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Simplified Multi-Stage and Per Capita Convergence: an analysis of two climate regimes for differentiation of commitments

M.G.J. den Elzen, M.M. Berk, P. Lucas

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

National Institute of Public Health and the Environment (RIVM)
Netherlands Environmental Assessment Agency
P.O. Box 1, 3720 BA Bilthoven
The Netherlands
Telephone : +31 30 2743584
Fax: : +31 30 2744427
E-mail : Michel.den.Elzen@rivm.nl

Abstract

Here, two post-Kyoto climate regimes for differentiation of future commitments, the simplified Multi-Stage approach and the Per Capita Convergence approach, are described and analysed in detail. The Multi-Stage approach consists of a system to divide countries into groups with different types of commitments (stages), resulting in a gradual increase over time in the number of countries involved and their level of commitment. Three new simplified Multi-Stage variants, which share three consecutive stages for the different commitments, have been developed and analysed. Stage 1 contains no quantitative commitments, while Stage 2 consists of emission-limitation targets and Stage 3, emission reduction targets. The Per Capita Convergence, or Contraction and Convergence approach defines emission permits on the basis of a convergence of per capita emissions under a contracting global GHG emission profile. The analysis focuses on two global greenhouse gas emission profiles, resulting in long-term CO_2-equivalent concentrations stabilising at 550 ppmv for the S550e profile and 650 ppmv for S650e profile. For the Per Capita Convergence, two variants are analysed for different convergence years, 2050 and 2100. The abatement efforts, or allocations, for Annex I regions with respect to the S550e profile for all variants generally range from 25%-50% below 1990 levels in 2025 (across regions and regimes) and 70-85% in 2050. For S650e, these efforts range from a 10% increase to a 25% reduction in 2025, and a 40-60% reduction in 2050. The 2100 Per Capita Convergence regime forms an exception, leading to lower emission targets for Annex I regions. Most non-Annex I regions will need to reduce their emissions by 2025 in comparison to baseline levels, but emissions can increase with respect to 1990 under all the regimes analysed. For non-Annex I regions, results are generally more differentiated for the various commitment schemes, stabilisation targets and time horizons (2025 versus 2050) than for Annex I regions. The analysis further highlights the major strengths and weaknesses of the Multi-Stage and Per Capita Convergence variants, as well as indicating important obstacles and pre-conditions for the feasibility and acceptability of these approaches.

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Samenvatting

Dit rapport beschrijft een analyse voor het (kwantitatief) verkennen van twee post-Kyoto regimes voor lastenverdeling in het internationale klimaatbeleid: 1. de eenvoudige Multi-Stage benadering, waarbij landen op grond van hoofdelijk inkomen en emissies worden ingedeeld in groepen met verschillende typen van doelstellingen (stadia). Deze benadering resulteert in een geleidelijke uitbreiding van het aantal landen met kwantitatieve doelstellingen alsmede van de stringentheid van hun doelstellingen. 2. de Per Capita Convergentie benadering, waarbij voor alle landen vanaf 2013 emissierechten worden gedefinieerd op basis van een convergentie van hoofdelijke emissie ruimte onder een (dalend) wereldwijd broeikasgas emissieplafond. Dit is gedaan met behulp van twee mondiale emissieprofielen voor broeikasgassen die resulteren in een stabilisatie van de CO_2-equivalente concentratie op een niveau van respectievelijk ongeveer 550 en 650 ppmv (S550e en S650e profielen).

De Multi-Stage benadering (toenemende participatie) gaat uit een kwantitatief raamwerk van geleidelijk toenemende participatie volgens een filosofie van graduatie. De benadering biedt een concept waarbinnen landen geleidelijk kunnen toetreden tot een mondiaal klimaatregime, overeenkomstig hun specifieke nationale omstandigheden en stadium van economische ontwikkeling. Het geleidelijk toetreden is vertaald naar meerdere stadia binnen het regime. Daarmee is het in staat om meerdere verdelingsprincipes en meerdere vormen van verplichtingen in meerdere stadia van één systeem te verenigen.

Drie eenvoudige Multi-Stage varianten zijn ontwikkeld met ieder verschillende deelnameregels en criteria voor zowel deelname als bijdrage, maar gemeenschappelijke opeenvolgende stadia van inspanningsniveau: stadium 1: geen verplichtingen; stadium 2: emissie beperkende maatregelen; en stadium 3: emissie reductiedoelstellingen. Voor de Per Capita Convergentie benadering zijn twee varianten geanalyseerd, met verschillende convergentiejaren (2050 en 2100).

De kwantitatieve analyse laat zien dat de reductie doelstellingen van Annex I landen voor S550e liggen in 2025 voor de verschillende benaderingen tussen de 25%-50% onder 1990 niveau (afhankelijk van regio en regime) en 70-85% in 2050. Voor S650e variëren deze doelstellingen van een 10% toename tot een 25% reductie in 2025 en een 40-60% reductie in 2050. Het 2100 Per Capita Convergentie regime vormt een uitzondering en leidt tot lagere doelstellingen voor Annex I landen. De meeste niet-Annex I regio's moeten voor alle geanalyseerde regimes in 2025 hun emissies reduceren ten opzichte van baseline, maar kunnen hun emissies nog laten groeien ten opzichte van 1990. De resultaten voor niet-Annex I regio's laten in de regel een diverser beeld zien voor verschillende regimes, stabilisatie doelen, regio's en tijdsperiodes (2025, 2050) dan die voor Annex I regio's.

Naast de kwantitatieve analyse is op basis van een multi-criteria analyse ook een kwalitatieve beoordeling gemaakt van de sterke en zwakke kanten van de verschillende Multi-Stage en Per Capita Convergentie varianten, en laat zien waar de belangrijkste obstakels en condities liggen voor een mogelijke uitvoerbaarheid en aanvaardbaarheid.

1 Introduction

In this report we will describe and analyse the implications of five variants of two different climate regime approaches for differentiating future mitigation commitments. Two of them are variants of the Per Capita Convergence approach (PCC), while the other three are new variants of the simplified Multi-Stage (MS) approach. For the analysis we will use the two global emission profiles for stabilising atmospheric greenhouse gas concentrations at 550 and 650 ppmv equivalent (S550e and S650e) (see Appendix A).[1]

The MS approach comprises a system to divide countries into groups with different types of commitments (stages) and results over time in a gradual increase in the number of countries and their level of commitment according to participation and differentiation rules. In this study we will present three new simplified variants of the MS approach, developed in collaboration with IEPE on the basis of the original MS approach from RIVM (Berk and Den Elzen, 2001; Den Elzen, 2002), and elements from an alternative climate regime approach, called Soft Landing (Criqui and Kouvaritakis, 2000).

The Per Capita Convergence approach, more commonly known as the 'Contraction & Convergence' approach, originating at the Global Commons Institute (Meyer, 2000). This approach allocates emissions on the basis of a convergence in per capita emission to equal per capita levels in the future under a contracting global GHG emission profile.

The two approaches have been selected because they show a number of structural differences. First, the MS approach is based on a gradual extension of the number of countries participating in global greenhouse gas emission abatement, while in the PCC approach, all countries participate from the start. Second, the MS approach defines different types of commitments, while in the PCC approach all countries have similar commitments (fixed targets). Third, where the MS approach concerns the allocation of emission abatement efforts (burden-sharing), the PCC approach is based on the allocation of rights to use the (constrained) capacity of the atmosphere to absorb greenhouse gas emissions (resource-sharing). Finally, the MS and PCC approaches are based on different equity principles, as will be discussed in Chapter 2.

Organisation of the report

The features - new, simplified variants of the MS approach - are described in more detail in Chapter 2. This Chapter also briefly describes the PCC approach. Chapters 3 and 4 present the analysis of the implications of the MS and Per Capita Convergence variants in terms of the regional emission allowances for the two profiles. For this analysis we used a Common POLES-IMAGE (CPI) baseline, which up to 2030 is largely based on the existing POLES model baseline scenario (see Criqui and Kouvaritakis (2000)), with an extension up to 2100 based on the IMAGE 2.2 model (IMAGE-team, 2001). The decision-support model FAIR 2.0 (Framework to Assess International Regimes for differentiation of future commitments) is used as framework for the analysis of allowances (Den Elzen, 2002; Den Elzen and Lucas, 2003). This model is designed to quantitatively assess the environmental effectiveness and abatement costs of a range of alternative differentiation schemes of future commitments under the UNFCCC (post-Kyoto) in the context of stabilising greenhouse gas concentrations. The calculations for the following 17 regions were presented here: Canada, USA, OECD-Europe, Eastern Europe, Former Soviet Union (FSU), Oceania and Japan (Annex I regions); Central America, South America, Middle East & Turkey, (the middle-

[1] The 'CO_2-equivalent concentration' indicates the forcing of the total GHG concentration expressed in terms of the hypothetical CO_2 that would lead to the same radiative forcing.

and high income non-Annex I regions); Northern Africa, Southern Africa, East Asia (incl. China) and South-East Asia (the low-middle income non-Annex I regions), Western Africa, Eastern Africa and South Asia, including India (i.e. the low-income non-Annex I regions). Chapter 5 compares the results of the PCC and MS variants in more detail, and highlights the major strengths and weaknesses of the MS and Per Capita Convergence variants; it also points out important obstacles and pre-conditions for their feasibility and acceptability. Findings are summarised in Chapter 6.

2 The climate regimes explored

2.1 The new Multi-Stage variants

The MS approach is an international climate regime for differentiating future (mitigation) commitments under the United Nations Framework Convention on Climate Change (UNFCCC). The MS approach consists of a system to divide countries into groups with different levels of efforts and types of commitments (stages). The aim of such a system is to ensure that countries with similar circumstances in economic, developmental and environmental terms have comparable responsibilities, i.e. commitments under the climate regime. Moreover, the system defines when a country's level of commitment changes according to pre-determined rules that take into account changes in its circumstances.

The MS approach thus results into an incremental evolution of the climate change regime, i.e. a gradual expansion over time of the group of countries with emission targets (the Annex I), with countries adopting different levels and types of commitments according to participation and differentiation rules. The various levels of participation could be organised as different annexes to the UNFCCC. The approach was first developed by Gupta (1998). Later, this approach was elaborated into a quantitative scheme compatible with the UNFCCC objective of stabilising the atmospheric greenhouse gas concentrations at a level that would *'prevent dangerous anthropogenic interference with the climate system'*. This had be done by Den Elzen et al. (1999), Berk and Den Elzen (2001), Den Elzen (2002), Den Elzen and Berk (2003) and Den Elzen et al. (2003).

Criqui and Kouvaritakis (2000) developed a detailed world energy and CO_2 projection, and then proposed an alternative 'multi-grouping' regime approach, called Soft Landing. This approach encompasses a scheme for a progressive limitation of emissions in non-Annex I countries, where timing of the moment of stabilisation of emissions is differentiated for groups of countries on the basis of their per capita emissions and per capita income levels, as well as on their population growth. Annex I countries keep reducing their emissions according to an 'extended Kyoto-type' trend. Blanchard et al. (2003) fully describe the corresponding complete scenario. In contrast to the MS approach, in the Soft-Landing approach all non-Annex I countries participate immediately.

Both the Soft-landing and the MS approach were part of the explorative phase of the 'Greenhouse gas Reduction Pathways in the UNFCCC post-Kyoto process up to 2025' project. In evaluating both, the MS and Soft-Landing approach, it was found that the MS approach provides a promising approach for extending the present KP in a gradual, but structured way. However, the original approach was considered as probably too complex and for this reason it was decided to reduce the number of stages and policy variables. The Soft-Landing approach provides for an early participation and smooth change in emission pathways of non-Annex I, but does not result into global emission reductions needed for stabilising GHG concentrations and lacks clear rules related to equity considerations in the UNFCCC.

Therefore, the RIVM and IEPE have collectively developed new variants of the MS approach. The criteria here were that the new variants should:
- account for various equity principles;
- result in a gradual shift from no emission control commitments to full participation in the emission-reduction stage via a transition stage;
- be relatively simple in nature; i.e. based on a limited number of policy variables.

It was felt that the elements of the Soft Landing approach could be used to further develop, and in fact simplify, the existing MS approach. Therefore the new, simplified MS variants are built on both RIVM's MS approach and IEPE's Soft-Landing approach but include several new elements. These simplified MS cases (hereafter MS cases) are described in more detail below.

2.1.1 Equity principles and stages of commitment

Accounting for equity principles

The design of the MS regime can be related to various equity considerations (see Box 2.1). Moreover, as we have suggested elsewhere, there is some hierarchy in equity principles (Den Elzen et al., 2003). The basic *need* principle would come first, as it exempts one from contributing, not even proportionally, so as to avoid hindrance of attaining basic development needs. Next, the *capability* principle foregoes the responsibility principle, as one cannot be expected to contribute proportionally to one's responsibility if this would constitute a disproportional or abnormal burden. Finally, the *responsibility* principle would subordinate the *sovereignty* principle, as international law does not allow a state to continue to emit freely if this is known to be harmful to other states.[2] This hierarchy of equity principles is largely reflected in the design of the new MS approaches:

- Stage 1 corresponds with securing basic needs by exempting the least developed countries from quantitative commitments and allowing them to follow baseline emissions.
- Stage 2 corresponds with contributing according to one's capability (and avoiding disproportional burdens), allowing for a transition towards a full contribution. Commitments in this stage limit the growth in emissions, but do not yet require absolute reductions (emission limitation commitments).
- Stage 3 corresponds with the responsibility principle by defining emission reduction commitments based on one's contribution to climate change.

