitments in the form of emission targets or other types of commitments limited to specific sectors of the economy;
- transnational sectoral targets for limiting transboundary GHG emissions, and
- sectoral CDM, which is the extension of project-based CDM to the sectoral level.

The first two types of commitments are of particular interest for developing countries, while the international targets might, along with the first two, be relevant to the developed countries.

National sectoral targets may be related to the limitation or reduction commitments for levels of either GHG emissions or energy use (efficiency) and be defined as either absolute or relative (e.g. pursuit of emission intensity improvements). These types of commitments are particularly suitable for developing countries, since they offer countries the option of addressing GHG emissions in a step-by-step manner (Bodansky, 2003), starting with commitments for specific sectors or greenhouse gases instead of the entire economy and all six types of gases. Sectoral targets may focus first on sectors whose GHG emissions are best known, easiest to address given available technical capabilities and least demanding from a monitoring and implementation perspective. Generally, developing countries have less capacity to adequately monitor all greenhouse gases from all activities. Moreover, activities in some sectors, like energy production and manufacturing, may lend themselves better to limiting GHG emissions than other sectors, like agriculture. They provide more certainty about their ability to comply with such international commitments and costs involved. Sectoral targets may also allow developing countries to engage early in international emissions trading, at least on the basis of the activities in the relevant sector. This could provide a potential source of financing for emissions abatement and technology improvements. From an international perspective, sectoral commitments for developing countries with industries that compete on the international markets could also reduce the risks of leakage and ease the competitiveness concerns of developed countries (Aldy *et al.*, 2003b).

Sectoral targets also have their drawbacks (Aldy *et al.*, 2003b). For example:

- separate sectoral targets would prevent countries and companies from making trade-offs across sectors – i.e., expending more effort in a sector where emissions can be reduced more cheaply and less in another where reductions are more expensive;
- if substitutes to the products of the capped activity were to become available outside the sector, emission leakage to other sectors without targets might occur.

The net effect on emission leakage will depend on the positive impact a sectoral target has in reducing leakage from countries with economy-wide commitments and the negative impact on inter-sectoral emissions leakage within the country (Aldy *et al.*, 2003b).

Transnational sectoral commitments /target

A final option for sector-based targets would be international sectoral targets, defining commitments for specific sectors, such as civil aviation, steel production or automobile manufacturing. These commitments would be comparable to those under international technology standards discussed above and may consist of either overall emission limitation or reduction targets for the total sector, or process or product-related targets, like regulated minimum energy-performance standards or the use of low-emission technologies. These types of commitments would be particularly interesting for internationally oriented sectors with a fairly limited number of actors – i.e., those who would be able to collectively adopt sector-wide targets. An example of an international sectoral commitment is the agreement between the EU and the European Automobile Industry Association (ACEA) in 1998 to reduce CO_2 emissions to 140 g/km by 2008 and 120 g CO_2 by 2012. While this agreement sets voluntary targets and only covers the EU market, it could be upgraded to a worldwide agreement with more binding commitments. The incentives for adopting such targets could be the creation of new markets for innovative products (like hybrid cars), the desire to avoid being exposed to a diversity of climate policies and measures in various countries, and even to be exempted from other regulations (e.g. taxation).

The advantages of such international sectoral targets include:
- a high level of policy effectiveness due to the global application of policy measures;
- avoidance of emission leakage and disturbance of the international competitiveness of internationally oriented industries.

The limitations include:
- The approach can be used mainly for the industrial and transport sectors. Contrary to the proposal by Edmonds and Wise (1999) to set standards for power plants, it may not even include an important sector such as energy production. In contrast to industrial processes, energy production is far more dependent on local circumstances, such as resource availability. Moreover, the energy sector is much less internationalized (i.e. controlled by multi-national companies) than some major heavy industrial processes, thus limiting its general access to modern technologies. Other sectors such as agriculture, services and households are much less easily regulated by international sectoral standards because of the larger number of actors involved, and the greater diversity in circumstances of production and consumption. A harmonization of national PAMs is a much more feasible approach for these sectors.
- While worldwide voluntary agreements among international industries or with a group of the main industrialized countries (such as the US, EU, Japan and South Korea for the automobile sector) are well conceivable, it would be more difficult to directly link these to future international climate regimes. In this case, the sector commitments would become part of the international climate regime. A potential obstacle for this approach is the lack of willingness on the side of national governments to accept special international arrangements under the UNFCCC with private multi-national companies that would limit their national jurisdiction to regulate these actors.

Sector-based CDM (S-CDM)

One specific approach to adopting sectoral commitments might be the sector-based CDM approach (Samaniego and Figueres, 2002). This CDM is geared to building on the project-based CDM under the Kyoto Protocol, while avoiding a number of its limitations, related to scale (project boundary), institutional overhead and options for marketing emission reductions (emission trading instead of Certified Emission Reductions - CERs). Under the S-CDM, developing countries would have an incentive for developing regional, (sub)sectoral, cross-sectoral or even regional projects that may be the result of specific sustainable development policies, measure the additional emission reduction attained and sell these on the international emission trading market. Examples of such projects would be the modernization of a country’s cement or steel-production sector, conversion of coal-fuelled power plants to natural gas or reduction of emissions from the transportation sector.

In contrast to sectoral targets discussed above, S-CDM, like project-based CDM, would operate without legally binding commitments. As for project-based CDM, baseline emissions under “business-as-usual” policies would need to be established and internationally agreed upon in order to determine generated emission reductions. However, Samaniego and Figueres propose change the additional requirements for the S-CDM. Additionally, they should be based on the adoption of policies and measures instead of project investments. The S-CDM has a number of acclaimed advantages over the binding national or sector targets and project-based CDM (Samaniego and Figueres, 2002), as explained below:

- S-CDM it will fit in well with the present climate regime by building on existing instruments under the Kyoto Protocol and profiting from the learning experiences in developing countries with project-based CDM;
- S-CDM provides better incentives for developing countries to transform entire sectors and thus help developing countries engage in low-carbon intensive developing pathways;
- the voluntary nature of the S-CDM will be more acceptable to developing countries than binding sectoral targets, and reduce the risk of setting lenient targets that result in tropical hot air;
- CDM S-CDM will, in comparison with project-based approaches, be more cost-effective by reducing institutional transaction costs and economy-of-scale effects, while also enhancing the international cost-effectiveness of emission mitigation by enlarging the supply of emission reduction credits from developing countries.

The S-CDM is also likely to encounter implementation problems related to:
- limitations of the institutional capacity in developing countries to develop, properly implement and monitor S-CDM projects,
- the establishment of credible baseline projections, and
- risks of fraud and overselling of emission reductions.

Nevertheless, S-CDM would seem to be an interesting intermediate step that developing countries could take before adopting binding national emission limitation or mitigation commitments – in particular for more advanced developing countries with sufficient institutional capacity to properly implement such an approach.

Sustainable Development Policies and Measures (SD-PAMs)

Given the low priority of climate mitigation in developing countries, some authors from the southern countries have proposed an approach that does not focus on climate goals, but on development objectives and country-specific development needs. This is called the "sustainable policies and measures (SD-PAMs)" approach. It is a pledge-based approach, particularly advocated by Winkler *et al.* (2002), to developing-country participation in mitigating climate change. The SD-PAMs approach starts by examining development priorities and identifying how they could be met in a (more) sustainable way. This is done by back-casting possible pathways for development from a desired future state of development and identifying the most sustainable pathways. Next, synergies between sustainable development policies and climate change policies – those policies and measures that also contribute to the limitation of greenhouse gas emissions – are identified. Finally, the net impact of a basket of SD PAMs on the development of greenhouse gas emissions (and other sustainability aims) is quantified.

The approach can be formalized under the UNFCCC to allow developing countries to demonstrate their capacity to control climate change, as well as to obtain funding for "full agreed incremental costs" (Article 4.1, UNFCCC). Formalized SD-PAMs might be supported by the Global Environment Fund, via the Clean Development Mechanism (CDM) or Sectoral CDM (see below), and either the Special Climate Fund or the Least Developed Country Fund.

The SD-PAMs approach is comparable to the sector-CDM approach. Like the S-CDM approach, SD-PAMs would be able to overcome the limitations and disadvantages of a project-base approach. And like the S-CDM, it also promotes more coherent and consistent policies that reduce the risks of leakage inherent in a project-based approach. Even more than the S-CDM, it fits in with development priorities of developing countries and enhances the mainstreaming of environmental concerns in development policies and makes explicit use of synergies between economic and environmental policies. The voluntary nature and pledge-based approach provides certainty on costs of policies. Finally, the approach enhances the build-up of institutional capacity in developing countries, required before binding commitments can be adopted and participation in international emissions trading becomes feasible.

The approach also has its limitations and drawbacks. The environmental gains from the approach are uncertain. Generally, the effectiveness will depend on the level of funding, as there is a need to cover incremental costs. The approach may not be effective enough to meet more stringent long-term climate targets, particularly where large and advanced developing countries would maintain it and fail to adopt more binding and stringent climate targets over time. From an economic perspective, the focus on “no-regret” measures and the dependence on CDM and other funding could form a limitation to the use of the emission-reduction potential in developing countries by developed countries. Practically speaking, linking SD-PAMs approach to an S-CDM approach may not be as easy as suggested, as there will be much more stringent monitoring and verification requirements. This option will probably only be feasible for more-advanced developing countries.

Overall, the approach is particularly attractive for engaging developing countries in climate mitigation in a way that avoids some disadvantages of CDM projects and encourages the mainstreaming of climate concerns into becoming economic development policies. Given its limited environmental effectiveness, the approach would seem particularly useful as an intermediate stage in the adoption of binding targets by developing countries. For a summary of our assessment results on the strengths and weaknesses of the various bottom-up approaches so far, please refer to Table 1.

2.3 The Triptych approach and other proposals for bottom-up approaches for defining national emission commitments

The Triptych approach

One bottom-up approach that still defines national emission targets is the so-called Triptych approach. It is a method to share emission allowances among a group of countries, based on sectoral considerations. In the Triptych approach, originally three broad categories of emissions are distinguished: the power sector, the sector of energy-intensive industries and the “domestic” sectors. The selection of these categories is based on a number of differences in national circumstances raised in the negotiations that are relevant to emissions and emission reduction potentials: differences in standard of living, in fuel mix for the generation of electricity, in economic structure and the competitiveness of internationally-oriented industries.