Shifting gradually from no emission control to emission reductions

All three new MS variants developed are based on the following consecutive stages for the commitments of non-Annex I countries:

- Stage 1. No quantitative commitments (exemption stage);
- Stage 2. Emission limitation targets, e.g. intensity targets (transition stage);
- Stage 3. Emission reduction targets, similar to those of Annex I countries (full participation).

However, the variants differ in the way the transition stage has been designed. All Annex I regions (including the US) are assumed to be in stage 3 after 2012.

Relatively simply in design

The MS variants are all based on a limited number of policy variables, as illustrated by the main characteristics of the three MS variants in Table 2.1.

[2] See preamble of UNFCCC: 'Recalling also that States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental and developmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or areas beyond the limits of national jurisdiction'.

Box 2.1 Equity principles

Equity principles refer to general concepts of distributive justice or fairness. Many different categorisations of equity principles can be found in the literature (Ringius et al., 1998; Ringius et al., 2000). In Den Elzen et al. (2003) 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 MS approach.

- *Stage 1 to Stage 2: from no-constraint to emission limitation (carbon intensity) targets*

The transition from Stage 1 to Stage 2 depends, for all MS variants considered here, on a Capability-Responsibility (CR) index.

This new element, the CR-index, is a composite index that intends to relate the degree of effort that each country should perform in emission abatement policies, according both to its responsibility in the problem (per capita emissions) and to its capability to act (per capita income). This index draws from the mention in Article 3.1. of the UNFCCC of the 'common but differentiated responsibilities and respective capabilities' that should be taken into account in defining the appropriate action of the different Parties. The CR-index is defined as the sum of the per capita income (expressed in PPP€1000 per capita), which relates to the capability to act, and of the per capita CO_2-equivalent emissions (expressed in tCO_2-equivalent per capita). This CR-index reflects the responsibility in climate change (illustrated in Table 2.2).[3] and is used to define the threshold for the transition from Stage 1 to 2.The CR-index originates from the Soft Landing approach (see Criqui and Kouvaritakis (2000)), where it was used to categorise countries into groups with different trajectories in the search for stabilisation of emissions on the basis of both their per capita income and levels. Because it combines variables of a different nature, this composite index should in principle be normalised or weighted. It happens however that, in this particular variant, a one-to-one weight produces fairly satisfactory results.

While resulting from a pragmatic approach, this indicator shows good 'screening' properties, in the sense that it allows to reproduce in a satisfactory way the existing Annex I, as well as relevant country groupings for non-Annex I regions. The ranking of regions, as it comes out from the 2000 index, is modified in 2025 for only a limited number of variants, in particular China and Southern Africa.

[3] Because it combines variables of a different nature, this composite index should in principle be normalised or weighted. It happens however that in this particular variant a one-to-one weight produces fairly satisfactory results.

Table 2.1: The main characteristics of the three MS variants

	MS 1	MS 2	MS 3
Stage 1 No quantitative commitments			
Stage 2 (emission-limitation stage)			
First threshold (to Stage 2)	Capability-Responsibility (CR) index	Same as MS 1	Same as MS 1
Emission-limitation targets	Income-dependent intensity targets	Same as MS 1	Prescribed emission stabilisation profile
Stage 3 (emission-reduction stage)			
Second threshold (to Stage 3)	World-average per capita emissions	CR-index value	--
Absolute targets, reductions proportional to burden sharing key	Per capita emissions	Same as MS 1	Same as MS 1

Table 2.2: Regional Capability-Responsibility (CR) index values in 1995 and in 2025 for the CPI scenario. regions ranked by decreasing value in 1995

	1995			2025		
	Per capia GDP	Per capia emissions	CR-index	Per capia GDP	Per capia emissions	CR-index
	1000 PPP$	tCO2-eq		1000 PPP$	tCO2-eq	
USA	28	26	54	47	27	73
Canada	24	21	45	39	21	60
Oceania	17	19	36	30	20	51
Japan	24	11	35	39	13	52
OECD Europe	20	11	31	37	12	50
Former USSR	5	12	18	13	17	30
Eastern Europe	7	9	15	17	11	28
Middle East	5	7	12	9	11	20
South America	7	5	12	12	8	19
Central America	5	5	10	10	6	17
Southern Africa	2	4	7	3	6	9
East Asia (China)	3	4	7	11	7	18
Northern Africa	3	3	6	6	5	11
South East Asia	3	3	6	8	5	14
South Asia (India)	2	2	4	5	3	8
Western Africa	1	1	2	1	2	4
Eastern Africa	1	1	2	1	2	3

Compared to a single capability oriented threshold, like per capita income as in the original MS (Berk and Den Elzen, 2001), the CR-index generally tends to result in an earlier participation of low-income regions, in particular, those that have relatively high per capita emission levels (for example Southern Africa). Based on the experience with the Soft Landing approach, proper weighting of both Capacity and Responsibility factors can prevent countries that are too poor having to participate early on.

In Stage 2, the MS 1 and MS 2 variants share GDP-related emission intensity targets. More specifically, the GHG emission intensity improvement rate is defined as a linear function of per capita income level (*IC* in PPP€ per capita), i.e. max [$a*IC_R(t)$, EIR_{max}], where t is the year of calculation, a, a coefficient and EIR_{max} the exogenous maximum de-carbonisation rate. The EIR_{max} was adopted to avoid de-carbonisation rates that would outpace those of economic growth and result in absolute reduction targets for middle-income regions. The basic idea behind the coefficient a is that the rate reaches a maximum at 50% of (1990) Annex I income, where the corresponding income level is IC_{max} in PPP€ per capita per year, can be calculated as: EIR_{max} / IC_{max}.

The MS 3 variant provides a prescribed emission limitation growth target for Stage 2, leading to a stabilisation of emissions as in the Soft-Landing approach. The length of this stabilisation period given by the transition constant, *TC,* is calculated by dividing the *TC* by the per capita emission levels (in tCO_2-eq per capita) before the first CR-threshold is met.

For example, if the transition constant is 70, a region with per capita emission levels of five will have to bring down its emission growth rate to zero in 14 years. [4]

Box 2.2 Transition constant

The concept of a transition constant is most directly related to the original Soft Landing approach. The idea was to have developing country emissions gradually bending towards a stabilisation of emission levels, taking into account differences between various countries. In earlier discussions on the development of this MS 3 variant, it was proposed to relate the length of the transition period to the initial emission growth rate at the point of reaching the CR-threshold: the higher this rate, the shorter the transition period. This would discourage countries from raising their emission rates just before meeting the participation threshold. However, it was found that this could result in unreasonable outcomes, which would contradict the concept of capability, central to the emission-limitation stage. High initial growth rates can be the result of population growth and structural change (e.g. industrialisation) in a country's economy, and not necessarily due to inefficiency only. In fact, while countries' growth may be high, their absolute (per capita) emission levels are not necessarily high (yet). Because of these factors, it was considered unreasonable to punish countries with high initial growth rates by requiring a shorter transition rate. Instead, a link between the length of the transition period and the per capita emissions was adopted. A long-range reference year was introduced to reduce the problems related to the use of data from a single reference year.

- *Stage 2 to Stage 3: from emission-limitation to reduction targets*

The three MS variants differ in the way the transition from Stage 2 to Stage 3 is defined:
- In MS 1, the entry to Stage 3 depends on a second threshold, defined as a proportion of the world average per capita emission level. As the level of this threshold changes over time due to mitigation actions by other parties, it is not a fixed (like the CR-values) but a dynamic threshold.
- MS 2 uses a second CR-index with a value that is about twice that used for the Stage 1 to Stage 2 threshold.
- In MS 3, the entry to Stage 3 is not defined by a threshold, but begins after the fixed and pre-determined stabilisation period has ended.

Given these characteristics, we have labelled the MS 1 variant a 'dynamic threshold', MS 2 a 'double CR-threshold' and MS 3 a 'transition path'.

All new MS variants in Stage 3 assume the same burden-sharing key: per capita GHG emissions.[5] This key tends to result in some convergence of per capita emission levels over time.[6]

[4] The emissions during Stage 2 are calculated as: $E(t-1)+V_0*(1-((t-t_0)/LTS))$, where E(t-1) are the emissions of the previous year, t_0 is the start year, LTS is the length of the stabilisation period and V_0 is the average increase in the emissions before the CR threshold is passed.

[5] 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_r over all regions, with E_r the total emissions and pcE_r the per capita emissions. In this way, two regions with equal per capita emissions, but different total emissions, have the same relative reduction effort compared to their emissions.

[6] As referred to in the preamble of the Marrakesh Accords: 'Emphasising that the Parties included in Annex I shall implement domestic action in accordance with national circumstances and *with a view to reducing emissions in a manner conducive to narrowing per capita differences between developed and developing country Parties* while working towards achievement of the ultimate objective of the Convention' (italics added).

The levels chosen for the different thresholds and the rules applied to the entry in each stage have been adjusted to the global emission profile, as will be described in Chapters 3 and 4 (Table 3.1 and Table 4.1).

2.1.2 Other new features

Apart from the new features of the variants some other generic changes were made to enhance the policy realism of the approaches. The first one is related to the incorporation of a *policy delay.* In the original MS analyses performed so far, countries have immediately changed the stage when exceeding any of the thresholds. In reality, (reliable) information on the threshold indicators is only available after some time (normally 3-5 years). In addition, negotiations are needed to define commitments for countries that have kept within threshold levels. In the present Kyoto Protocol system, targets for future commitment periods would ideally be defined as five years before the commitment period (CP) begins, perhaps to avoid interference with policy implementation. This would imply another five years of delay. However, it remains to be seen if this will be realised in practice. To account for the policy delay, all MS variants assume that if the threshold has to be met in the middle of the CP, T (2010, 2015, …), the country will enter a new stage at T +5 (2015, 2020, …). This implies a policy delay of at least five years, which is considered to be the shortest thinkable delay; in practice, a ten-year delay would seem more likely.

Another change relates to the use of a *reference period for threshold levels*. Using a single reference year for measuring whether a (non-Annex-I) country has met a threshold level has a number of disadvantages. First, indicator values such as those for per capita emissions or income tend to fluctuate substantially from year to year. Second, such figures are generally surrounded by substantial uncertainty. Third, a single reference year brings the risk of anticipative behaviour and/or fraud. These problems are reduced when the measurement of the threshold indicator is based on more robust long-range averages. A suitable reference period would seem to be 5-10 years. However, in the perfect model world, it is not necessary to introduce such a period, and we simply define for the reference year the value at CP T.

The implications of the reference period and policy delay factor in the model can be illustrated in the following example for the MS 1 and MS 2 variants. If a country's 2012 level meets the first threshold level, this will be observed at time, 2015, the middle of the second CP (2013-2017). The country will adopt its first new emission intensity target for 2020, the middle of the third CP (2018-2022). At this point, the emissions change according to the intensity improvement factors taken from 2016 to 2020, using the emissions of 2015 as the reference.[7] In the MS 3 variant, where per capita emissions in the reference period determines the length of the transition period (LTS), the end of the transition period is extended with a policy time delay, necessary to fit in with middle of the next CP.[8]

Another change is the use of *CO_2-equivalent emission allowances* in preference to CO_2 emission allowances. Earlier analyses with RIVM's MS were performed on the basis of (fossil) CO_2 emissions only. A multi-gas approach has now been adopted using GWPs to convert all gases to CO_2-equivalent units. In addition, the KP allows for emission trading in CO_2 equivalent units. This implies that once countries engage in emission trading, their real

[7] If the first threshold level is already exceeded by 2005, a start will be made with the implementation of the emission intensity targets by 2012.
[8] For example, if the calculated end of the transition period is 2022, the period is extended to 2025, the middle of the next CP (2023-2027).

emissions can no longer be used as a basis for target-setting /burden sharing and threshold indicator values; furthermore, burden sharing will have to be based on assigned amount units. This also implies the necessity for a multi-gas approach.

2.2 The Per Capita Convergence variants

The Per Capita Convergence (PCC) or ‘Contraction & Convergence’ approach (Meyer, 2000), as it is commonly called, starts from the assumption that the atmosphere is a global common to which all are equally entitled. It defines emission rights on the basis of a convergence of per capita emissions under a contracting global emission profile. In the PCC approach, all Parties take up immediate participation in the regime (in the post-Kyoto period), with per capita emission permits (rights) converging to 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.

The PCC approach is based on a combination of both the egalitarian and sovereignty principles. The egalitarian principle is used within this approach to underpin the final convergence of per capita emission allowances. However, as the approach starts from the current distribution of emissions and only approaches this convergence in time, it is also clearly related to the sovereignty principle.

The assumptions for the PCC variants are indicated in Table 2.3. The two PCC variants assume a convergence of per capita CO_2-equivalent emissions by 2050 and 2100 for both emission profiles (PCC50 and PCC100 variants).

In the original Contraction and Convergence approach of the GCI, based on a non-linear convergence formula, the actual degree of convergence in per capita depends on the rate of convergence selected. This rate of convergence determines whether most of the per capita convergence takes place at the beginning or end of the convergence period. Another important parameter in the approach is (accounting for) population growth. GCI has indicated that the approach might be combined with the option of applying a cut-off year, after which population growth is no longer accounted for. For reasons of transparency, a linear converge of per capita emissions in the PCC regime variants explored has been assumed and no cut-off year for population growth has been applied. Population projections used are from the CPI baseline scenario.

Table 2.3: Two alternative variants of the Per Capita Convergence (PCC) approach for the S550e and S650e profile

Key parameters	*PCC50*	*PCC100*
Year of convergence	2050	2100
Rate of convergence	Linear	Linear
Cap population	Not applied	Not applied

3 Analysis of the Multi-Stage and PCC variants for stabilising at 550 CO_2-eq ppmv

3.1 The Multi-Stage variants

The parameter values for the MS variants and the S550e profile (as listed in Table 3.1) were selected on the following grounds: (i) meeting the global emission profile; (ii) timely participation of the non-Annex I regions and (iii) realisation of some convergence in the per capita emissions for the Annex I and non-Annex I regions before 2050.

Table 3.1: Assumptions for the MS variants for the S550e profile

Key parameters	*MS 1*	*MS 2*	*MS 3*
Stage 1 No quantitative commitments			
Stage 2 Emission limitation targets: -			
-Adoption of intensity targets	CR = 5 (*)	Same as MS 1	Same as MS 1
-Participation threshold			
-De-carbonisation rate / stabilisation	Income-dependent intensity targets (**)	Same as MS 1	Prescribed stabilisation path
Stage 3 Emission Reduction targets: participation threshold	world average per capita emissions	CR = 12	Stabilisation period (TC=70)
Burden-sharing key	Per capita CO_2 emissions	Same as MS 1	Same as MS 1

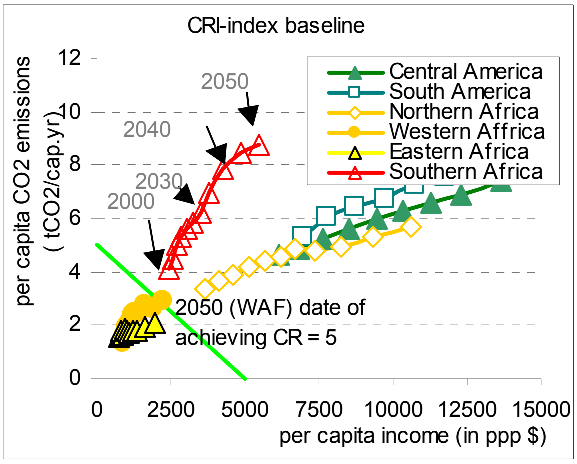
(*) The CR-index is defined as the sum of per capita income (in PPP€/cap) and per capita CO_2-equivalent emissions (tCO_2/cap yr.
(**)The de-carbonisation rate (in percentage) is a linear function of per capita income (PPP€/cap): a * PPP/cap, a = 0.33, and using a maximum de-carbonisation rate of 3%.

The same first CR-threshold of 5 is chosen for all three MS variants under the S550e profile, since in this way all non-Annex I regions, except the low-income non-Annex I regions South Asia and Western and Eastern Africa, participate in the emission-limitation stage after 2012.[9] South Asia (including India) already enters the emission-limitation stage in 2015, whereas Western and Eastern Africa participate in this stage from 2055 and 2065, respectively (CR-index exceeded 5-10 years earlier). Figure 3.1 shows per capita emissions versus the per capita income over 2000-2050, and illustrates when the CR-threshold of 5 is exceeded.

First threshold for stage 2 – CR-values under 5 imply earlier participation of Western and Eastern Africa regions, so these low-income regions already acquire intensity targets in the second commitment period. This seems too stringent and probably politically difficult to accept. Adopting such a low value only slightly affects the overall outcomes for these regions (see Figure B.1, Appendix B), since the de-carbonisation rates in stage 2 de-carbonisation are low (low-income level). This leads to emissions close to their baselines. CR-values between 5 and 10 give roughly the same results as a CR-threshold of 5. For instance, a CR-value of 8 delays the participation in the emission-limitation stage of the low-income non-Annex I regions by 10-15 years, and slightly decreases their emission allowances in the short-term. Higher CR-values (above 10) would delay the participation of low- and middle-income non-Annex I regions too long, in particular, East Asia. This not only increases the emission reduction burden of Annex I, but could also hinder the development of a viable emissions trading market. Moreover, it would imply that many

[9] For MS 1 and MS 2, these low-income non-Annex I regions have their first emission intensity targets in the middle of second commitment period (2015). For MS 3 these regions enter the stabilisation stage after 2012.

non-Annex I regions were considerably behind schedule or had even completely skipped the emission-limitation stage, since they are already able to meet the second threshold for stage 3 burden sharing, i.e. world average per capita emission threshold (MS 1) or the CR-threshold (MS 2). This would lead to sudden strong emission reductions for the non-Annex I regions when entering the emission-reduction stage (see also Figure B.1, Appendix B).



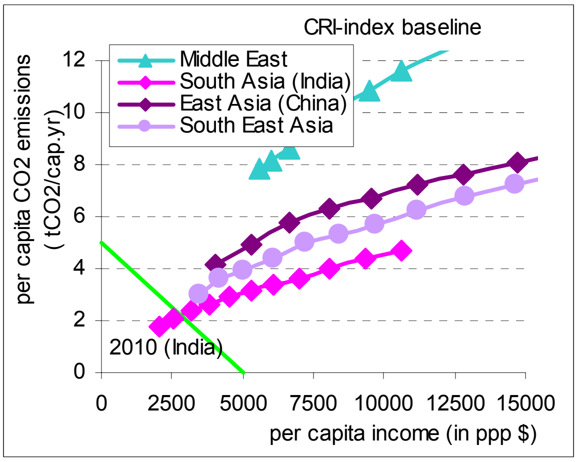


Figure 3.1: Per capita emissions versus per capita income over the 2000-2050 period for Latin American and African regions (left), and Asian regions (right), for the CPI baseline scenario. The green line depicts the threshold value, CR = 5. The dates show when this threshold is reached. Note: the dots refer to the values in 2000,2005, …, 2050.

Table 3.2: Participation of non-Annex I regions in the emission-limitation stage (stage 2) for the MS variants

Regions	Central America	South America	Northern Africa	Western Africa	Eastern Africa	Southern Africa	Middle East	South Asia	East Asia	SE Asia
Stage 2	2012	2012	2012	2055	2065	2012	2012	2015	2012	2012

Note: participation in 2012 means that from 2012 on a region participates in the emission-limitation stage, with their first emissions intensity target by 2015.

Main finding

- Under the S550e emission profile, a first threshold based on a Capability–Responsibility (CR) index of five results in early participation (2015) of all non-Annex I regions, except for South Asia (after 2015) and Western and Eastern Africa (after 2050) in the emission-limitation stage.

Second threshold MS 1 –For the second participation threshold for the emission-reduction stage, the MS 1 variant assumes 100% of world average per capita emissions. This threshold results in a gradual convergence of per capita emissions between Annex I and non-Annex I overtime. A value below 100% results in a premature participation of the non-Annex I regions. The per capita emissions of Annex I and non-Annex I also start to diverge. A value of more than 110% results in a convergence of the Annex I and non-Annex I per capita emissions before 2040. The East Asia (China) region plays a key role in this outcome. When East Asia enters the emission reduction regime, its emission allowances will have to decrease considerably, thereby relaxing the emission reductions for the other participating regions. For this reason, East Asia's entry strongly determines the reduction efforts of the Annex I countries. For the 100% variant, East Asia enters the emission-reduction stage in 2020, for 110%, 5 years later and for 120%, again 5 years later (see Figure B.2 in Appendix B).

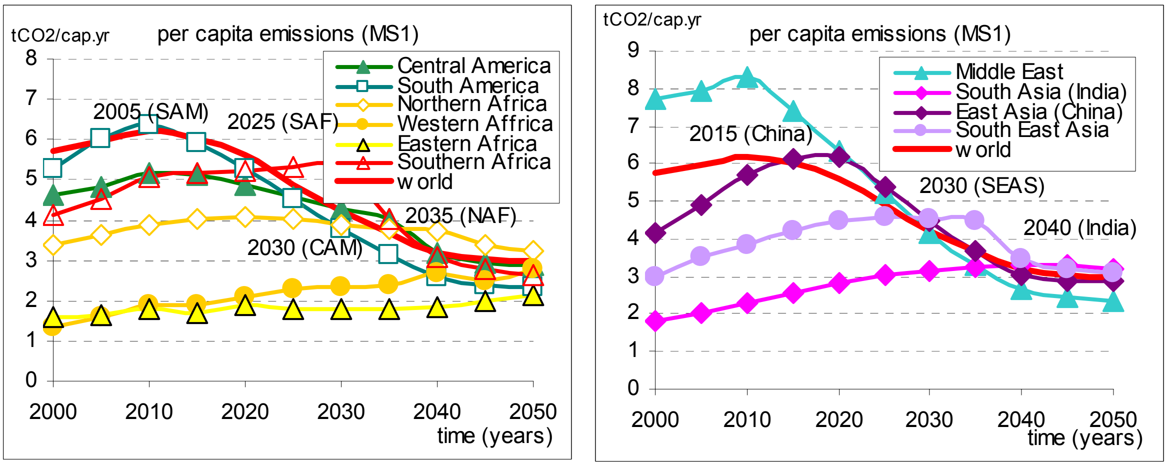


Figure 3.2: Per capita CO_2-equivalent emissions over the 2000-2050 period for Latin American and African regions (left), and Asian regions (right), for the MS 1 variant. The thick red line depicts the threshold value of world average per capita emissions. The dates show when this threshold is reached.

Table 3.3 shows when non-Annex I regions start participating in the emission-reduction stage. The moment the threshold level is reached is depicted in Figure 3.2. This clearly shows that the actual participation is delayed by 5-9 years due to policy delays (see section 2.2). Almost all non-Annex I regions now participate before 2050, except for Western and Eastern Africa. South America and the Middle East & Turkey will have to participate directly in the emission-reduction stage after Kyoto, since they already reach the per capita emission threshold by 2000 and, so, skip the emission-limitation stage.

Table 3.3: Participation of non-Annex I regions in the de-carbonisation and emission-reduction stage (stages 2 and 3) for the MS1 variant

Regions	Central America	South America	Northern Africa	Western Africa	Eastern Africa	Southern Africa	Middle East	South Asia	East Asia	SE Asia
Stage 2	2012	----	2012	2055	2065	2012	---	2015	2012	2012
Stage 3	2035	2012	2040	2060	2075	2030	2012	2045	2020	2035

Main findings

- A participation threshold based on world average per capita emissions implies that the emission reduction efforts of Annex I regions will enhance the participation of the non-Annex I regions.
- This threshold in combination with the use of per capita emissions as burden-sharing key tends to result in some convergence of per capita emissions of Annex I and non-Annex I regions in the long term (by 2050).

Second threshold MS 2 – The assumptions for the MS 2 variant are the same as for MS 1, except for the threshold for the emission-reduction stage, which is now based on a second CR-index set on CR = 12. Higher CR-values represent the main delay in the participation of the major non-Annex I regions (in particular, East Asia), thereby increasing the Annex I reduction efforts (see also Figure C.1). A lower CR-value would imply the early participation of the low- and middle-income non-Annex I regions, especially for East Asia and Southern Africa, which may not be realistic. CR-values as high as 15 lead to negative emission allowances for the Annex I regions. Therefore, a CR-threshold value of 12 was chosen.

Compared to their participation under the dynamic per capita emission threshold, a participation threshold based on a CR = 12 value results into an earlier participation of the low- and middle-income non-Annex I regions, especially East Asia and South-East Asia. This threshold delays the participation of the low- and middle- income non-Annex I regions, especially Southern Africa, with a low per capita income, but relatively high per capita emissions, and the low-income non-Annex I regions (see Tables 3.4) (see also Figure 3.3). There are now also a number of regions that skip the emission-limitation stage, and enter the emission-reduction stage directly after Kyoto, i.e. Central America, South America, Middle East & Turkey and East Asia. The outcomes are quite sensitive for the exact CR-value (see also Figure C.1).

Table 3.4: Participation of non-Annex I regions in the de-carbonisation and emission-reduction stage for the MS 2 variant (the difference with the entry date of stage 3 for MS 1 is also given here, in which the grey boxes indicate the earlier entry variants)

Regions	Central America	South America	Northern Africa	Western Africa	Eastern Africa	Southern Africa	Middle East	South Asia	East Asia	SE Asia
Stage 2	---	---	2012	2055	2065	2012	----	2015	---	2012
Stage 3	2015	2012	2050	2100	2100	2060	2012	2050	2015	2030
Comp. to MS 1	20 yr earlier	Same	10 yr later	40 yr later	25 yr later	30 yr later	Same	5 yr later	5 yr earlier	5 yr earlier

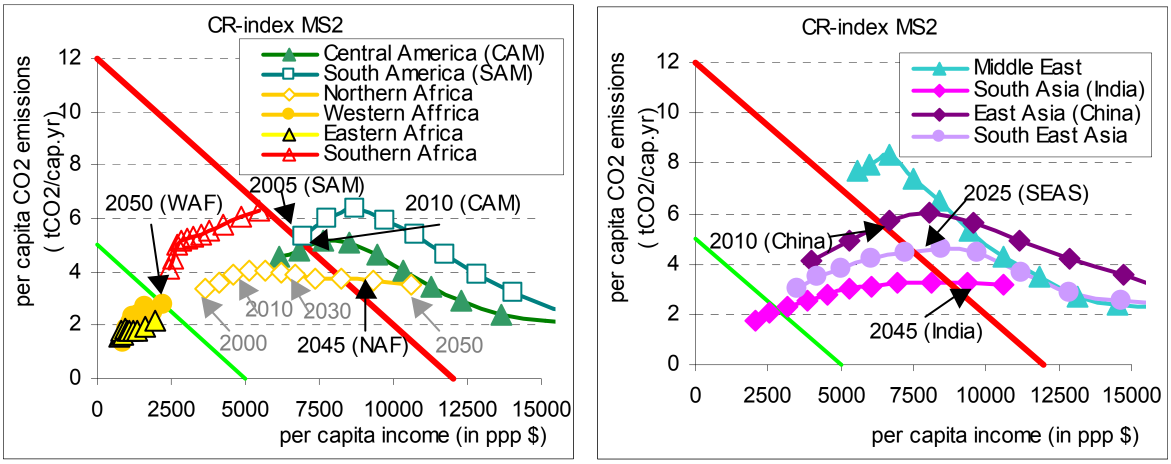


Figure 3.3: Per capita emissions versus per capita income over the period 2000-2050 for Latin American and African regions (left), and Asian regions (right), for the MS 2 variant. The green line depicts the first threshold value CR = 5 and the red line the second threshold CR = 12. The dates show when this threshold was reached.