Different criteria are used for the different sectors to calculate partial emission allowances. More specifically, Groenenberg (2002) prescribes convergence trajectories in each of the three energy-consuming sectors: convergence of energy efficiency in the energy-intensive industrial sector, convergence of GHG emission intensity in electricity production and convergence of per capita emissions in the domestic sector. Global long-term targets are defined for each of these variables. Improvement and transfer of technology will be necessary for ultimate achievement of these targets. The total calculated emission allowances add up to binding national emission allowances for each country. Only one national target per country is proposed, no sectoral targets, to allow countries the flexibility to pursue any cost-effective emission reduction strategy. An overview of the development of the Triptych approach is given in Box 1.

Table 1: Strength and weaknesses of different types of bottom-up commitments.

Type of Commitment	Strengths	Weaknesses
Technology standards	• More certainty on actions and policies • Easy to monitor • Certainty on costs • No disturbance of international competitiveness • Compliance based on market forces • Enhanced technological spill-over and transfer	• Uncertainty on environmental effectiveness • Rigid; leaves no policy choice • Not acceptable for DCs • Technically complex negotiations • Economically inefficient • No incentive for technological innovation /over-performing • Risk of technological lock-in • Risk of trade conflicts on process-related standards
R&D commitments	• Enhanced long-term perspective • Compensated for market failures • Enhanced technological capacity DCs	• Uncertainty on environmental effectiveness • Risk of selecting less effective or efficient technologies • Lack of market incentives to apply technologies
Sectoral targets (national / transnational)	• Easier to negotiate, implement and monitor • Policy effectiveness • Creates level playing field for international sectors • Option for link with sector base-CDM • Enhanced technological spill-over / transfer	• Definition problems • Need to separate sectors from national emissions and national jurisdiction • No account taken of different national circumstances • Economically less efficient • More carbon leakage if not globally applied • Compliance complicated
Sector-based CDM	• Fits-in with development priorities (of DCs) • More certainty about actions and policies • Certainty about costs • Use of policy synergies • Enhances institutional capacity DCs	• Uncertainty on environmental effectiveness • Economically not optimal • Difficult to link to IET • Complicates the CDM project • Difficult to compare efforts
SD-Policy and Measures	• Fits-in with development priorities (of DCs) • More certainty about actions and policies • Certainty about costs • Use of policy synergies • Enhances institutional capacity DCs	• Uncertainty on environmental effectiveness • Limited environmental effectiveness • Limited use of economic efficient potential • Financing via S-CDM will be complicated • Difficult to compare efforts

Apart from the Triptych approach, there have been other proposals for architectures with emission targets being defined bottom-up. These include:

Multi-Sector Convergence approach (MSC) (Sijm *et al.*, 2001). It combines features of the Contraction & Convergence and Triptych approach. In principle, it aims at a converge of per capita emission levels, but tries to account for differences in national circumstances that cause variations of per capita emission requirements among countries. It groups emission sources into seven sectors for defining national emission allowances (electric power generation, households, transportation, heavy industry, services, agriculture, and waste), but this grouping could be adjusted. For each of these sectors global convergence rates are defined on the basis of global trends in activity level and emission factors. National emission allowances result from combining the sectoral allowances.

Jacoby Rule approach. Another bottom-up approach for burden-sharing is the so-called "Jacoby rule", introduced by Jacoby *et al.* (1999) as an illustrative model of accession and burden-sharing. The basic principle behind this approach is the ability to pay. In contrast with the other approaches being analysed here, the regional emission allowances are not calculated by sharing the emission space of the global emission target profile using pre-defined burden-sharing rules, but by using a mathematical equation for calculating the emission allowances. The basis of this equation is that Parties only enter the international climate regime (and reduce their emissions) once they have exceeded a level of per capita welfare (a welfare "trigger"). Otherwise, they follow their reference emissions (unconstrained no-policy emissions trajectory). The emissions reduction is calculated on the basis of the difference between the per capita welfare income trigger level and a region's per capita welfare. Therefore, the total regional emissions are calculated from the bottom-up.

Emission Intensity Targets approach. Basically, it assumes that all regions adopt GHG intensity targets directly after the Kyoto Protocol period upon reaching a certain income threshold (den Elzen and Berk, 2003). This proposal is an extension of ideas developed by Philibert *et al.* (2003) and the Climate Change initiative of the Bush Admistration (White-House, 2002). However, this approach includes rules for differentiating the level of improvements in GHG intensity. These are related to levels of per capita income and initial carbon intensity. In this way, the differentiation of commitments is based both on the ability to *pay* as well as (initial) national circumstances. Western Europe and Japan, both OECD regions that are already relatively efficient and therefore do not lend themselves to much improvement, are assumed to improve at a rate of 50% of the maximum rate. In the default calculations this approach also assumes a 50% higher maximum de-carbonization rate for the FSU, since the emission intensity of this region is much higher compared with other regions. For the emission intensity level, it is assumed that *all* other regions will ultimately converge to the level of these - most efficient - regions and then follows similar rates of improvement.

These bottom-up approaches are not evaluated here. For an evaluation of these approaches see den Elzen *et al.* (2003) and den Elzen and Berk (2003).

Box 1: Overview of the development of the Triptych approach

Original Triptych (1997) – The Triptych approach was originally developed at the University of Utrecht (Blok *et al.*, 1997).The approach reviews energy related CO_2 emissions under the European Union's situation and was initially designed to answer the question on how the European Union's joint emission reduction target should be shared among its Member States in 2010. The Original Triptych approach highlights three sectors: 1) electric power generation; 2) internationally orientated, energy-intensive sectors of industry (or heavy industry); and 3) households.

Global Triptych (2001) – The Global Triptych approach refers to an expansion of the Original Triptych approach to 50 countries, based on the work of Groenenberg *et al.* (2001). There are some significant methodological changes from the Original Triptych approach (the industrial and electricity scenarios), but focus remains on CO_2 emissions on the three main sectors: the electric power generation, heavy industry and households. Furthermore, this approach is based on reviewing differentiation commitments for the year 2015.

Global Convergence Triptych (2002) – The Extended Global Triptych, based on the work of Groenenberg (2002) builds on the Original and Global Triptych approaches by including Kyoto GHG emissions other than CO_2 (CH_4, N_2O, HFCs, PFCs and SF_6) and reviews the emissions in three other sectors: fossil-fuel production, agriculture, and Forestry. The emission allowances are calculated by applying different rules in the different sectors. The rules are convergence trajectories in each of the three energy-consuming sectors: and convergence of per-capita household emissions, convergence of energy efficiencies in the energy-intensive industrial sector, and convergence of emission intensities in electric power generation. It is based on reviewing commitments for the year 2020.

Global Triptych – ECOFYS (2003) –The ECOFYS' Extended Global Triptych is largely built on Groenenberg's Global Triptych approach, but extends it to include other non-CO_2 greenhouse gases and three other sectors: fossil fuel production, agriculture, and forestry, as described in Höhne *et al.* (2003).

Global Triptych – FAIR 2.0 (2003) – The RIVM has also implemented the Extended Global Triptych approach above on a regional scale in its FAIR model (den Elzen, 2002; den Elzen and Lucas, 2003). The population and economic growth trajectories are now based on the implemented IPCC SRES scenarios, instead of the exogenous trajectories as assumed in Groenenberg (2002). Other minor differences exist with respect to data sources used, and deforestation is not taken into account in the final calculations of the future commitments. This approach is reviewing differentiation commitments for the year 2010-2050.

3 Description of the Triptych approach versus other top-down approaches

This Chapter describes briefly the methodology of the Triptych approach as implemented in the FAIR 2.0 model (section 3.1), and two main top-down approaches: the Multi-Stage approach and Contraction & Convergence (section 3.2). The Contraction & Convergence approach is selected here, as it is the most widely known, and has much appeal in the developing world. The Multi-Stage approach is also selected here, as it best satisfied the various types of criteria (environmental, political, economic, technical, institutional) in the multi-criteria evaluation of various approaches of Höhne *et al.* (2003) and den Elzen *et al.* (2003).

3.1 The Triptych approach

1. The internationally oriented energy-intensive industry
Internationally oriented energy-intensive industry covers internationally oriented industrial enterprises, where competitiveness is determined by the costs of energy and energy efficiency. In the approach the sector covers the following six sub-sectors: iron and steel, chemicals, pulp and paper, non-metallic minerals, non-ferrous metals and energy transformation. The energy transformation sector includes petroleum refining, the manufacture of solid fuels, coal mining, oil and gas extraction and any energy transformation other than power production. GHGs emitted from this sector compromise combustion-related emissions of CO_2, CH_4 and N_2O, as well as process emissions of N_2O, mainly from production of nitric and adipic acid, and polyfluorinated compounds (PFCs), from the production of aluminium.

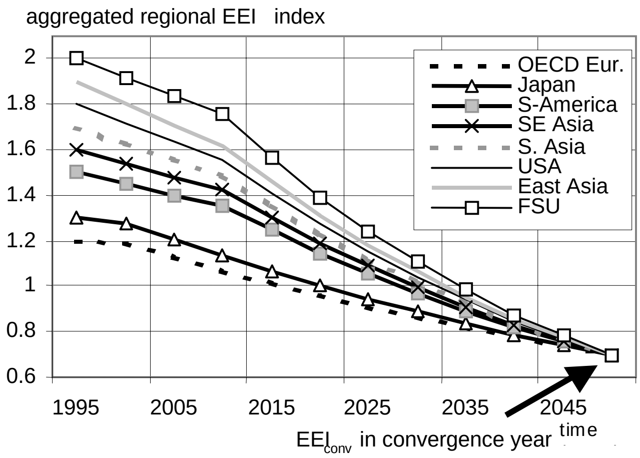
Compared with other economic sectors, heavy industry generally has a relatively high energy use per value added and in most regions also high GHG per value added. Countries with a large share of heavy industry will therefore have relatively higher GHG emissions per unit of GDP than countries that concentrate primarily on light industry and services. The international character of this sector implies that countries lacking sizeable energy-intensive industries themselves import goods from other countries and thus indirectly benefit from other countries' efforts in this sector.