Main findings

- Compared to a participation threshold based on world average per capita emissions (MS 1), a threshold for the emission-reduction stage based on a Capability–Responsibility index (MS 2) of 12 results in the short-term in an earlier participation of middle- and high-income non-Annex I regions (Latin America, Middle East & Turkey) and South-East & East Asia. However, the participation of Southern and Northern Africa (low per capita income and relatively high per capita emissions) and the low-income non-Annex I regions comes later.

Second threshold MS 3 – The MS 3 variant differs from the previous MS 1 and MS 2 variants with respect to the second transition stage. Instead of de-carbonisation targets, allowable emissions in the transition stage are determined by a prescribed slowing-down of the emission growth to a final stabilisation. The length of the transition period is not determined by the level of as second threshold, but by a transition constant (TC) value, the length of which is calculated by dividing the TC value by per capita emissions (in tCO_2/cap yr[?? zie pag. 18]) in the reference period. Here, a value of 70 was chosen for TC as this results by 2040 in a convergence in Annex I and non-Annex I per capita emissions under the S550e profile. A sensitivity analysis for different TC values is presented in Appendix D (Figure D.1), while Table 3.5 presents the length of the stabilisation period, which is also indicated with the red line in Figure 3.4.

Compared to a per capita emission threshold (MS 1), this approach leads for the non-Annex I regions, except for Central America, Northern Africa and South-East Asia, to a later participation in the emission-reduction stage. However, compared to a CR-threshold (MS 2), this approach leads to a later participation of middle- and high-income non-Annex I regions and an earlier participation of the low-income non-Annex I regions.

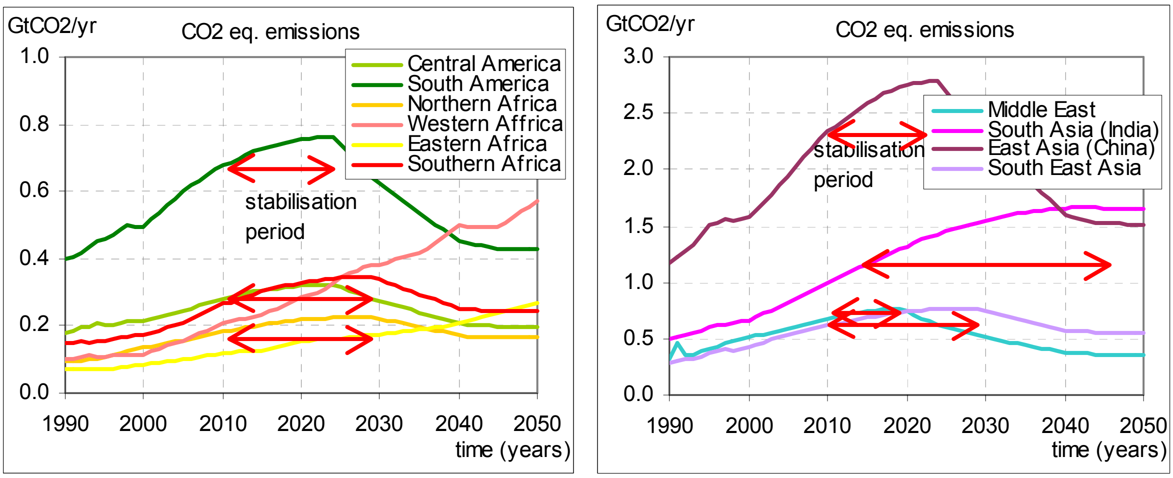


Figure 3.4: Total emission allowances over the 2000-2050 period for the Latin American and African regions (left), and Asian regions (right), for the MS 3 variant. The red line shows the stabilisation period in which the first threshold was reached.

Table 3.5: Participation of non-Annex I regions in the de-carbonisation and emission-reduction stage for the MS 3 variant (the differences between entry date of stage 3 for MS 1 and for MS 2 are also given, in which the grey boxes indicate the earlier entry variants)

Regions	Central America	South America	Northern Africa	Western Africa	Eastern Africa	Southern Africa	Middle East	South Asia	East Asia	SE Asia
Stage 2	2012	2012	2012	2055	2065	2012	2012	2015	2012	2012
Stage 3	2025	2025	2030	2085	2095	2030	2020	2045	2025	2030
Stab. Period	15	15	20	30	30	20	10	30	15	20
Comp. to MS 1	10 yr earlier	15 yr later	10 yr earlier	5 yr later	20 yr later	5 yr later	10 yr later	Same	5 yr later	5 yr earlier
Comp. to MS 2	10 yr later	15 yr later	20 yr earlier	15 yr earlier	5 yr earlier	30 yr earlier	10 yr later	5 yr earlier	5 yr later	Same

Main findings

- The MS 3 approach with a TC value of 70 leads in the short-term to later participation of the middle- and high income non-Annex I (East Asia).

3.2 The Multi-Stage and Per Capita Convergence results

Timing of participation for the MS variants – Table 3.6 briefly overviews the participation of the non-Annex I regions in the emission-limitation and emission-reduction stage. All three MS variants show an early entry in the emission-limitation stage – before 2020 – of most non-Annex I regions, except for Western and Eastern Africa, which only enter after 2050.

For the emission-reduction stage, MS 2 leads to the earliest entry for the middle- and high-income non-Annex I regions, whereas the MS 3 variant shows the latest entry. All three MS variants lead for the low-income non-Annex I regions to a late entry, especially for the MS 2 and MS 3 variants. For the low- and middle-income region Southern Africa, there are notable differences in the entry dates. Due to its relatively high per capita emission level, this region participates early in Stage 3 in the MS 1 variant (emission trigger) and MS 3 variant (short transition period), whereas the CR-threshold in MS 2 delays the participation in Stage 3.

Table 3.6 S550e profile, entry dates of non-Annex I regions in Stage 2 and 3

Regions	Central America	South America	Northern Africa	Western Africa	Eastern Africa	Southern Africa	Middle East	South Asia	East Asia	SE Asia
Stage 2	2012	2012	2012	2055	2065	2012	2012	2015	2012	2010
Stage 3										
Multi-Stage 1	2035	2010	2040	2060	2075	2030	2012	2045	2020	2035
Multi-Stage 2	2015	2012	2050	2100	2100	2060	2012	2050	2015	2030
Multi-Stage 3	2025	2025	2030	2085	2095	2030	2020	2045	2025	2030

* For each region, white boxes indicate the earliest entry variant, dark-grey the latest, and light grey in between.
** South America and Middle East & Turkey enter directly into Stage 3 after Kyoto

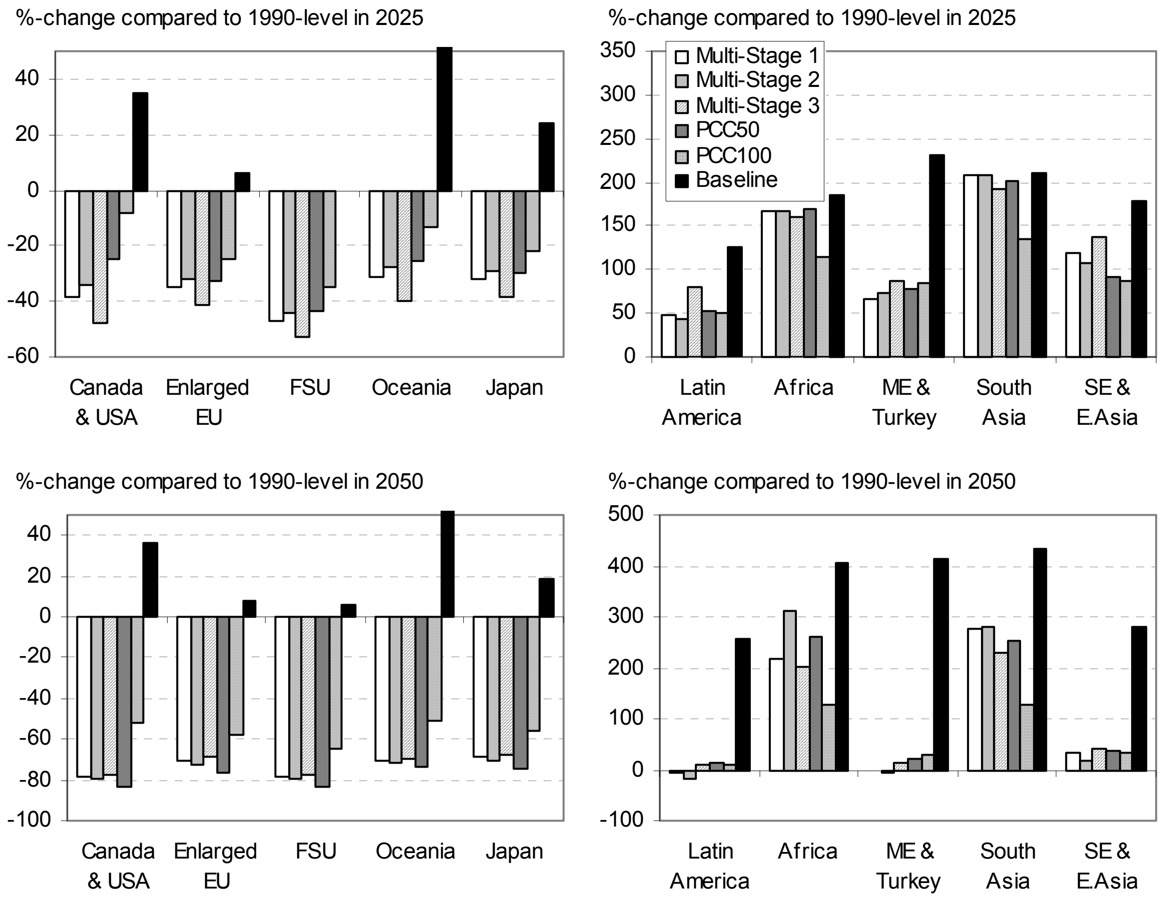


Figure 3.5: Percentage change in the CO_2-equivalent emission allowances relative to the 1990 level for the MS and PCC variants in 2025 and 2050 under the S550e profile.

Figure 3.5 depicts the change in the ratio of allowances to the 1990 level for 10 aggregated regions and two time horizons, short-term (2025) and long-term (2050). Regional emission allowances can also be compared with the corresponding baseline emissions, providing more information on the magnitude of actual effort required from the different Parties (Figure 3.6). Therefore, Table 3.7 provides both ratios of reduction.

Comparing emission allocations for the MS variants – For the Annex I regions, the lowest reductions are for MS 2, whereas MS 3 shows the highest reduction levels. This is a direct result of the respectively early and late entry into stage 3 of middle- and high-income non-Annex I regions. These regions show an opposite pattern, with the lowest reductions in MS 3. The East Asia region plays a key role in the MS outcomes, since when East Asia enters the emission-reduction stage, it considerably relaxes the reductions for the other participating regions, i.e. Annex I. For the low-income non-Annex I regions, the MS 3 variant is, in general, the regime with the strongest constraints due to higher reductions in the emission-limitation stage. For the Southern Africa region, the differences in the entry dates for MS variants explain the wide range in outcomes (Table 3.6).

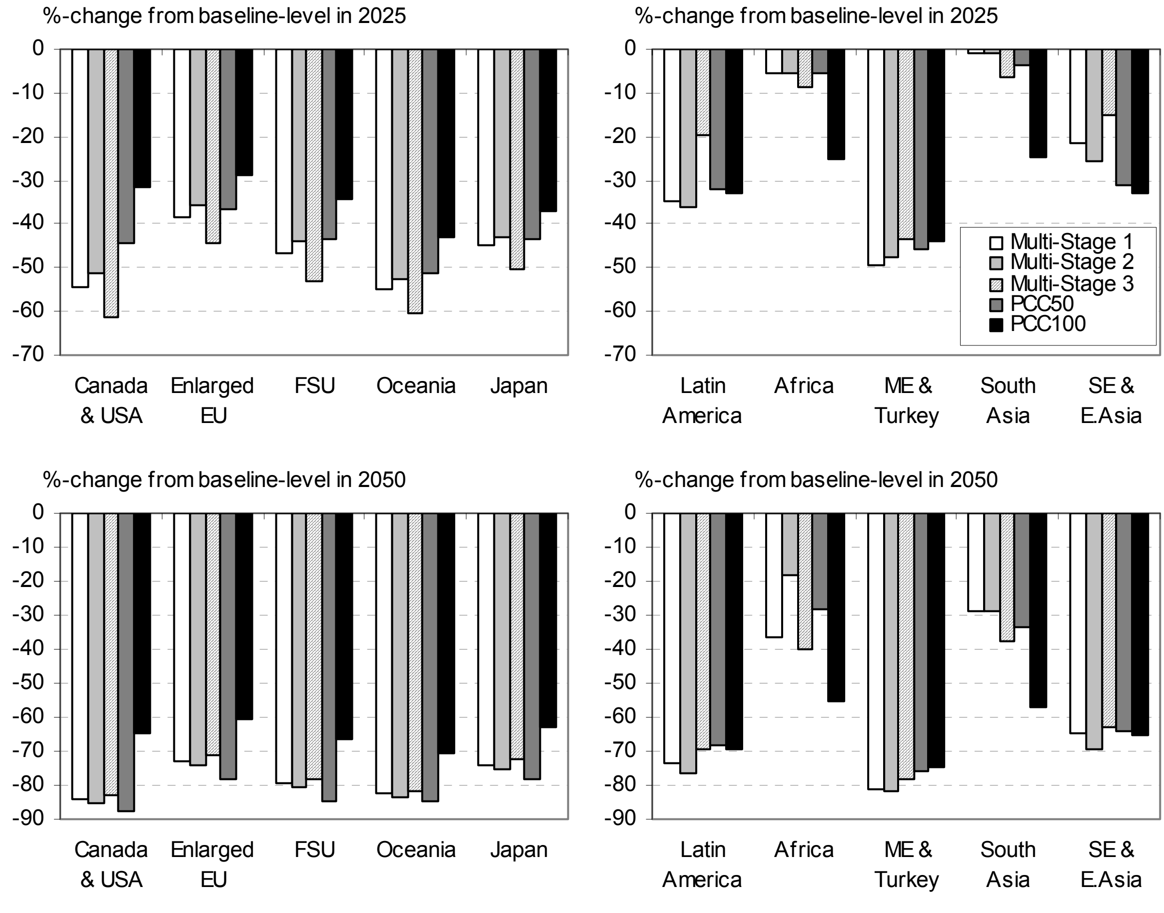


Figure 3.6: Percentage change in the CO_2-equivalent emission allowances relative to the baseline-level for the MS and PCC variants in 2025 and 2050 under the S550e profile.