Apart from international specialization, the share of heavy industry in the overall economy is generally related to a country's level of development. Initially, at a low level of development, a country's share is low, but with increasing development its share tends to increase at the expense of primary sectors (agriculture, mining). Only at later stages of development does the share of energy-intensive industry in the total economy tend to decline again with the growth in the share of the service sector.

The regional GHG emission allowances are calculated on the basis of:

1. *Future growth of production* on the basis of a income-differentiated growth rates of per capita physical production as a function of per capita PPP income (in PPP-corrected 1995 US$ per capita) on the basis of historical trends (Groenenberg *et al.*, 2002);
2. *Improvement in the rate of energy intensity*. For the energy intensity of production (energy used per unit of production) levels a world-wide convergence in energy

efficiency levels, expressed in an aggregated Energy Efficiency Indicator (EEI)[5] (Phylipsen *et al.*, 1998), of all regions over time is assumed. The improvement rates depend on the initial (2010) values of the indicator, the year of convergence and the final convergence level, which is a fraction of the Indicator value under the best current practices or best available technologies (as illustrated in Figure 1).



Regions	1995-EEI:	eff (%/yr)
OECD Europe	1.2	1.7
Japan	1.3	1.9
Canada	1.3	1.9
Latin America	1.5	2.5
South East Asia	1.6	2.6
Middle East	1.6	2.6
Africa	1.6	2.6
South Asia	1.7	2.7
Oceania	1.7	2.4
Eastern Europe	1.7	2.4
United States	1.8	2.8
East Asia	1.9	2.9
Former Soviet Union	2.0	3.1

Figure 1: The convergence in the aggregated Energy Efficiency Indices (EEIs) by 2050 (reference case) to 70% the current reference level. The legend shows the 1995 Aggregated Energy Efficiency Indices (EEIs) at regional level (Groenenberg et al., 2002) and the calculated yearly energy-efficiency improvements in per cent per year for the convergence period.

2. The domestic sector

The domestic sector includes households, and the commercial, transportation, light industry and agricultural sectors. It includes non-CO_2 emissions, which account for about 16% of the total emissions. CH_4 and N_2O emissions relate to both combustion products and waste generated by this sector, the latter including emissions from landfills and wastewater treatment. Emissions of fluorinated gases are derived from a range of sources (semi-conductors, refrigeration, air conditioning equipment, fire extinguishers, and aerosol applications).

The regional GHG emission allowances are calculated on the basis of:

1. *Future growth of population size*, since they are determined by the number of people in dwellings, at workplaces and those needing transport, etc.
2. *Per capita domestic emission levels,* which converges to a common level of per capita domestic emissions.

3. The power-production sector

The power-production sector is treated separately because specific GHG emissions from power production vary to a large extent due to large differences in the share of nuclear power and renewables, and in the fuel mix in fossil fuel-fired power plants. The potential for cutting GHG emissions arising in this sector differs accordingly. Therefore fuel mix in

[5] The EEI index is defined as the ratio between the specific energy consumption (SEC) (energy consumption per tonne of product) for each region divided by a reference SEC level. The reference SEC is equal to the SEC with best current practices or best available technologies. Here, the SEC of a package of energy-intensive commodities is used instead of a single product. This results in aggregated EEIs for all regions, each representing a relative measure of the average efficiency of the energy-intensive industry in that specific region (Groenenberg *et al.*, 2002; Phylipsen, 2000).

power generation is an important national circumstance to take into account in the differentiation of commitments.

The regional GHG emission allowances are calculated on the basis of:

1. *Future growth in electricity consumption* is approximated by the weighted sum of the emission growth in energy-intensive segments of industry and the domestic sectors. Furthermore, the share of the two sectors in power consumption is assumed to remain constant in the future.
2. Improvement rate in emissions intensity. A convergence of greenhouse gas intensities of the electricity produced to low greenhouse gas intensity levels is assumed. This low intensity level is calculated on the basis of share of capacity based on renewable energy, natural gas and nuclear power, with a high conversion efficiency in total electricity production in the convergence year.

Besides these three main sectors, the emissions of non-CO_2 GHG emissions are calculated from fossil fuel production and agricultural sources (den Elzen and Lucas, 2003):

4. Fossil fuel production

Methane emission from coal mining, and from oil and gas production and distribution, amounts to only about 5% of total (2000) global GHG emissions; however, this amount can be reduced drastically by up to 95% below the 1995 levels. Since large reductions are already achieved in the baseline emissions (through efficiency improvements), we assume the emissions from this sector to be scaled with the ratio baseline emissions and triptych emissions from the three energy-consuming sectors. An additional reduction factor further reduces the emissions, reaching its maximum reduction in a target year.

5. Agriculture

The CH_4 and N_2O agricultural emissions are assumed to be linearly reduced by a final reduction level (in %), compared with their baseline emissions between a starting-year and target year.

Table 2: Main policy parameters of the Triptych approach.

1. Energy-intensive industry sector
- Growth rates of per capita production (income-dependent)
- Year of convergence Energy Efficiency Index
- Level of convergence Energy Efficiency Index

2. Domestic sectors
- Year of convergence of per capita domestic emissions
- Year of convergence per capita domestic emissions

3. Power production sector
- Year of convergence emission intensity
- Level of convergence emission intensity

4. Fossil fuel production
- maximum reduction factor
- Starting year and target year of maximum reduction factor

5. Agricultural emissions
- Reduction percentage compared with baseline emissions in a target year
- Starting year and target year for final reductions

3.2 Multi-Stage and Contraction & Convergence approaches

(1) The *Multi-Stage approach* is an incremental but rule-based approach to extend the present Kyoto Protocol regime, and consists of a system for a gradual broadening of the group of countries taking on quantified emission limitations and reduction objectives and deepening of their commitments over time (Berk and den Elzen, 2001).

(2) The *Contraction & Convergence* (C&C) approach assumes universal participation and defines emission allowances on the basis of a convergence of per capita emission allowances under a contracting global emission profile (Meyer, 2000).

The *Multi-Stage approach* consists of a system to divide countries into groups with different levels of efforts and types of commitments, or stages. The aim of such a system is to ensure that countries with similar circumstances in economic, developmental and environmental terms have comparable commitments under the climate regime. Moreover, the system defines when a country's level of commitment changes according to pre-determined rules related to a change in its circumstances.
The Multi-Stage approach thus results in an incremental evolution of the climate-change regime – i.e., a gradual expansion over time of the group of countries with commitments (Annex I), with countries adopting different levels and types of commitments according to participation and differentiation rules. The approach was first developed by Gupta (1998). Later, in Berk and den Elzen (2001) and den Elzen (2002), the approach was elaborated into a quantitative scheme for defining mitigation commitments under global emission profiles compatible with the UNFCCC objective of stabilising GHG concentrations. Den Elzen *et al.* (2004a; 2004b) developed a simpler case with some new types of participation thresholds. From this work we have focussed on of the most promising case. Here, the Multi-Stage approach is based on three consecutive stages for the commitments of non-Annex I regions beyond 2012. These are Stage 1 – no commitment (baseline emissions), Stage 2 – emission limitation targets (intensity targets) and Stage 3 – absolute reduction targets. Participation thresholds are used for the transition from Stage 1 to 2, and from Stage 2 to 3.

Participation thresholds are based on a Capability-Responsibility index. The index originates in the principles used by Criqui and Kouvaritakis (2000), and is defined as the sum of per capita GDP income (in PPP€1000 per capita), which relates to the capability to act, and of per capita CO_2-equivalent emissions (in tonnes of CO_2 per capita), reflecting historical responsibility for climate change. Because it combines variables of a different nature, this composite index should in principle be normalized or weighted. It happens, however, that a one-to-one weight combined with a normalization (to make it unit-less) produces satisfactory results. At any date, the index can simply be computed as the sum of GDP and of total GHG emissions, divided by the population of the region or country under consideration (Criqui *et al.*, 2003). Current (2000) index values vary widely among countries. They range from below 2 for West and East Africa, 4 for India and 8 for China to as high as 29 for the Enlarged EU and 25 for the USA.

For Stage 2, the intensity improvement targets are defined as a linear function of per-capita income level, and thereby relax the emission limitations for the low-income non-Annex I regions. A maximum rate is adopted to avoid de-carbonization rates that would outpace those of economic growth. In Stage 3, the total reduction effort[6] to achieve the global

[6] The difference in the remaining emissions, i.e. global emissions of profile minus the total emissions of all regions in Stage 1 and 2 at times t and t-1.

emission profile is shared among all participating regions on the basis of a burden-sharing key (here per capita emissions).[7] This key tends to result in a convergence of per capita emission levels, as mentioned in the pre-amble of the Marrakech Accords. It is assumed that all Annex I regions (including the USA)[8] are in Stage 3 after 2012.

Table 3: Main policy parameters of the simplified Multi-Stage approach.

- First participation threshold (Stage 1): Capability-Responsibility* index value
- Second participation threshold (Stage 2): Capability-Responsibility* index value.
- Income-dependent intensity targets (maximum de-carbonization rate)
- Burden-sharing key (stage 3: reduction stage)

* The Capacity-Responsibility index is defined as the sum of per capita income (in 1000€) and per capita CO_2-equivalent emissions (in tCO_2), using a one-to-one weighting combined with a normalization, to make it unit-less (Criqui *et al.*, 2003)

Contraction & Convergence - An alternative approach that would represent a major shift from the current Kyoto Protocol approach is the so-called "Contraction & Convergence" (C&C) approach (Meyer, 2000). Instead of focusing on the question of how to share the emission reduction burden as in the present Kyoto Protocol, this approach starts from the assumption that the atmosphere is a global common to which all are equally entitled, and focuses on sharing the use of the atmosphere (resource-sharing). More specifically, the approach defines emission rights on the basis of a convergence of per capita emissions under a contracting global emission profile. In the approach, all Parties participate immediately after 2012, with per capita emission permits converging towards equal levels over time. More specifically, over time, all shares converge from actual proportions in emissions to shares based on the distribution of population in the convergence year.

Table 4: Main policy parameters of the Contraction & Convergence approach.