Annex I and non-Annex I targets for the MS variants – In 2025, the Annex I regions need to reduce their emissions by about 30-60% compared to 1990 levels, whereas the non-Annex I regions can still increase their emissions compared to 1990 levels. Nevertheless, the non-Annex I regions do have to reduce their emissions compared to the baseline levels. The reductions are more differentiated across non-Annex I regions than across Annex I regions (see Table 3.7). The low-income non-Annex I regions experience small emission constraints in all MS variants, with emissions close to their baseline (less than 10-20% reduction).

In 2050, the differences for the Annex I regions are relatively small, with reductions in the order of 70-80% for the MS variants. The middle- and high-income non-Annex I regions show high reductions. For the low-income non-Annex I regions, the reductions compared to the baseline emissions are still less compared to the other regions, but already reach percentages of 30-40% for South Asia, and 30-70% for Northern and Southern Africa; only Western and Eastern Africa still follow their baseline emissions.

Main findings:
Emission-limitation stage
- For the emission-limitation stage all MS variants show an early participation of the non-Annex I regions, except for Western- and Eastern Africa (after 2050).

Emission-reduction stage
- For the middle- and high-income non-Annex I regions MS 2 leads to the earliest entry (already in the second CP), whereas MS 3 shows the latest entry.
- For the low-income non-Annex I regions, all three MS variants show a late entry, especially for MS 2 and MS 3.

Emission allowances
Short-term:
- For the Annex I regions the MS 2 variant leads to the lowest emission reduction efforts, whereas MS 3 leads to highest reduction efforts. This is a result of the earlier entry of middle- and high-income non-Annex I regions for MS 2.
- The middle- and high-income non-Annex I region show an opposite pattern.
- The emissions of low-income non-Annex I regions are close to the baseline emissions.

Long-term
- For the Annex I regions all MS variants lead to high emission reductions efforts.
- Also the middle- and high-income non-Annex I regions show high reductions.
- For the low-income non-Annex I regions, the MS 3 variant represents the regime with the strongest constraints due to higher reductions in stage 2.

Table 3.7: Reductions for the MS (MS) and PCC variants in the year 2025 and 2050 under the S550e profile for the CPI baseline scenario
(a) compared to baseline emissions

S550e profile	2025					2050				
Regions	MS1	MS2	MS3	PCC50	PCC100	MS1	MS2	MS3	PCC50	PCC100
USA	54	51	61	43	30	84	85	83	88	64
Canada	57	55	62	53	45	82	83	81	85	70
OECD Europe	40	37	46	38	30	73	74	72	78	61
Eastern Europe	33	30	39	31	24	71	73	70	77	59
Former USSR	47	44	53	44	34	80	81	78	85	66
Oceania	55	53	61	51	43	83	83	82	85	71
Japan	45	43	50	44	37	74	75	73	78	63
Central America	25	34	20	29	32	65	74	67	63	67
South America	39	37	20	33	33	77	78	71	70	70
Northern Africa	12	12	11	19	28	42	36	57	46	59
Western Africa	0	0	0	-13	19	0	0	0	-8	39
Eastern Africa	0	0	0	-44	-1	0	0	0	-40	22
Southern Africa	9	9	17	32	38	70	28	72	66	74
ME & Turkey	49	48	43	46	44	81	82	78	76	75
South Asia	1	1	6	3	25	29	29	38	33	57
SE & E.Asia	21	26	15	31	33	65	69	63	64	66
World	32	32	32	32	32	64	64	64	64	64

(b) compared to 1990 emissions

S550e profile	2025					2050				
Regions	MS1	MS2	MS3	PCC50	PCC100	MS1	MS2	MS3	PCC50	PCC100
USA	39	34	48	24	6	79	80	77	84	51
Canada	40	37	48	35	24	75	77	74	79	58
OECD Europe	34	31	41	32	24	70	72	69	76	57
Eastern Europe	37	34	43	35	28	71	73	70	77	59
Former USSR	47	44	53	44	35	79	80	77	84	65
Oceania	32	28	40	26	13	71	72	69	74	51
Japan	32	29	38	30	22	69	71	67	74	56
Central America	-63	-43	-74	-53	-47	-19	13	-10	-24	-10
South America	-40	-44	-84	-53	-54	16	18	-7	-8	-8
Northern Africa	-138	-138	-139	-117	-93	-135	-158	-74	-117	-64
Western Africa	-240	-240	-240	-286	-174	-466	-466	-466	-513	-244
Eastern Africa	-135	-135	-135	-239	-138	-291	-291	-291	-446	-203
Southern Africa	-154	-154	-131	-88	-73	-73	-318	-63	-98	-51
ME & Turkey	-67	-73	-87	-78	-86	3	6	-12	-23	-29
South Asia	-208	-208	-191	-200	-134	-278	-279	-231	-255	-128
SE & E.Asia	-119	-107	-137	-92	-87	-34	-17	-41	-36	-31
World	-22	-22	-22	-22	-22	15	15	15	15	15

3.2.1 The Per Capita Convergence results

- *Comparing emission allocations with the Per Capita Convergence variant* – The PCC variants generally show larger differences in regional emission allowances than the MS variants. By 2025 Annex I reductions from 1990 levels range from 25 to 45% for the PCC50 variant and less than 10% to 35% for the PCC100 variant. The difference in convergence year appears to have a major influence on the distribution of emission allowances among Annex I and non-Annex I regions. A delay in the convergence year results in much smaller reductions in Annex I emission allowances on both the short and longer term. The PCC100 variant results in substantial smaller emission reductions for the Annex I regions than the PCC50 variant and also than the MS variants, and vice versa for the non-Annex I regions. The results of PCC50 variant are comparable to the MS variants, with some qualifications. First, for Annex I, the emission reductions for the PCC50 variant tend to be smaller in the short term and larger in the long term than the MS variants. Particularly in the variant of the USA/Canada, the MS variants in the short term result in much larger reductions than the PCC50 variant. Second, for SE& East Asia, the PCC50 also results in larger emission reductions (from baseline levels) than in the MS variants, since their per capita emissions are close to the world-average. Finally, it is interesting to note that Western and Eastern Africa gain from the excess emission allowances (not shown). However, under the considered baseline and S550e profile, the PCC50 variant does not lead to significant amounts of excess emissions. In fact, due to the higher per capita emissions of Southern Africa, there are no excess emissions for Africa as a whole. In contrast, Africa, like South Asia, would already need to substantially limit its emissions in the PC100 variant.

Figure 3.7 also depicts for eight aggregated Annex I and non-Annex I regions the emission allowances for all MS and PCC variants, as well as their baseline emissions.

Main findings:

- The PCC100 variant results into substantial smaller emission reduction efforts for the Annex I regions than the other MS variants and PCC50 variant. The PCC100 variant is thus the most attractive for Annex I and least attractive for the non-Annex I regions. The results of PCC50 variant are more comparable to the MS variants.
- On the short term, for the US & Canada the PCC50 variant is more attractive than the MS variants; for the other Annex I regions the differences are relatively small. The MS 3 variant remains the least attractive for the Annex I regions on the short term.
- In the long term, the PCC50 variant is less attractive for Annex I regions than the MS variants.
- For the middle- and high income non-Annex I regions (Latin America, Middle East & Turkey) the MS 3 approach remains the most attractive approach.
- For the low-income non-Annex I regions the differences in results of the PCC and MS variants are relatively large. The PCC50 variant is generally not more favourable for the low-income regions than the MS variants. In particular MS 2 variant is generally more favourable.
- The PCC approach can result into excess emission allowances. However, under the S550e profile and the CPI baseline, the PCC variants do not lead to significant amounts of excess emissions.

Box 3.1 Relative attractiveness of the MS and PCC variants

Table 3.8 and 3.9 ranks the percentage change relative to the baseline-emission level for the target year, 2025, of each regime in comparison to the outcomes of the other regimes explored. The approach resulting in, relatively speaking, the lowest relative emission reductions (or highest emission allowances) is indicated in green, hereafter classified as the most favourable or most attractive approach compared to the other regimes explored. The approach resulting in the highest relative emission reductions (or lowest emission allowances) is indicated in red; this will be forthwith classified as the most favourable or most attractive approach compared to the other regimes explored. White indicates an intermediate position. It should be noted that this ranking is always in relative comparison to the outcomes of the other regimes explored.

*Table 3.8: Regional relative scores for different approaches by **2025** for the reference variants compared to baseline for the S550e profile* *

S550	MS 1	MS 2	MS 3	PCC50	PCC100
Canada &USA	55	51	61	44	32
OECD-Europe	40	37	46	38	30
EEUR &FSU	44	41	50	41	32
Oceania	55	53	61	51	43
Japan	45	43	50	44	37
Latin America	35	36	20	32	33
Africa	6	6	8	6	25
ME & Turkey	49	48	43	46	44
South Asia	1	1	6	3	25
SE & East Asia	21	26	15	31	33

* *Green area indicates most attractive regime, and red area indicates least attractive regime for each region*

*Table 3.9: Regional relative scores for different approaches by **2050** for the reference variants compared to baseline for the S550e profile* *

S550	MS 1	MS 2	MS 3	PCC50	PCC100
Canada &USA	84	85	83	88	65
OECD-Europe	73	74	72	78	61
EEUR &FSU	78	79	77	83	65
Oceania	83	83	82	85	71
Japan	74	75	73	78	63
Latin America	73	77	70	68	70
Africa	37	18	40	28	55
ME & Turkey	81	82	78	76	75
South Asia	29	29	38	33	57
SE & East Asia	65	69	63	64	66

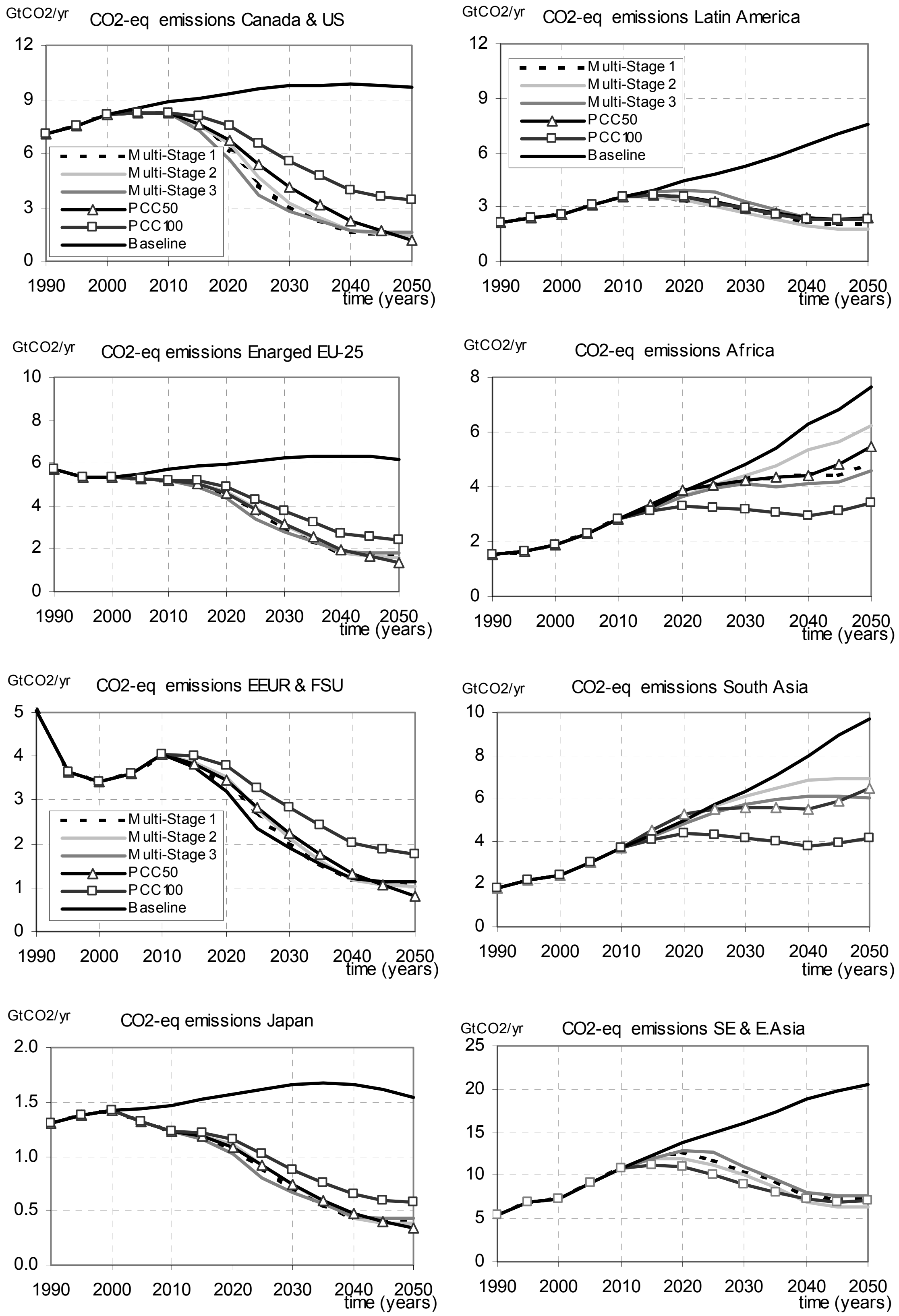


Figure 3.7: CO_2-equivalent emission allowances for the MS and PCC variants for the S550e profile for the period 1990-2050 for the selected Annex I and non-Annex I regions.