- Convergence year
- Type of convergence: (a) linear convergence, or (b) non-linear convergence (rate of convergence)
- Cap on population (including, or excluding)

[7] The share of a region *r* in the total emission reduction is calculated as $X_{r} = (E_r * pcE_r)$ divided by the sum of X over all regions, with E_r representing the total emissions and pcE_r the per capita emissions. In this way, two regions with equal per capita emissions but different total emissions make the same relative reduction effort compared with their emissions.

[8] Obviously, there is no certainty that this will happen, but the same also holds for the assumption made in this analysis that the Kyoto Protocol will enter into force. However, it is hard to conceive any global climate regime compatible with stabilising GHG concentrations at 550 ppmv equivalent if the USA would were to decide to stay out even after 2012.

4 Quantitative analysis of the Triptych approach versus top-down approaches

This Chapter analyses the regional emission allowances and abatement costs for the reference cases of the Triptych approach, and the two top-down-approaches: the Multi-Stage and Contraction & Convergence approach compatible with stabilising the GHG concentrations at 550 and 650 ppmv CO_2-equivalent[9]. This Chapter starts with a more detailed description of the reference cases.

4.1 Reference cases

For the top-down approaches Multi-Stage and Contraction & Convergence we use the global GHG emission profiles that would lead to stabilization of 550 ppmv CO_2-equivalent in 2100 and 650 ppmv CO_2-equivalent in 2150, respectively, hereafter referred to as S550e and S650e (Box 2). The cases of the Multi-Stage and Contraction & Convergence for both profiles are described in detail in den Elzen *et al.* (2004a; 2004b), and correspond to the cases in the EU research project “Greenhouse gas reduction pathways in the UNFCC post-Kyoto process up to 2025” (Criqui *et al.*, 2003) (see Table 5). Here, the parameters of the reference cases are chosen in a way that the Annex I countries take the lead in the reduction efforts compared to the baselines, followed by the middle- and high income non-Annex I regions and, finally, low-income non-Annex I regions.

To allow for a comparison of the Triptych approach and the two top-down approaches, we have attuned the overall stringency of the commitments such that the total of all regional emission allowances is comparable with the global emissions of the profiles. Choosing the model parameters of the S550e case at the lower bound of the ranges of Groenenberg (2002) and for S650e the upper bound (Table 5) gives the best fit with the profiles (Figure 2). The resulting cumulative emissions differ less than 1.5% for the S550e profile and even less than 1% for the S650e profile for the period 2012-2050.

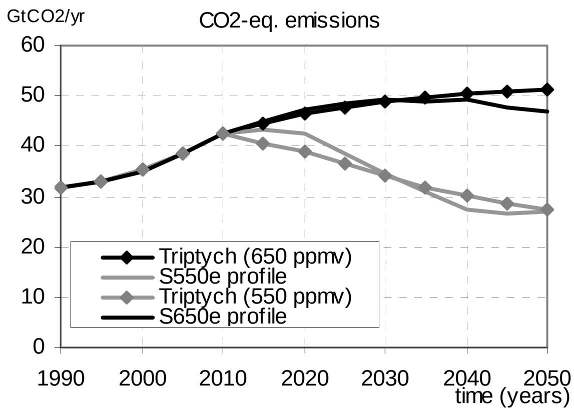


Figure 2: Global emission allowances for the Triptych approach aiming at stabilization of the CO_2-equivalent concentration at 550 ppmv and 650 ppmv (Triptych (550 ppmv) and Triptych (650 ppmv)) and the global emissions profile (S550e and S650e profile). Source: FAIR 2.0 model.

[9] The CO_2-equivalent concentration is a measure of radiative forcing of the set of the six Kyoto GHGs expressed in terms of the CO_2 concentration that would result in the same level of (additional) radiative forcing.

Box 2: The global emission reduction objective for stabilization of GHG concentrations at 550 and 650 CO_2-equivalent

In our analysis we use the Common POLES IMAGE baseline scenario (Criqui *et al.*, 2003; van Vuuren *et al.*, 2003) as the baseline scenario (Fig. 2). This scenario assumes a continued process of globalization, medium technology development and a strong dependence on fossil fuels. GHG emissions in this scenario increase from 35 $GtCO_2$-equivalent today, to more than 90 $GtCO_2$-equivalent in 2050 for the set of six GHGs considered in the Kyoto Protocol, which corresponds to a medium-level emission scenario when compared with the IPCC SRES emissions scenarios.[10] As a result, by 2100 the baseline reaches a GHG concentration of 930 ppmv CO_2-equivalent.

The baseline emissions are compared with two constrained GHG emission profiles, corresponding to a stabilization of total GHG concentration at a level of 550 ppmv CO_2-equivalent in 2100 and 650 ppmv CO_2-equivalent in 2150, respectively, hereafter referred to as S550e and S650e (Figure 3). These profile was developed with the integrated climate assessment model IMAGE 2.2 (IMAGE-team, 2001), as described in Eickhout *et al.* (2003). For the short term (up to 2012), the profile incorporates the implementation of the Annex I Kyoto Protocol targets (including banking of excess emission allowances) for the Annex I regions excluding Oceania (Australia) and the USA. The US follows the proposed greenhouse-gas intensity target (White-House, 2002), but this leads to emissions which do not significantly differ from their baseline emissions (van Vuuren *et al*., 2002). The Annex I region Oceania and the non-Annex I regions are assumed to follow their baseline emissions in the 1995-2012 period. It should be noted, however, that the flexibility in achieving the 550 ppmv stabilization is very limited as even under stringent reductions by 2020 the concentration will have already reached the 500 ppmv level, and absolute reductions of global emissions would be needed to avoid overshooting the target (Eickhout *et al.*, 2003). The emissions therefore already need to return to 1990 levels by 2030 as shown in Figure 3. The difference between the baseline scenario and the stabilization scenario is the global emissions reduction objective. For the S650e profile emission levels could peak later (around 2030) and at a higher level and would not have to be back to 1990 levels before 2070.

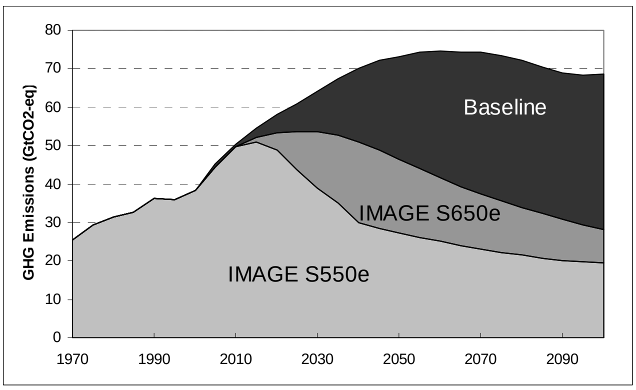


Figure 3: Global emission profiles for stabilising GHG concentrations at 550 and 650 ppmv CO_2 equivalent (S550e and S650e profile) and the baseline scenario (Eickhout et al., 2003). Source: IMAGE 2.2 model.

[10] The baselines and emission profiles are all expressed in CO_2-equivalent emissions, calculated using the emissions of the set of the six greenhouse gases covered under the Kyoto Protocol (i.e. carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6)) combined with the 100 year Global Warming Potentials (GWPs) (IPCC, 2001b).

Table 5: The reference cases of the regimes Multi-Stage (MS) and Contraction & Convergence (C&C) and Triptych (TT) for the S550e and S650e profile.

	Parameters	S550e profile	S650e profile
MS	• First participation threshold for stage 2	CR[a] index = 5	CR index = 12
	• Second participation threshold for stage 3	CR index = 12	CR index = 20
	• Intensity targets (stage 2)	Maximum of 3.0%/yr[b]	maximum of 2.0%/yr[b]
	• Burden-sharing key (stage 3)	Per capita emissions	Per capita emissions
C&C	• Convergence year	2050	2075
	• Type of convergence	linear	linear
	• Cap on population	No cap	No cap
TT	**1. Energy-intensive industry sector**		
	• Growth rates of per capita production	Income-dependent	Income-dependent
	• Year of convergence EEI*	2050	2075
	• Level of convergence EEI	0.5	0.75
	2. Domestic sectors		
	• Year of convergence of per capita emissions	2050	2075
	• Year of convergence per capita domestic emissions	1.5 tCO_2-eq/cap.yr	3.0 tCO_2-eq/cap.yr
	3. Power production sector		
	• Year of convergence emission intensity	2050	2075
	• Level of convergence emission intensity	125 gCO_2-eq/kWh	300 gCO_2-eq/kWh
	4. Fossil fuel production		
	• Maximum reduction factor	90%	50%
	• Starting year and target year of maximum reduction factor	2010-2050	2010-2075
	5. Agricultural emissions		
	• Reduction percentage compared to baseline emissions in a target year	35%	15%
	• Starting year and target year for final reductions	2010-2040	2010-2075

[a] CR = Capability-Responsibility; [b] maximum de-carbonization rate at 50% of 1990 Annex I pc PPP$-income; EEI = Energy Efficiency Index;

From bottom-up to top-down approach. For a full comparison without any differences among the profiles, the bottom-up approach for the domestic sector is finally adjusted here to a top-down approach. In this case the convergence in domestic per-capita emissions by 2050 accommodates the emission space available for domestic emissions under the global domestic emission ceiling. This domestic emission ceiling is equal to the difference between the ceiling for global CO_2-equivalent emissions for stabilization at 550 and 650 ppmv and the sum of the emissions allocated to the power and energy-intensive industry sector. This top-down approach results in more domestic emission allowances up to 2030 compared with domestic allowances under the bottom-up approach.

4.2 Regional emission allowances

The first step in the evaluation of the three approaches is a more general comparison of emission reduction levels for Annex I and non-Annex I regions. Later we will discuss in more detail the differences between the approaches for the different regions. Figures 4 and 5 depict the change in the emission allowances compared with the 1990 levels for ten aggregated Annex I and non-Annex I regions[11] for the S550e and S650e profile for two time horizons, short-term (2025) and long-term (2050). Regional emission allowances can

[11] Calculations were done at the level of 17 regions, i.e. Canada, USA, OECD-Europe, Eastern Europe, FSU, Oceania and Japan (Annex I regions); Central America, South America and Middle East and Turkey (middle- and high income non-Annex I regions); Northern Africa, Southern Africa, East Asia (incl. China) and South-East Asia (low-middle income non-Annex I regions); Western Africa, Eastern Africa and South Asia (incl. India) (low-income non-Annex I regions) (IMAGE-team, 2001).

also be compared with the corresponding baseline emissions. This provides much more information on the magnitude of effort required from the different Parties, and has a closer relation with the actual effort, although it is not immediately observable.
Table 6 provides information for the reductions compared with the baseline levels.

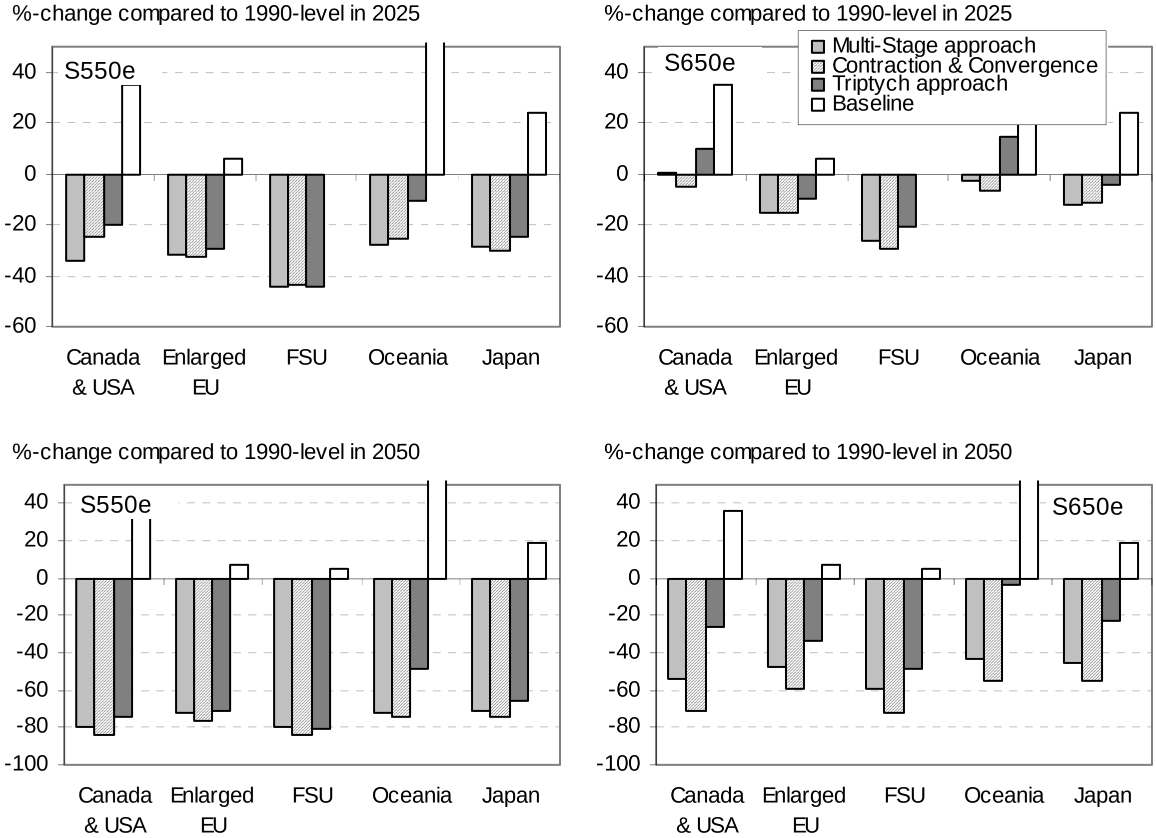


Figure 4: Comparison of the Annex I emission allowances for the three regimes explored for the S550e (left) and S650e (right) profile. Source: FAIR 2.0 model.

Annex I regions - Figure 4 show that the Annex I emission reductions are more influenced by the assumed emission profiles than by the regime options explored. More specifically, for each region the range of outcomes from the different approaches of the S550e profile do not overlap with the range of outcomes from the S650e profile. The Figure shows that for all Annex I countries reductions in emission allowances of at least 20-50% compared with the 1990-levels are necessary to achieve the 550-ppmv target in 2025, whereas for the 650-ppmv target this ranges from an increase of 10% to a reduction of 35% compared with 1990 levels in 2025. In 2050, the reductions are 40-90% (S550e) and 20-70% (S650e), respectively.

Non-Annex I regions - Table 6 gives the emission reduction efforts compared with the baseline emissions for the aggregated non-Annex I regions. The situations are generally more differentiated across non-Annex I regions than across Annex I regions. Over the medium term (2025), the low-income non-Annex I regions Africa and South Asia (including India) appear in all cases with much lower required reductions, while the middle- and high income non-Annex I regions Latin America and the Middle East have comparable reduction efforts as the Annex I regions. South-east and East Asia (including China) lie in an intermediate position, between both non-Annex I groups. Over the longer term, the picture becomes more mixed.

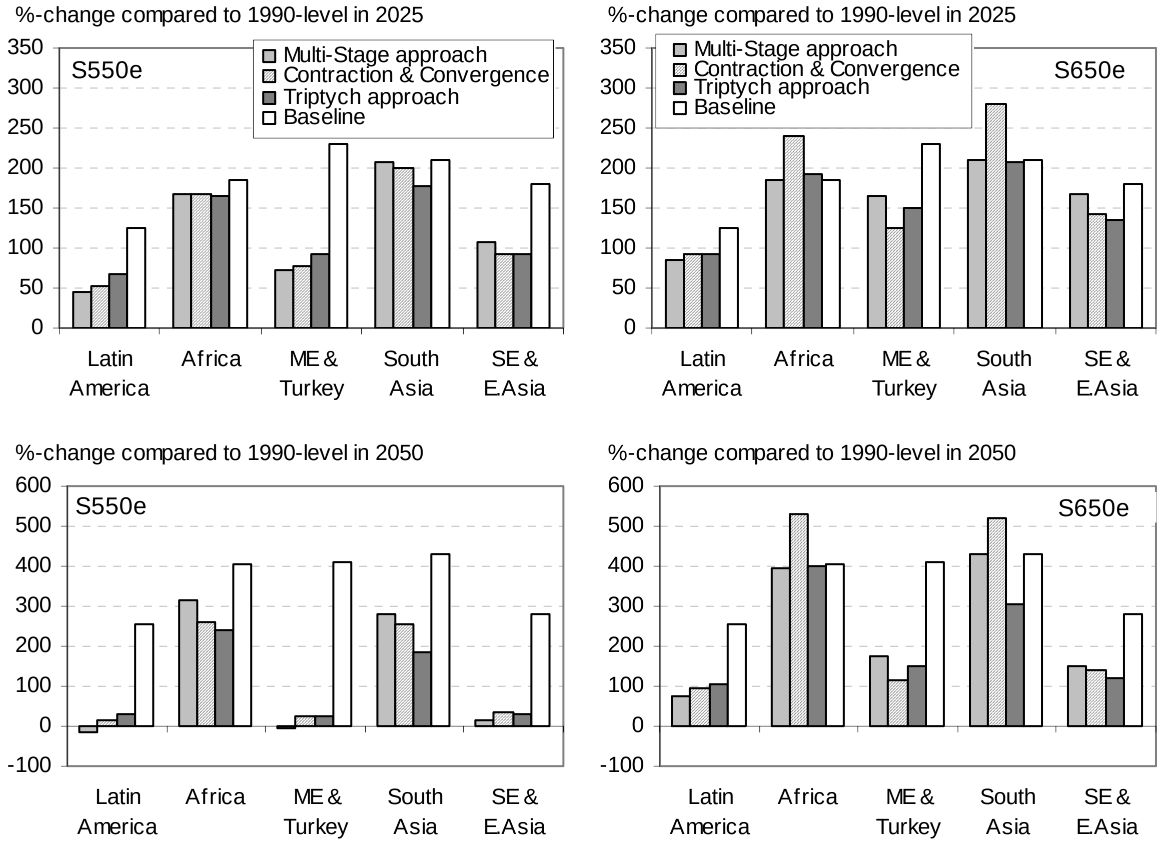


Figure 5: Comparison of the non-Annex I emission allowances for the three regimes explored for the S550e (left) and S650e (right) profile. Source: FAIR 2.0 model.

Under the low emission profile (S550e), all non-Annex I regions in 2025 have emission allowances that are lower than their baseline even in the Contraction & Convergence case, in which they may theoretically be higher resulting in excess emissions. However, the required reductions are limited for Africa and South Asia – i.e. less than 10% (see Table 6). In the other non-Annex I regions, reductions rise to about 30-40% for Latin America, 40-50% for Middle East, and 30% for South-east and East Asia. With the higher S650e emission profile, Africa and South Asia are even less constrained and even significant excess emissions appear in the Contraction & Convergence case. Even South-east and East Asia have low reductions of less than 10% in 2025, except for the Triptych case. For Latin America and the Middle East, reductions compared with the baseline are limited to 10-15% and 10-30%, respectively.

In 2050 and for the low emission profile, the emission reductions compared with baseline levels of the middle- and high-income non-Annex I regions turn out to be very similar to those of Annex I regions, as they all participate in the absolute emission reduction system. Reductions are already rather high for South Asia (around 30-40%) and Africa (about 30-50%). In the higher S650e profile, Africa and South Asia still benefit from their excess emissions. In Latin America and the Middle East, the emission reductions are in the same order as the Annex I reductions. Only for South-east and East Asia the reductions are lower than those of Annex I.

Table 6: Emission reductions compared with the baseline scenario for the cases of the regimes explored. Source: FAIR 2.0 model.