3.3 Robustness of results for the Multi-Stage variants for the S550e profile

As the results found are based on various assumptions we explored the robustness of our findings by performing a sensitivity analysis by varying the key parameters. We focused on the assumptions for the MS variants since the sensitivity of the PCC results to the selection of the convergence year is already shown. We varied the values of the main participation thresholds of the Stage 3 for MS 1 and MS 2, as well as the transition constant for MS 3 (first three column bars). More specifically, for MS 1: 80-120 % of world-average per capita emission threshold, for MS 2 CR-threshold 10-15 and for MS 3: TC value 50-100. Figure 3.8 shows the results (first three columns).

Figure 3.8 shows that for the Annex I regions, MS 3 retains the highest reductions in the short term. In general, the difference in the outcomes of MS 1 and MS 2 are small. Depending on the parameter settings of MS 1 and MS 2, PCC50 may now no longer result in fewer reductions than the MS variants in the short term, and the largest reduction in the long term. PCC100 remains the variant with the lowest reductions in both the short and long term.

For the middle- and high-income non-Annex I regions, changes in the parameter values do affect the outcomes, but MS 3 still leads to the smallest reductions. For these regions, different thresholds for the entry to stage 2 can have a significant influence on the allowances under the MS 1 regime, since their per capita emissions are close to the world average (especially for the South-East and East Asia and the Middle East). Changing the Capacity-Responsibility threshold (MS 2) seems to have a smaller impact on the outcomes.

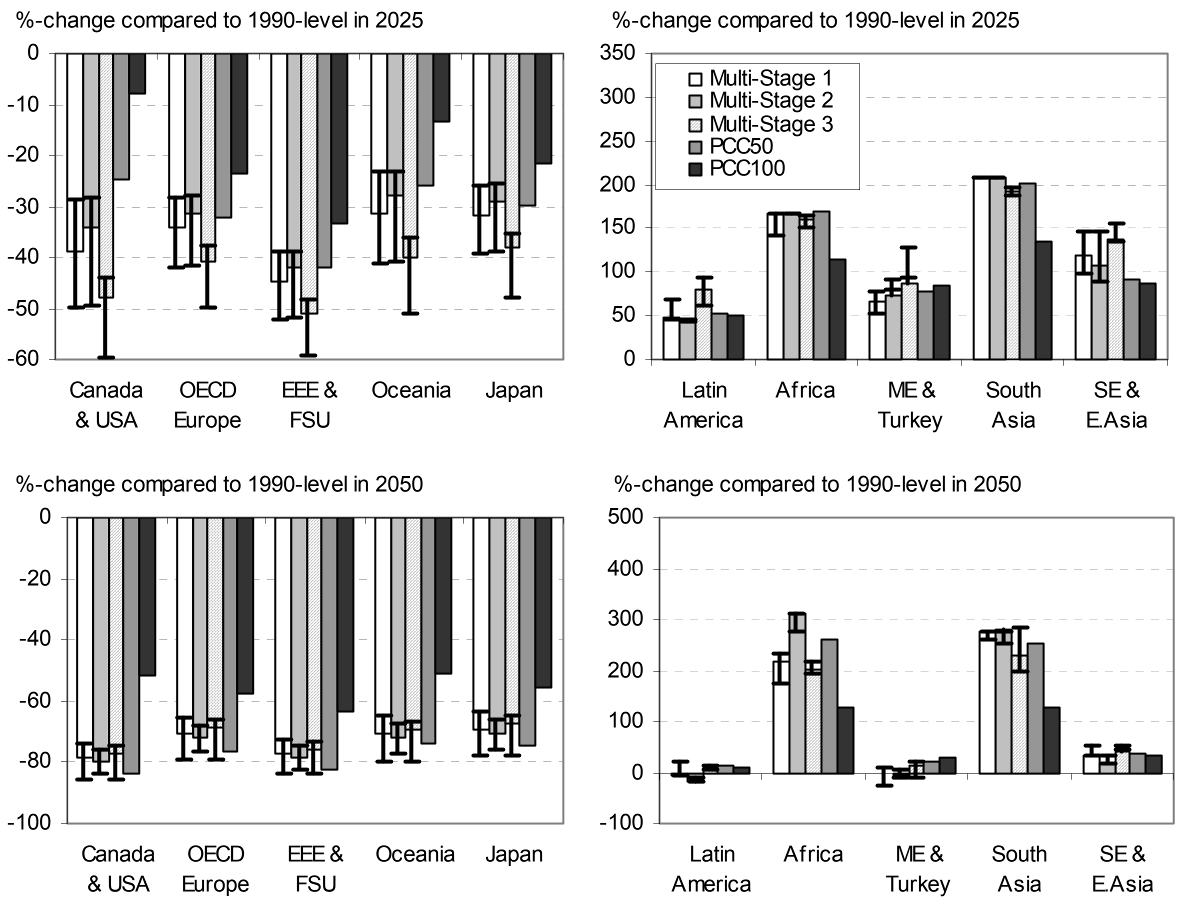


Figure 3.8: Robustness of results for the MS variants under the S550e profile.

For the low-income non-Annex-I regions, changes of parameter values for the MS 1 and MS 2 variants do not affect the outcomes in the short-term, since they do not yet participate in the emission-reduction stage. For MS 3, the effect of changing the TC value is also small. For the Annex-I regions, MS 3 remains the one with the highest reductions on the short-term and PCC100 the one with the lowest reductions. Depending on the parameter settings of MS 1 and MS 2, now PCC50 may no longer be more the one with the lower reductions. In general, the difference the outcomes of MS 1 and MS 2 are small. In the long term the differences between the MS variants and PCC50 become small.

4 Analysis of the Multi-Stage and PCC variants for stabilising at 650 CO_2-eq ppmv

4.1 The Multi-Stage variants

The S650e profile corresponds to a significantly less severe constraint and results in a less pressing need for non-Annex I regions to contribute to global emission control. Thus, the different parameters can be significantly relaxed in the S650e variant compared to their values in the much more stringent S550e variant. The CR-threshold values are higher, the maximum value for the de-carbonisation rate is lower and the stabilisation periods are longer. Table 4.1 provides an overview of the assumptions made in implementing the various MS variants under the S650e profile. All MS variants again use the same assumptions for the following policy variables: (i) first participation threshold, (ii) linear de-carbonisation rate, and (iii) burden-sharing key.

Table 4.1: Assumptions for the MS variants for the S650e profile

Key parameters	*MS 1*	*MS 2*	*MS 3*
Stage 1 No quantitative commitments			
Stage 2			
Adoption of intensity targets Participation threshold	CR = 12	Same as MS 1	Same as MS 1
De-carbonisation rate / Stabilisation	Linear de-carbonisation rate(*)	Same as MS 1	Same as MS 2
Stage 3 Burden-sharing regime Participation threshold	120% of world average per cap emissions	CR = 20	Stabilisation period (TC = 100)
Regime of burden sharing	Per capita CO_2 emissions	Same as MS 1	Same as MS 1

(*) The de-carbonisation rate (in percentage) is a linear function of per capita income (PPP€/cap): a * PPP/cap, a = 0.33, and using a maximum de-carbonisation rate of 2.5%.

First threshold for stage 2 – As early participation of non-Annex I regions and stringent intensity improvements are no longer necessary, the first CR-threshold level has been relaxed to 12, and the maximum de-carbonisation rate has been reduced to 2.5%/year. This results in a sufficiently early participation of middle- and high-income non-Annex I regions in Stage 3, while still leaving them some time in the transition stage. Table 4.2 depicts the moment of participation in the emission-limitation stage for the non-Annex I regions based on different CR-threshold values (see also Figure F.1). A threshold of CR = 10 leads to an early participation of the middle- and high-income non-Annex I regions (including East Asia) in the second commitment period (see also Figure F.1), which for this higher emission profile is not necessary, and probably also politically unacceptable. A higher threshold of CR = 15 results in late participation of the middle- and high-income non-Annex I regions in the emission-limitation stage. For instance, East Asia would participate only after 2025. Furthermore, in the MS1 variant, the regions stay for only a very limited time (less than 5-10 years) in the emission-limitation stage, since their per capita emission levels would soon exceed the world average levels.

This is why we selected the middle CR-value of 12, which leads to late participation for Northern and Southern Africa, South Asia (India) and South-East Asia, however, participation was still before 2050. Western and Eastern Africa do not participate in the emission-limitation stage at all before 2050. The high-income non-Annex I regions (Central America, Latin America and the Middle East & Turkey) participate directly after Kyoto, whereas the East Asia region enters the transition stage only after 10 years.

Table 4.2: Time at which CR-threshold for participation of non-Annex I regions in the transition stage is met

Regions	Central America	South America	Northern Africa	Western Africa	Eastern Africa	Southern Africa	Middle East	South Asia	East Asia	SE Asia
CR = 10	2012	2012	2025	----	----	2040	2012	2040	2012	2020
CR = 12	2015	2012	2040	----	----	2040	2012	2050	2015	2025
CR = 15	2025	2015	2055	----	----	2040	2012	2055	2025	2035
CR = 12 Comp. to S550e	5 yr later	Same	15 yr later	45 yr later	35 yr later	35 yr later	Same	35 yr later	5 yr later	15 yr later

Main findings

- Under the S650e profile, a first threshold of CR = 12 leads to late participation for Northern and Southern Africa, South Asia (India) and South-East Asia, however, participation is still before 2050. The high-income non-Annex I regions participate directly after 2012, while East Asia participates 10 years later. Low-income non-Annex I regions do not participate in the emission-limitation stage at all before 2050.

Second threshold for MS 1 – The MS 1 variant assumes a second threshold of 120% of world average per capita emissions for participation in the emission-reduction stage. This results in some convergence of Annex I and non-Annex I per capita emissions over time, but not before 2050. Setting the threshold at 100%, instead of 120% (see Figure F.2 in Appendix F), increases the contribution of non-Annex B regions, and does not result in divergence, but instead in some convergence of Annex I and non-Annex I per capita emissions. If the threshold is set at 125% or more, there is a late entry of the non-Annex I regions into the emission-reduction stage, and non-Annex I regions per capita emissions will exceed the Annex I per capita emissions.

The 120% factor leads to an entry of the Middle East & Turkey in 2012, East Asia and Southern Africa in 2040, but all other non-Annex I regions do not enter the emission-reduction stage at all. The emission intensity factors already lead to lower growth rates of per capita emissions, the final per capita emissions never exceed the 120% level. The resulting per capita emissions of Annex I and non-Annex I tend to converge by 2100.

Table 4.3: Participation of non-Annex I regions in the de-carbonisation and emission-reduction stage (stage 2 and 3) for the MS 1 variant

Regions	Central America	South America	Northern Africa	Western Africa	Eastern Africa	Southern Africa	Middle East	South Asia	East Asia	SE Asia
Stage 2	2015	2012	2040	----	----	2040	2012	2050	2015	2025
Stage 3	----	----	2090	----	----	2045	2012	----	2045	----

Main findings

- Under the S650e profile, a participation threshold based on 120% of world average per capita emissions implies that the per capita emissions of Annex I and non-Annex I tend to converge by 2100.

Sensitivity in the maximum de-carbonisation rate – Appendix F.3 illustrates the impact of different maximum de-carbonisation rates for the MS 1 variant, clearly indeed that this factor has a large impact on the emission reduction efforts of the Annex I and the participating non-Annex I regions.

Second threshold for MS 2 – The same assumptions are made here, except for the participation threshold for the emission-reduction stage, which is now based on a threshold of CR = 20. Lowering the CR-value reduces the Annex I reduction efforts, but results in a short emission-limitation stage for non-Annex I regions. Higher CR-values delay the participation of the middle-income non-Annex I regions and lead to high Annex I reduction efforts (see also Figure G.1). In the short term, the impact of different CR-values between 15 and 30 is limited, but in the long term can lead to a wide range of outcomes for both the Annex I regions, and the middle- and high income non-Annex I regions.

Again, just as under the S550e profile, the double CR-threshold approach leads to an earlier participation of non-Annex I regions than the MS 1 variant (see Table 4.4), except for Southern Africa and the Middle East. Especially Southern Africa gains from the CR-threshold, due to its low-income combined with high per capita emissions. The per capita emissions from these countries eventually exceed by far the 120% level of the world average per capita emissions, and also the Annex I per capita emissions.

Table 4.4: Participation of non-Annex I regions in the de-carbonisation and emission-reduction stage for the MS 2 variant (the difference between MS2 variant and the entry date of stage 3 for MS 1 is also given here, where grey boxes indicate the earlier entry variants).

Regions	Central America	South America	Northern Africa	Western Africa	Eastern Africa	Southern Africa	Middle East	South Asia	East Asia	SE Asia
Stage 2	2015	2012	2040	----	----	2040	2012	2050	2015	2025
Stage 3	2055	2045	2075	----	----	----	2045	2080	2040	2050
Comp. to MS 1	45 yr earlier	55 yr earlier	15 yr earlier	Same	Same	55 yr later	35 yr later	20 yr earlier	5 yr earlier	50 yr earlier

Main findings

- Under the S650e profile, a participation threshold for burden sharing based on the CR-threshold implies an earlier entry of the middle-and high income non-Annex I regions than one based on world average per capita emissions.

Second threshold for MS 3 – For the MS 3 variant under the S650e profile, we use a TC value of 100 (instead of the 70 for the S550e profile) to extend the stabilisation period for the non-Annex I regions, thereby reducing their reduction efforts under this profile. Figure D.1 analyses the influence of different TC values; from this it can be seen that the influence is rather limited (see Figure H.1).

Table 4.5 shows the timing of participation in the emission-reduction stage. Similar to the MS 3 variant under the S550e profile, this variant leads to an earlier participation of the non-Annex I regions in the emission-reduction stage, especially for Central America, South America, Northern Africa, and South (India) and East Asia, when compared to MS 1.

Table 4.5: Participation of non-Annex I regions in the de-carbonisation and emission-reduction stage for the MS 3 variant (the difference in the entry date of stage 3 between MS 1 and MS 3 is also given here, where the grey boxes indicate the earlier entry variants)

Regions	Central America	South America	Northern Africa	Western Africa	Eastern Africa	Southern Africa	Middle East	South Asia	East Asia	SE Asia
Stage 2	2015	2012	2040	----	----	2040	2012	2050	2015	2025
Stage 3	2035	2030	2065	----	----	2060	2025	2075	2035	2050
Stab. period	20	19	25	0	0	15	15	25	20	25
Comp. to MS 1	65 yr earlier	70 yr earlier	25 yr earlier	Same	Same	15 yr earlier	15 yr earlier	25 yr earlier	10 yr earlier	50 yr earlier
Comp. to MS 2	20 yr earlier	15 yr earlier	10 yr earlier	Same	Same	40 yr earlier	20 yr earlier	5 yr earlier	5 yr earlier	Same

This earlier entry of Central America in the emission-reduction stage leads in the long term to lower emissions compared not only to the MS 1 variant, but also to the MS 2 variant. However, during the transition period (short term: 2025), the emission intensity changes in the MS 3 variant are lower than the intensity changes according to MS 1 and MS 2, and therefore result in higher emissions. The same holds for South America, Northern Africa and South-East & East Asia. The differences between MS 3 and MS 2 for the other non-Annex I regions are small in the short term.

Main findings

- The MS 3 approach with a TC value of 100 leads to an earlier entry of the middle- and high-income non-Annex I regions into the emission-reduction stage than suggested in the entry dates under the world average per capita emission threshold (MS 1).

4.2 The Multi-Stage and Per Capita Convergence results

- *Timing for participation of non-Annex I regions* – Table 4.6 gives a brief overview of the participation of the non-Annex I regions in the emission limitation and emission reduction stage. For the emission limitation stage, most middle- and high-income non-Annex I regions show similar early entry dates to those under S550e (in the second commitment period); however, SE Asia shows this ten years later and Northern and Eastern Africa 30 years later. For the emission reduction stage, the middle- and high-income non-Annex I regions participate much later than in the S550e profile, although they still have to participate before 2050. Conversely, the low-income non-Annex I regions enter Stage 2 very late, only after 2070 for South Asia and 2100 for Western and Eastern Africa.

Table 4.6 S650e profile, entry dates of non-Annex I regions in Stage 2 and 3

Regions	Central America	South America	Northern Africa	Western Africa	Eastern Africa	Southern Africa	Middle East	South Asia	East Asia	SE Asia
Stage 2	2015	2012	2040	----	----	2040	2012	2050	2015	2025
Stage 3										
Multi-Stage 1	----	----	2090	----	----	2045	2012	----	2045	----
Multi-Stage 2	2055	2045	2075	----	----	----	2045	2080	2040	2050
Multi-Stage 3	2035	2030	2065	----	----	2060	2025	2075	2035	2050

*For each region, white boxes indicate the earliest entry variant, dark-grey the latest, and light-grey in between

Main findings
Emission-limitation stage
- All non-Annex I regions participation before 2050 in the emission-limitation stage in all MS variants, except for Western and Eastern Africa. However, compared to the S550e profile many regions participate much later (e.g. South Asia: 2045 instead of 2015).

Emission-reduction stage
- For all three MS variants the low-income non-Annex I regions show a very late entry, South Asia after 2070, and Western and Eastern Africa after 2100.
- The MS 3 variant results into a much earlier participation of non-Annex I regions with relatively high per capita emissions (such as Western Asia, South and Central America) in the emission-reduction stage than under MS 2.

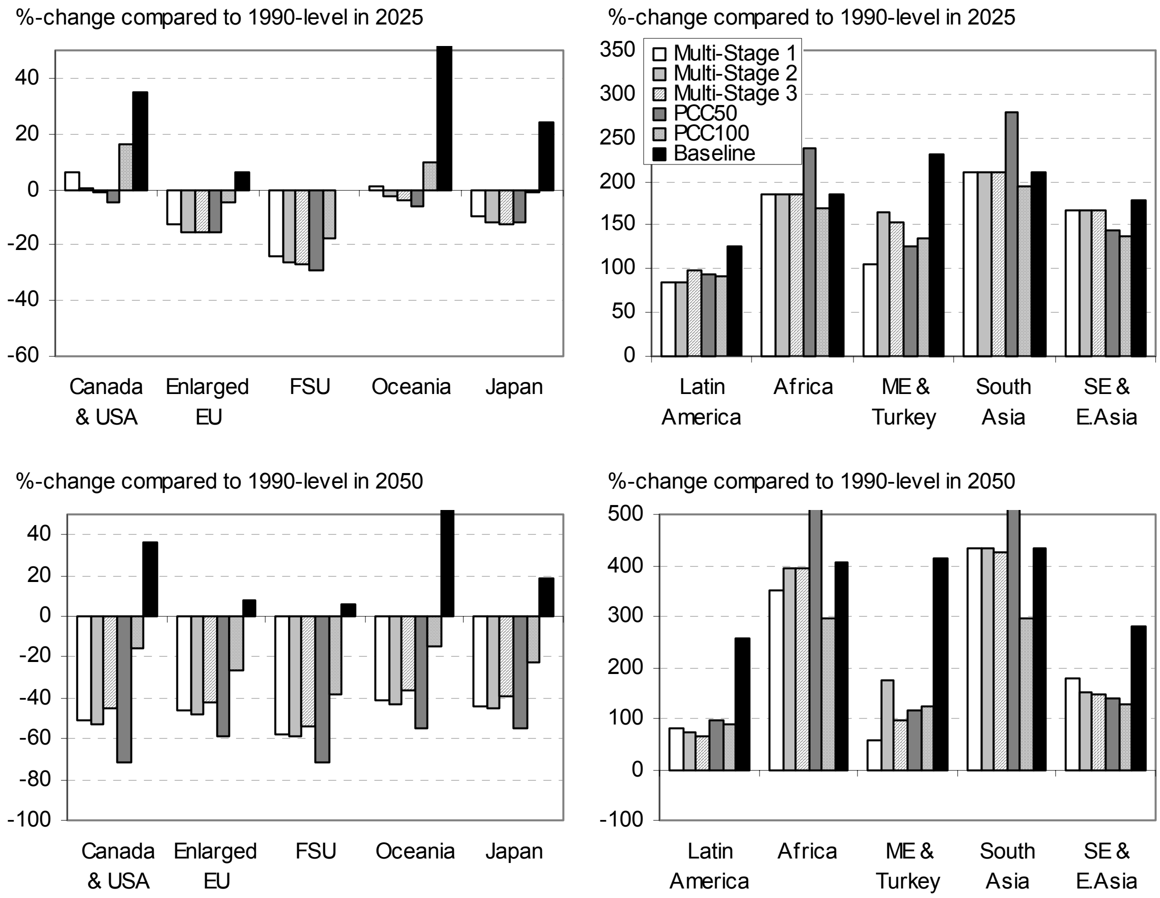


Figure 4.1: Percentage change in the CO_2-equivalent emission allowances relative to the 1990-level for the MS and PCC variants in 2025 and 2050 under the S650e profile.

- *Comparing emission allocations for the MS variants* – Figure 4.1 depicts the reduction efforts or growth percentage compared to the 1990 levels for ten aggregated regions (see again Figure 4.2, for the comparison with the baseline emissions, and Tables 4.7 for more details). The entry date of East Asia in the reduction stage again plays an important role for the future Annex I reduction efforts. The MS 3 variant with the earliest entry of East Asia leads to the lowest efforts, and vice versa for MS 2. For the Middle East, MS 1 is the most stringent because here it almost directly enters stage 3 (emission reductions). The MS 3 variant provides higher allowances for high-income non-Annex I regions as it allows for some transition time (Figure 4.3). For the low-income non-Annex I regions, there are almost no differences in the outcomes for the three MS variants, since these regions do not participate before 2050.

Table 4.7: Reductions for the MS (MS) and PCC variants in the year 2025 and 2050 under the S650e profile for the CPI baseline scenario.
(a) compared to baseline emissions

S650e profile	2025					2050				
Regions	**MS1**	**MS2**	**MS3**	**PCC50**	**PCC100**	**MS1**	**MS2**	**MS3**	**PCC50**	**PCC100**
USA	20	24	26	28	12	64	66	60	79	37
Canada	36	39	39	41	31	64	65	61	74	47
OECD Europe	19	21	22	22	12	51	52	46	63	32
Eastern Europe	12	14	15	13	4	48	50	44	60	29
Former USSR	24	26	27	29	17	60	61	56	73	41
Oceania	34	36	37	39	28	65	66	62	73	49
Japan	27	29	30	29	20	53	54	49	62	35
Central America	16	16	7	11	15	46	46	47	36	43
South America	20	20	14	16	15	51	53	56	48	49
Northern Africa	0	0	0	-2	9	12	12	6	6	29
Western Africa	0	0	0	-43	-2	0	0	0	-89	-6
Eastern Africa	0	0	0	-82	-28	0	0	0	-143	-35
Southern Africa	0	0	0	15	22	20	1	3	41	55
ME & Turkey	38	20	23	32	29	70	46	62	58	56
South Asia	0	0	0	-22	5	0	0	1	-16	25
SE & E.Asia	5	5	4	13	15	27	34	35	38	40
World	14	14	14	14	14	37	37	37	37	37

(b) compared to 1990 emissions

S650e profile	2025					2050				
Regions	**MS1**	**MS2**	**MS3**	**PCC50**	**PCC100**	**MS1**	**MS2**	**MS3**	**PCC50**	**PCC100**
USA	-8	-2	0	4	-18	51	54	45	72	15
Canada	12	15	16	18	4	50	52	46	64	26
OECD Europe	12	14	15	14	4	46	47	41	59	25
Eastern Europe	17	19	19	18	9	48	50	44	59	29
Former USSR	24	26	27	29	17	58	59	53	72	38
Oceania	-1	3	4	6	-9	41	43	36	55	14
Japan	10	12	12	12	1	44	45	39	55	23
Central America	-83	-83	-102	-94	-85	-83	-83	-79	-116	-92
South America	-85	-85	-97	-93	-94	-80	-71	-61	-88	-88
Northern Africa	-169	-169	-169	-175	-144	-254	-254	-280	-278	-186
Western Africa	-240	-240	-240	-387	-246	-466	-466	-466	-968	-500
Eastern Africa	-135	-135	-135	-328	-200	-291	-291	-291	-851	-429
Southern Africa	-179	-179	-179	-138	-119	-363	-478	-466	-245	-163
ME & Turkey	-106	-166	-153	-125	-134	-56	-175	-96	-115	-125
South Asia	-211	-211	-211	-279	-196	-431	-431	-427	-518	-297
SE & E.Asia	-166	-166	-167	-143	-136	-180	-151	-148	-138	-129
World	-54	-54	-54	-54	-54	-48	-48	-48	-48	-48

- *Annex I and non-Annex I targets for the MS variants* – In 2025 the allowances result in reductions from baseline that are less pronounced, and also show a wider range. This range varies from a growth of 10% for the USA to 30% reduction compared to 1990-levels for the FSU. Most non-Annex I regions hardly have to limit their emissions in 2025, as the Africa regions and South Asia are no longer constrained in the MS variants. Reductions are limited to 5-10 % for South-East & East Asia, 5-20 % for Latin America and 20-40% for Middle East & Turkey.

In 2050, the Annex I emissions are by 40-60% below 1990 levels, resulting in a reduction of 45-70% compared to the baseline levels. The low-income non-Annex I regions have very low required reductions compared to the baselines. In the other non-Annex I regions the reductions compared to the baseline emissions remain globally lower than for Annex I, with 40 %, 50 % and 60 %, respectively for South-East & East Asia, Latin America and the Middle East & Turkey.