	2025			2050		
S550e profile	MS	PCC	TT	MS	PCC	TT
Canada & USA	56	49	47	-85	-88	-81
Enlarged EU	47	47	40	-74	-78	-73
FSU	40	38	35	-81	-85	-81
Oceania	52	48	52	-83	-85	-70
Japan	41	41	36	-75	-78	-71
Latin America	-36	-32	-26	-77	-68	-64
Africa	-6	-6	-7	-18	-28	-32
ME & Turkey	-48	-46	-42	-82	-76	-75
South Asia	-1	-3	-11	-29	-33	-47
SE & E.Asia	-26	-31	-31	-69	-64	-65
World	33	33	33	67	67	67
S650e profile	2025			2050		
Canada & USA	-25	-30	-19	-66	-79	-46
Enlarged EU	-20	-20	-15	-52	-62	-38
FSU	-26	-29	-21	-61	-73	-51
Oceania	-36	-39	-25	-66	-73	-43
Japan	-29	-29	-23	-54	-62	-36
Latin America	-18	-14	-15	-51	-45	-42
Africa	0	19	3	-3	25	-1
ME & Turkey	-20	-32	-25	-46	-58	-51
South Asia	0	22	-1	0	16	-23
SE & E.Asia	-5	-13	-16	-34	-38	-42
World	16	16	16	43	43	43

Comparison of the regimes. We will now look in more detail into the implications of the three regime approaches for the various regions by comparing the results for the three profiles. We start with evaluating which approaches are more and less favourable or attractive for the various regions. The approach resulting in relatively the least emission reductions (or highest emission allowances) is hereafter classified as the ("most" favourable or most attractive) approach (compared with the other regimes explored). The approach resulting in relatively the highest emission reductions (or lowest emission allowances) is hereafter classified as the ("least" favourable or least attractive approach). Note that this ranking is always relative to the outcomes of the other regimes explored. The main findings are summarized below:

- The Multi-Stage approach case gives emission allowances similar to the Contraction & Convergence case, as the assumed burden-sharing key per capita emissions also results in some convergence in the per capita emissions by 2050 (S550e) and 2075 (S650e). The Multi-Stage case is amongst the least attractive approaches for Canada & US due to the per capita emissions burden-sharing key. The Multi-Stage cases are generally attractive for low-income non-Annex I regions, because they can follow their baseline emissions. However, for Africa - in particular for Eastern and Western Africa – the Multi-Stage case is less attractive than the Contraction & Convergence case because it does not experience excess emission.
- The Contraction & Convergence case is relatively attractive for OECD-Europe and Japan because of their relative low per capita emissions and the fact that under Contraction & Convergence all countries contribute, although the differences with Multi-Stage are small. The earlier contribution of the non-Annex I regions makes Contraction & Convergence relatively a less attractive approach for South Asia and South-east and East Asia. In general, since the per capita emissions for South-east and East Asia are close to the world average per capita emissions, they do not gain from the per capita convergence, and therefore the Contraction & Convergence case is not particularly attractive. South Asia is over the long-term better off by the income thresholds under the Multi-Stage case, in particular over the long-term for S550e. However, in the short-term, South Asia and also Africa (in particular Eastern- and Western Africa) gain from the excess emissions. These excess emissions depend on the stringency of the profile, baseline emissions and

convergence year. Under the S550e profile, the excess emissions are limited for Western- and Eastern Africa, whereas under the S650e profile there are more excess emissions, also for South Asia.

• The Triptych approach is in general attractive for the OECD regions with relatively low emission intensities, like for OECD-Europe and Japan. An exception is Australia (within the region Oceania): since the Triptych approach assumes no mitigation of the agricultural non-CO_2 emissions until 2020, Oceania, with a relatively high share of these emissions, gains under this approach. It is also attractive for some middle- and high-income regions, such as Latin America, Middle East and Turkey. The Triptych approach is in particular unattractive for South Asia (including India), South-east and East Asia (including China) due to their relative inefficiency of the power sector and industrial sector, and their dependency on coal. For the S650e profile, surplus emissions occur for Africa and also South Asia (India), due to the convergence in the domestic emission allowances. This also depends on the assumed convergence-year (2050 or 2075) for the emission profiles.

4.3 Regional abatement costs

Estimating costs of regimes is beset with substantial uncertainties (van Vuuren *et al.*, 2003). Obviously, the uncertainties increase for the medium- to long-term calculations. Therefore, we focus on the short-term (2025) only. The net regional costs or gains for the different regimes result from the costs of domestic abatement combined with the costs or gains from emissions trading. Given the large differences in income between the regions, the costs (or gains) are compared to regional GDP levels (in PPP) (the ratio is further referred to as “effort rate”), thereby giving an indication of costs in comparison to the “carrying capacity” of the local economy. The regional effort rates as well as the global effort rate are presented Table 7. The effort rates differ largely across the various regimes and regions, while these differences can be explained by the differences in regional reduction objectives (Table 6), reduction potentials and income levels.

Table 7: Regional abatement costs as percentage of GDP for the cases of the regimes explored. Source: FAIR 2.0 model.

2025	S550e profile			S650e profile		
S550e profile	MS	PCC	TT	MS	PCC	TT
Canada & USA	0.79	0.59	0.51	0.08	0.06	0.10
Enlarged EU	0.35	0.36	0.32	0.06	0.03	0.05
FSU	0.93	0.91	0.93	0.11	0.08	0.18
Oceania	0.75	0.64	0.35	0.07	0.05	0.04
Japan	0.39	0.40	0.35	0.09	0.06	0.07
Latin America	0.51	0.39	0.26	0.12	0.04	0.03
Africa	-0.47	-0.80	-0.71	-0.06	-0.19	-0.39
ME & Turkey	1.51	1.40	1.15	0.23	0.29	0.25
South Asia	-0.49	-0.41	-0.17	-0.03	-0.08	-0.13
SE & E.Asia	0.14	0.29	0.32	-0.01	0.05	0.06
World	0.32	0.32	0.32	0.04	0.04	0.04

Annex I regions – For the S550e profile, the effort rates of the Annex I regions are about 0.25-1%. Although the differences are small, total abatement costs tend to be relatively high for Canada and USA and Oceania (regions with the highest per capita emissions), and somewhat lower for Europe and Japan (regions with medium per capita emissions). Furthermore, the costs are much higher for the FSU due to their relatively high emissions per capita and a medium income. For the S650e profile the effort rates are much smaller, ranging from 0-0.2%.

Non-Annex I regions – In line with the emission reduction objectives, the costs between the non-Annex I regions are also much more differentiated than between the Annex I regions. The Middle East and Turkey is confronted with the highest effort rates (1-2%), mainly due to their relatively high per capita emissions and medium income, while the effort rates of Latin America are in the same order as of the Annex I regions for both profiles. South-east & East Asia (including China) gain in all regimes and both profiles, up to 3% of their GDP. Finally, for the low-income regions (Africa and South Asia) the effort rates are below the world average. This is due to their relatively high gains from emission trading, which partly compensates their costs for emission control. Again, the effort rates are much smaller for the S650e profile, while the pattern of costs and gains is similar as under the S550e profile.

Comparison of the regimes. In general, the differences in regional costs between region reflect the differences in reduction targets, since the reduction efforts and abatement costs are strongly related. However, due to a limited reduction potential and/or a low income, regimes with low reduction efforts, as for example the Multi-Stage case for the Middle East and Turkey, can still lead to high abatement costs, and might therefore not be that attractive. Den Elzen *et al*. (2004c) have analysed systematically the regional effort rates of three regime approaches, i.e. Brazilian Proposal (not analysed here), Multi-Stage and C&C approach. By comparing the effort rates with the world average, they identified four groups of regions with similar efforts. These are: 1) regions with high per capita emissions and a high income (Annex I regions, excluding the FSU) that are confronted with average costs in comparison to other regions; 2) regions with medium to high per capita emissions, but a medium to low income (FSU, the Middle East and Turkey, and to a lesser extent, Latin America) that are confronted with average to high costs; 3) regions with low to medium income levels and per capita emissions (South-east & East Asia) that show low to medium cost levels, and 4) regions with low per capita emissions and a low to medium income (Africa and South Asia) that show net gains from emissions trading for most regimes. Table 7 shows that this grouping also holds for the additional Triptych approach under both profiles analysed here.

Table 7 can also be used to evaluate whether regimes are more or less attractive for the various regions in terms of their cost burden. It can be concluded that for group 1 the Multi-Stage, Triptych and to a lesser extent C&C approach are all attractive. For the Middle East and FSU (group 2) almost all regimes seems unattractive, since they all lead to high costs. For group 3, in particular for Southern-Africa, C&C is less attractive than regimes with income thresholds (Multi-Stage). For group 4 all three regimes are reasonably attractive.

Summarising over all regions and stabilization profiles, it can be concluded that the Triptych approach results in a more even distribution of costs than the two other approaches, in particular among the Annex I regions, although the FSU remains more strongly affected. It also results in lower burdens for Latin America and Middle East and Turkey, at the expense of the other developing regions (e.g. less gains for the least developed (low-income) regions and higher costs for South-east and East Asia). However, it should be acknowledged that emission and cost implications of approaches is dependent on the policy parameter settings and the baseline emissions scenarios chosen (Table 5). Elsewhere (den Elzen *et al*. (2003); den Elzen (2002)) we have showed that the chosen parameter settings can be as important as the choice of the regime. The most important policy parameters are threshold levels, burden-sharing key and convergence dates. In den Elzen *et al.* (2004) explores the impact of other baseline emissions and marginal abatement costs curves on the regional abatement costs. This means that we have to be careful with drawing conclusions about regimes on the basis of the quantitative outcomes presented. Moreover, in practice, regime proposals will be evaluated on the basis of a much wider set of considerations. Therefore, in the next chapter, we will perform a qualitative multi-criteria analysis to identify relative strengths and weakness of the regime approaches.

5 A multi-criteria evaluation of bottom-up versus top-down regime approaches

In the previous chapter we quantitatively assessed the implications of the various regimes for the allocation of emissions among the various world regions. On the basis of this analysis we have indicated which approaches would be relatively favourable and which would be unfavourable for each region from an emissions-control perspective. However, in practice, regime proposals will be evaluated on the basis of a much wider set of considerations. The quantitative results are also dependent on the policy parameters selected, while other parameter settings may affect the results found (e.g. den Elzen *et al.* (2003)). In this chapter we will perform a qualitative multi-criteria analysis to identify relative strengths and weakness of the regime approaches examined.

5.1 Criteria

In defining a set of evaluation criteria we elaborated on a number of more recent studies, notably Torvanger *et al.* (1999), Berk *et al.* (2002), Höhne *et al.* (2003) and den Elzen and Berk (2003). Like in Höhne *et al.* (2003), we make a general distinction between environmental criteria, political criteria, economic criteria and technical criteria.[12] For all types of criteria some specific elements have been identified.

Environmental criteria. A clear first requirement of any regime is *environmental effectiveness*, that it possesses the ability to effectively control and eventually reduce global GHG emissions with the aim of stabilizing GHG concentrations. The effectiveness of a climate change regime depends on a number of factors such as (a) the level of participation of significant emitters; (b) the comprehensiveness of the regime with respect to the gases and sources covered; and (c) the stringency of the commitments adopted. If some countries remain outside the regime, part of the efforts undertaken by participating states can be offset by leakage: the increase in the emissions of non participating countries resulting from factors such as lower international energy prices and a relocation of production from participating to non-participating countries due to improvement in competitiveness (terms of trade). Moreover, with the growing share of developing countries in global GHG emissions, the environmental effectiveness of any post-Kyoto climate regime will to a large extent depend on the actions taken by the larger developing countries in particular. For this reason, a further environmental criterion is whether a given regime approach provides *incentives for developing countries to take early action*, that is before adopting quantified commitments.

Political criteria. Political criteria generally relate to factors directly affecting the political acceptability of a climate change regime. One of the political criteria will be its perceived equity or fairness. Perceptions about an equitable differentiation of future commitments differ widely. In looking for acceptable climate change regimes it thus seems wise not to focus on any single equity principle, but instead to look for approaches embracing different equity principles, although these may not be much more than compromises, since distinct principles often contradict each other (e.g. egalitarian and sovereignty principles). *Robustness regarding equity principles*, as they were set out in Box 3, is thus considered a relevant first criterion. At the same time, it is clear that a regime is unlikely to come about or to be effective when it fundamentally conflicts with the positions of some key countries. Thus the idealism in the application of principles should be tempered by realism in

[12] Here a subset of criteria has been selected based on more elaborated list of criteria in den Elzen et al. (2003).

acknowledging the power relations resulting from the need to ensure the regime's *acceptability for key countries,* in particular those with significant emissions such as the US, FSU, EU, China and India. This relates to considerations beyond the reduction efforts required, as listed in Table 5.

Box 3: Equity principles

Equity principles refer to general concepts of distributive justice or fairness. Many different categorizations of equity principles can be found in the literature (Ringius *et al.*, 1998; Ringius *et al.*, 2000). In den Elzen *et al.* (2003b) a typology of four key equity principles was developed that seem most relevant for characterising various proposal for the differentiation of post-Kyoto commitments in the literature and international climate negotiation to date:

- *Egalitarian:* i.e. all human beings have equal rights in the 'use' of the atmosphere;
- *Sovereignty and acquired rights:* all countries have a right to use the atmosphere, and current emissions constitute a 'status quo right';
- *Responsibility / polluter pays:* the greater the contribution to the problem, the greater the share of the user in the mitigation /economic burden;
- *Capability:* the greater the capacity to act or ability to pay, the greater the share in the mitigation / economic burden.

The basic needs principle is included here as a special expression of the capability principle: i.e. the least capable Parties should be exempted from the obligation to share in the emission reduction effort so as to secure their basic needs. An important difference between the egalitarian and sovereignty principle, on the one hand, and responsibility and capability, on the other, is that the first two are *rights-based,* while the latter two are *duty-based*. This difference is related to the concepts of *resource-sharing,* as in the PCC approach, and *burden-sharing* in the Multi-Stage approach.

Up to now there has been a clear policy divide between the developed and developing countries in the climate change negotiations, with developing countries sticking together in the G77 notwithstanding clear differences in their interests (e.g. between the Alliance of Small Island States (AOSIS) and OPEC member states). This historic North-South policy divide will have to be overcome in order to broaden participation and differentiate developing country commitments in the climate change regime. Another important policy criterion for a climate change regime would be that the regime be *conducive to trust building* between the Parties. Generally, trust can be enhanced by making decisions in a fair and transparent way, by agreement on regime rules binding all Parties (avoiding arbitrariness in future decision making), and by respecting previously agreed stipulations in the UNFCCC. Finally, a regime proposal ideally should be sufficiently flexibility in order to leave *room for negotiation* to reach compromises. This means that the approach includes enough policy variables or allows for addition or modification of parameters to provide sufficient room for negotiation, without directly affecting its basic architecture.

Economic criteria. A first clear economic criterion, stipulated by the UNFCCC (Article 3.3), is that of *cost-effectiveness:* reducing emissions at the lowest possible cost. This criterion is important because the potential for and costs of GHG emission abatements differ widely between countries. With the introduction of the Kyoto Mechanisms (KMs) (international emission trading, project-based Joint Implementation, and the Clean Development Mechanism (CDM) countries and companies have gained the option of allocating emission reductions abroad if this is more cost-effective than internal reductions. The KMs thus have created so-called "where" flexibility. If these mechanisms are preserved in the future climate change regime, they would help in attaining a high level of cost-effectiveness regardless of the allocation of commitments. However, the cost-effectiveness to be expected from emission trading is higher than for JI and CDM because of lower transaction costs and an easier utilization of reduction potentials (accessibility factor). This implies that the highest level of cost-effectiveness is attained in a regime where most countries are able to participate in emission trading.

Another important economic criterion is *certainty about costs.* Certainty about the level of costs and related economic impacts is important to avoid the risk of high costs possibly resulting in a disproportional or abnormal burden (see under equity). It is also important for the willingness of countries to take on commitments (Philibert and Pershing, 2001). This is particularly the case for developing countries that fear that taking on climate change commitments poses a threat to their economic development. Reducing the uncertainty about future mitigation costs may thus increase the willingness of developing countries (and Australia and the US) to take on emission control commitments. Next, it will be important that a climate change regime proves able to *accommodate different national circumstances* resulting from factors such as geographical situation, (energy) resource endowment, and economic structure and international specialization (Articles 3.2, 3.3, 3.4, 4.8 UNFCCC). A climate change regime that fails to take account of such circumstances may result in disproportional or abnormal burdens for some (groups of) countries This would not just be unfair, but also politically unacceptable.

Technical and institutional criteria. These criteria concern technical and institutional requirements of regime approaches related to both the negotiation process and the implementation and monitoring of commitments. These requirements can be technical, legal, or organizational in nature. A first is criterion is *compatibility with the KP and UNFCCC.* From a legal point of view, and given the importance of continuity in policymaking, it is desirable that a future climate change regime does not require major legal revisions of the UNFCCC and or the KP. As second criterion is *simplicity of the negotiation process*. Regime approaches that are complex in nature, either conceptually, due to need for complex calculations, data requirements or the number of policy variables, complicate international negotiations. They make it more difficult for Parties to assess the implications of regimes, will result in a long and complex negotiation process and are hard to communicate to high-level policy makers and constituencies. Complex regime approaches are particularly to the disadvantage of developing countries that posses less scientific and analytical capacity and negotiating staff.

A third related criterion "*ease of implementation*", concerns the technical and institutional feasibility of implementation, monitoring and enforcement. Even conceptually simple approaches can pose major implementation problems due to their technical and institutional requirements, particularly in less developed countries. Any regime approach that implies monitoring and enforcement action from least developed countries will face major implementation problems. Involving these countries in international emission trading will be difficult due to lack of reliable emission data, statistical capacity to meet eligibility requirements, and sufficient capacity for verification and enforcement (Baumert *et al.*, 2003).

5.2 Multi-criteria evaluation

We applied the above set of criteria to qualitatively evaluate the various regime approaches. It should be realized beforehand that the different criteria may well be in conflict at times. For this reason there are some pay-offs between meeting the different criteria, e.g. environmental effectiveness versus certainty about costs (accounting for national circumstances versus ease of negotiation and implementation) and global equity versus political acceptability to key countries. It is thus unlikely that any regime will perform well on all criteria, which also means that the overall evaluation of a regime will depend on the weight attached to the various criteria. However, it is hard to say what weight should be attached to each criterion, although it can be expected that political and economic criteria will tend to dominate policy-makers' considerations. Moreover, giving scores inevitably involves some arbitrariness because they would have to be based on an *ex ante* assessment, and many criteria cannot be easily measured. For these reasons, we have not applied a formal quantified multi-criteria evaluation methodology, but based our evaluation on a qualitative assessment only. Nevertheless we have tried to give an overall rating for each of the categories of criteria. Our results, summarized in Table 8, will be briefly discussed below.

The Multi-Stage approach. The environmental effectiveness of our top-down application of the Multi-Stage approach seems, in general, to be confirmed. However, it is conceivable that, in practice, a more bottom-up implementation of the approach will be followed. In this case, the environmental effectiveness will be less certain. Moreover, the intensity targets during the second stage enhance the risks of leakage, not only towards countries without quantitative commitments (stage 1) but also to countries with intensity targets (stage 2). Industries may move from countries with fixed targets to countries with intensity targets. While increasing overall emission levels, this may still bring down emission-intensity levels in emission-intensive countries. The participation thresholds based on a Capability-Responsibility index chosen in the Multi-Stage reference variant do not provide strong incentives for non-participating developing countries to take action before entering the second stage. However, the per capita emission-burden-sharing key of the last stage may provide an incentive to limit emissions as much as possible.

Table 8: Multi-criteria evaluation of the regime approaches explored.

Criteria	Multi-Stage	C&C	Triptych
Environmental criteria	+	+/++	-/+
Environmental effectiveness	+	++	-
Incentives for developing country action	- / +	-	+
Political criteria	+	0	0/+
Comprehensiveness of equity principles	++	+	+
Acceptability for key countries	0	-	0
Supportive to building trust	+	++	0/+
Room for negotiation	+	--	0/+
Economic criteria	0	-	0/+
Cost-effectiveness	+	++	+
Certainty about costs	0	--	0
Accounting for national circumstances	0	-	+
Technical and Institutional criteria	+	0/-	-
Compatibility with the KP and UNFCCC	++	-	+
Simplicity of the negotiation process	0	++	--
Ease of implementation	0/-	--	--

Legend: ++: fully satisfied; +: generally satisfied; 0: partly satisfied; - poorly satisfied; --: not satisfied at all

The Multi-Stage approach performs well when it comes to the coverage of equity principles. Furthermore, it respects the principle that developed countries "should take the lead in combating climate change" (Article 3.1 UNFCCC). Nevertheless, the economic implications of the approach do not need to be balanced, and some countries may still be confronted with disproportional burdens due to specific national circumstances (see below). In general, the Multi-Stage approach would not seem to face strong principle-based objections from any of the key countries. The intensity targets seem appealing to developing countries. The Multi-Stage approach is likely to help in building trust by providing for a transparent build-up of developing country commitments, although there may be resistance amongst developing countries to dividing the G77/China group. The various thresholds, different types of targets and flexibility in setting targets provide the approach with considerable room for fine-tuning in negotiation. The Multi-Stage approach is cost-effective if the Kyoto Mechanisms (KMs) are available. However, it will be less than optimal in this regard if a group of developing countries does not directly participate and the adoption of an intensity-targets approach, since it would complicate the functioning of the international emission-trading market (Müller *et al.*, 2001). The intensity targets take away some of the uncertainty about the economic impacts of quantitative commitments for developing countries, but as noted elsewhere (de Moor *et al.*, 2002), also impose economic risks in cases where economic growth stalls or goes into reverse.

Without proper conditionality clauses or other arrangements (like dual intensity targets, as suggested by Kim and Baumert (2002)), intensity targets may still result in excessive costs. Because the intensity targets are defined as a percentage improvement, the Multi-Stage approach does account for different starting positions of developing countries due to differences in national circumstances. However, in the emission reduction stage, structural differences between developed countries are no longer adjusted for. The Multi-Stage approach fits in well with the protocol approach taken under the UNFCCC where commitments for groups of countries are based on annexes to the Convention. The introduction of intensity targets is likely to complicate both the negotiation process and the implementation of commitments because of the need for reliable emission and economic data from developing countries and additional emission trading requirements.

Contraction & Convergence approach - The environmental effectiveness of the Contraction & Convergence approach is high, since it is based on global emission targets and since all countries participate in binding quantitative emission limitations. The approach also provides incentives for developing countries to take action to limit GHG emissions because this creates emission allowances that can be sold on the market. But, in the case of large amounts of excess emission allowances, this incentive may be weak. Contraction & Convergence is not robust across the various equity principles, in particular, (historical) responsibility. On the other hand, it does take into account the egalitarian principles of sovereignty. The approach is expected to meet resistance from the USA and other regions with high per capita emission levels (Oceania, the Middle East and Turkey and FSU) and possibly from China. This resistance will be based on both economic concerns related to the large resource transfers to developing countries as well as political opposition against the global commons and egalitarian concepts underlying the approach. Nevertheless, it could help in building trust between developed and developing countries by its transparent and comprehensive nature. The approach does not leave much room for negotiation apart from the convergence year and overall emission target. This could increase if allowance factors for accounting for national circumstances were to be included (Aslam, 2002).

Triptych approach –The environmental effectiveness of the bottom-up Triptych approach is not as certain as the top-down approaches. If the effectiveness of the approach falls short, it can be compensated for in subsequent commitment periods, but at the price of substantial policy delay. In any case, the analysis showed that depending on how the Triptych parameters are set, stringent global emission goals could be reached with all major countries included. The approach also provides incentives for developing countries to limit their emissions. Early action in the domestic sectors is rewarded, since per capita emissions of these sectors will eventually converge and less reduction will be necessary to reach the per capita convergence level. For industry, the assumption of converging energy efficiency may provide a link to the discussions on international transfer of technology to developing countries, and this, combined with accounting for income distributed growth rates, may be an incentive for developing countries to participate.

The Triptych approach is mainly based on the opportunity to act in principle, since countries are allowed to grow in terms of electricity and industrial production, but have to improve their production efficiency. The opportunity to act in principle is not the same as capability to act, which is based more on the level of economic development. This may be particularly a problem for the least developing countries due to their early participation in a global Triptych approach. The principle of responsibility (polluter pays) is addressed through the requirement for countries with higher emission levels in the domestic sector to reduce emissions further. The historical responsibility of countries is not explicitly taken into account.

This approach may not have to face too many strong objections from the key countries. Most developing countries have clearly indicated their preference for the convergence of per capita emissions. However, some developed countries are strictly opposed to the concept of per capita emissions. The combination of convergence of per capita emissions in the domestic sectors with the flexibility for growing emissions (in industry and electricity production, and accounting for structural differences, could be attractive to many countries as a compromise solution, and thereby could help in building trust. The various parameters and accounting for structural differences leaves room for negotiations.

Electricity production and industrial production may grow, but efficiency has to be improved. In this way, emission targets will become largely compatible with the existing technical emission reduction potentials in the various countries. Allowing emission trading introduces an additional degree of cost-effectiveness, as for the other approaches. Although this approach is based on sector-specific considerations, a national target has been provided instead of several sectoral targets, to allow countries the flexibility to pursue cost-effective emission reduction strategies. Parties can reduce emissions across sectors and, if emission trading and CDM is allowed, also outside of their territory. The approach does not give certainty about costs, although it accounts for projections of production growth rates. Structural differences are taken explicitly into account at a sector level. The differences taken into account are in the standard of living, in future population growth, in fuel mix for power generation, in the economic structure and energy efficiencies and in projected future changes in economic structure. The emissions of all GHGs are also considered, and so, cover all major emission sectors of developing and developed countries.

The Triptych approach is essentially a method to differentiate emission reduction targets among countries before a commitment period. As such it can form part of the structure of the UNFCCC. The Triptych approach is relatively complex compared with some of the other approaches. The concept of the Triptych approach can nevertheless be easily explained. Countries have to agree on the Triptych criteria applicable to all countries, such as the convergence level of the domestic sectors and changes in the fuels mix for electricity generation. Further, the approach requires a set of scenarios, including expected growth rates of production in the various sectors. The countries themselves could provide these. There is, however, an incentive to provide high growth scenarios. This problem could be overcome by making adjustments after the commitment period, if the projected growth rate was considerably higher than the actual one or using the actual production growth rate. Once the targets are defined, the requirements regarding verification of the implementation of the targets are the same as for the Kyoto Protocol. Overall, implementation of the approach remains rather complex, which becomes particularly problematic if applied to (the least) developing countries.

5.3 Strengths and weakness of the regime approaches

On the basis of the multi-criteria evaluation we can tentatively define some major strengths and weaknesses of the various regime approaches:

• The Multi-Stage approach scores relatively well on most criteria. It provides reasonable certainty about the environmental effectiveness of the regime, while limiting the cost uncertainty for particularly developing countries, and avoiding implementation problems by using a threshold for participation. However, politically grouping developing countries may face resistance, while also another burden-sharing key than used here, or a mix of keys, may have to be adopted to obtain a more acceptable distribution of efforts.

• The Contraction & Convergence approach scores high on the environmental criteria, but does much worse on the political criteria and the technical and institutional criteria. While its cost-effectiveness is high, the overall score on the economic criteria is also rather low, mainly due to a lack of consideration of national circumstances and baseline developments. However, inclusion of adjustment factors or a regional approach (e.g. an emission bubble), or both, as well as provisions for emission trading, could enhance its performance.

• The Triptych approach scores moderately well on most criteria, but scores particularly poorly on the technical and institutional criteria. Its does comparatively well on economic criteria, mainly since it better accounts for the national circumstances than the other approaches. However, the main weakness of the approach is still its complexity and the necessity of projections of production growth rates, which makes it particularly difficult to implement in the case of the least developed countries.

6 Conclusions

We have looked at bottom-up approaches for defining future climate change commitments and tried to identify their strengths and weaknesses. Bottom-up approaches relate to both types of commitments and to regime proposals for differentiating national climate targets. One such bottom-up regime is the Triptych approach. We compared the implications of the Triptych approach with those of two top-down approaches, the Multi-stage and Contraction & Convergence, and evaluated their strength and weaknesses.

From our assessment of the various bottom-up approaches to future commitments we can conclude that:

- Overall, it would seem that while bottom-up approaches can be valuable components of a future climate regime, they in themselves do not seem to offer a real alternative to a climate regime defining quantified emission reduction and limitation targets. This is because they provide little certainty about the overall environmental effectiveness of climate policies.

- International technology standards and R&D agreements can be useful - if not essential - additional components of a future climate regime based on emission targets and Kyoto mechanisms to enhance its long-term perspective and effectiveness avoid leakage and make use of market forces driving technological spill-over. These standards may form part of an international climate strategy with both “push” and “pull” components. In addition, some bottom-up approaches, notably SD-PAMs, sector-based CDM and sectoral targets, would seem to be useful intermediate stages for developing countries to gradually get more engaged in international GHG mitigation efforts. Finally, transnational agreements with international industrial sectors could also well supplement a future regime to link and strengthen its “push” and “pull” components. The feasibility of various options for such transnational agreements and how these could be formally linked to the climate regime requires further study.

Triptych approach

The Triptych approach, a method to differentiate emission reduction targets among countries based on technological considerations on the sector level, has the advantage that emission allowances are broken down according to sectors. This makes the link to real-world emission reduction strategies more concrete. It also allows for discussion in sectors that compete worldwide and makes “ natural” discussion possible on the role of developing countries in making contributions to emission limitation and reduction targets. A major downside of the approach is still its complexity and the necessity of projections in production growth rates.

In comparison with Multi-Stage and Contraction & Convergence, Global Triptych offers the opportunity of early DCs participation without the risk of creating large (and unacceptable) amounts of surplus emissions as in C&C. Its advantage over Multi-Stage is that it does not require the non-Annex I countries to be divided up and offers a means of early participation in international emission trading for all countries. At the same time, there will be substantial implementation problems due to the lack of institutional and technical capacity to define both proper baseline levels and to meet eligibility requirements of participating in IET. Thus it would seem better to exclude the LDCs in a global application of the Triptych approach, and make them first participate using one of the alternative bottom-up approaches such as the SD-PAMs. Another suggestion would be to combine the Multi-Stage and the Triptych approaches by using the Triptych approach for distributing the emission reduction burdens for the Annex I countries and the non-Annex I countries taking on quantified emission reduction targets.

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