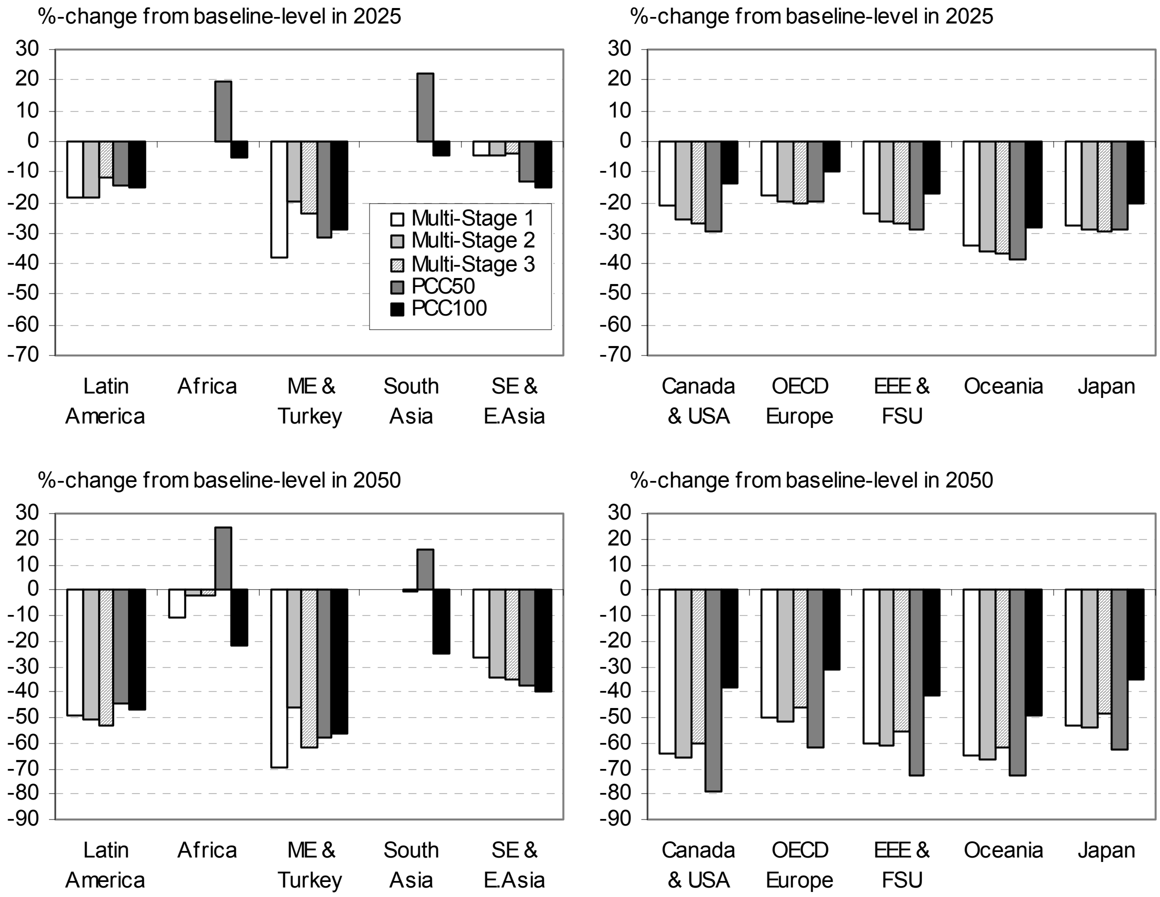


Figure 4.2: Percentage change in the CO_2-equivalent emission allowances relative to the baseline-level for the MS and PCC variants in 2025 and 2050 under the S650e profile.

Main findings

- For the Annex I regions, the MS 1 variant leads to the lowest emission reduction efforts in both the short and long terms due to the earlier participation of some non-Annex I regions in the emission-reduction stage than in the MS 2 and MS 3 variants.
- For some middle-income non-Annex I regions like South and Central America, Middle East & Turkey, the MS 1 variant leads to the highest reductions, because they almost directly enter the emission-reduction stage. The MS 3 approach leads to the lowest constraints for these regions as it allows for some transition period.
- Under the S650e profile, there is no need for the low-income non-Annex I regions, to participate before 2050.

Comparing emission allocations with Per Capita Convergence variant – The PCC variants again show large differences in outcomes, particularly in the long term. For the PCC50 variant, the emission reductions by 2025, compared to 1990, for Annex I regions range from a few per cent for USA/Canada and Oceania to about 30% for the FSU, which is comparable to the MS variants. The PCC100 variant again results in much lower emission reduction efforts for the Annex I regions than the PCC50 variant, and the least of all five variants. The allowable emissions for USA/Canada and Oceania are even still above 1990 level by 2025. In contrast, the PCC50 variant results in emission reductions for the Annex I regions that are higher than in the MS variants, making it the most stringent scheme for these regions in both the short and long term. An important reason for this is that under the S650e profile, the PCC50 variant results in large amounts of surplus emissions, not only for all African regions but also for South Asia, and not only in the short term but now also in the long term. The PCC50 variant provides the low-income non-Annex I regions with the highest emission allowances of all PCC and MS variants. The middle-income non-Annex I regions are less sensitive to the convergence year, since their per capita emissions are closer to the world average. For Latin America and the Middle East, the PCC variants result in more emission allowances than the MS variants (except for MS 1 for the Middle East), while for South-East & East Asia the PCC variants result in fewer emission allowances.

The results for both per capita convergence variants and for the three alternative MS variants under the S650e profile are compared in Figures 4.3.

Main findings:

- Like under the S550e profile, the PCC100 variant results into substantial smaller emission reduction efforts for the Annex I regions than the other MS variants and PCC50 variant.
- The PCC50 variant results into more reductions for Annex I regions that the MS variants and becomes for them the least attractive approach, except for OECD-Europe.
- For the more developed non-Annex I regions the MS 3 approach is no longer the one with the lowest reductions. The PCC50 leads to the lowest emission allowances for the South-East & East Asia regions, whereas for the Middle East & Turkey, MS 1 leads to the highest constraints. This is because the world average threshold is met much earlier than the second CR-threshold in MS 2, and no stabilisation period is allowed, as in the variant of MS 3.
- For the least developed non-Annex I regions (South Asia, Africa) the PCC50 variant is by far the most favourable variant due to large amounts of excess emissions. At the same time there are no or hardly any differences in the outcomes for the MS variants since these regions do not yet participate before 2050.

Box 4.1: Relative attractiveness of the MS and PCC variants under the S650e profile

Table 4.8 and 4.9 ranks the percentage change relative to the baseline-emission level for the target year, 2025, of each regime in comparison to the outcomes of the other regimes explored. The approach resulting in, relatively speaking, the lowest relative emissions reductions (or highest emission allowances) is indicated in green, hereafter classified as the most favourable or most attractive approach compared to the other regimes explored. The approach resulting in the highest relative emission reductions (or lowest emission allowances) is indicated in red; this will be forthwith classified as the most favourable or most attractive approach compared to the other regimes explored. White indicates an intermediate position. It should be noted that this ranking is always in relative comparison to the outcomes of the other regimes explored.

*Table 4.8: Regional relative scores for different approaches by **2025** for the reference variants compared to baseline for the S650e profile* *

S650	MS 1	MS 2	MS 3	PCC50	PCC100
Canada &USA	21	25	27	30	14
OECD-Europe	19	21	22	22	12
EEUR &FSU	21	24	24	26	14
Oceania	34	36	37	39	28
Japan	27	29	30	29	20
Latin America	18	18	12	14	15
Africa	0	0	0	-19	5
ME & Turkey	38	20	23	32	29
South Asia	0	0	0	-22	5
SE & East Asia	5	5	4	13	15

* *Green area indicates most attractive regime, and red area indicates least attractive regime for each region*

*Table 4.9: Regional relative scores for different approaches by **2050** for the reference variants compared to baseline for the S650e profile* *

S650	MS 1	MS 2	MS 3	PCC50	PCC10 0
Canada &USA	64	66	60	79	38
OECD-Europe	51	52	46	63	32
EEUR &FSU	58	59	53	70	39
Oceania	65	66	62	73	49
Japan	53	54	49	62	35
Latin America	49	51	53	45	47
Africa	11	3	2	-25	22
ME & Turkey	70	46	62	58	56
South Asia	0	0	1	-16	25
SE & East Asia	27	34	35	38	40

* *Green area indicates most attractive regime, and red area indicates least attractive regime for each region*

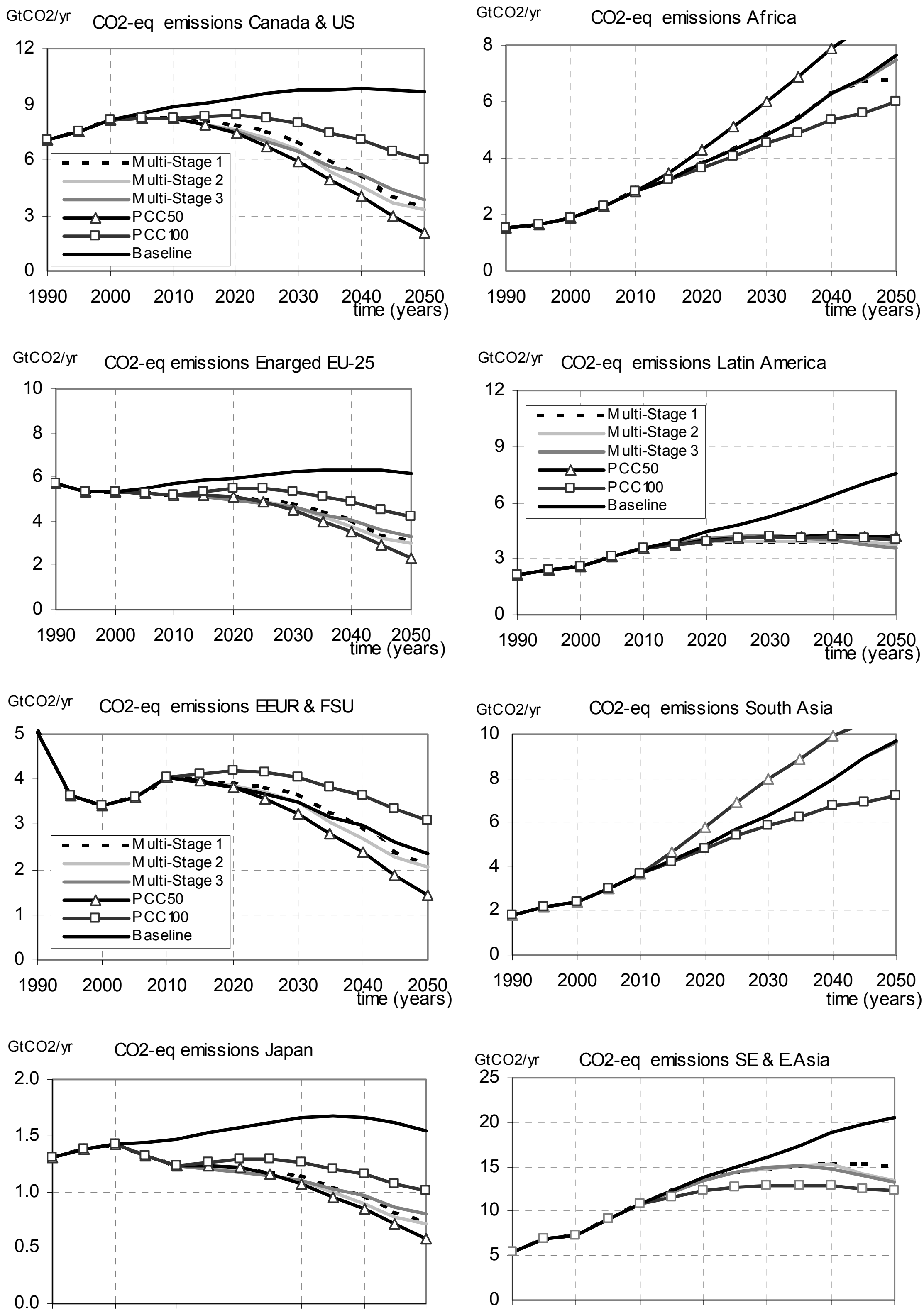


Figure 4.3: CO_2-equivalent emission allowances for the MS and per capita convergence variants for the S650e profile for the period 1990-2050 for the Annex I regions.

4.3 Robustness of results for the Multi-Stage variants under the S650e profile

A similar sensitivity analysis has been done for the S650e profile (Figure 4.4). In general, the results are fairly robust in the short term, since changing the participation thresholds or transition constant has only a small impact on the emission allowances of the high-income non-Annex I regions (Middle East & Turkey, Latin America) and Annex I regions. In general, the pattern of relative efforts resulting from the variants remains unaffected. For the Annex I regions, the PCC50 in the long term remains the approach that provides the largest emission reductions and the PCC100 the variant with the smallest reductions. The MS variants have an intermediate position. Among them, MS 1 is no longer the one presenting systematically the largest allowances. For the middle-and high-income non-Annex I regions, there are less clear differences between the variants, but the MS 1 variant shows the highest sensitivity. The low-income non-Annex I regions become less sensitive for the MS parameter settings as they generally only enter the regime at a late stage (beyond 2050).

The sensitivity analysis shows that the future emission reductions of the three MS variants depend just as much on the MS variant chosen as on the exact parameter values used. The most important parameters are the threshold levels and the burden-sharing keys.

In general, the emission reductions under S550e profile are more sensitive to changing the participation thresholds for the emission reduction stage in the short term than in the long term. An opposite pattern is found for the S650e profile due to the delayed entry dates of the non-Annex I regions in the emission reduction stage.

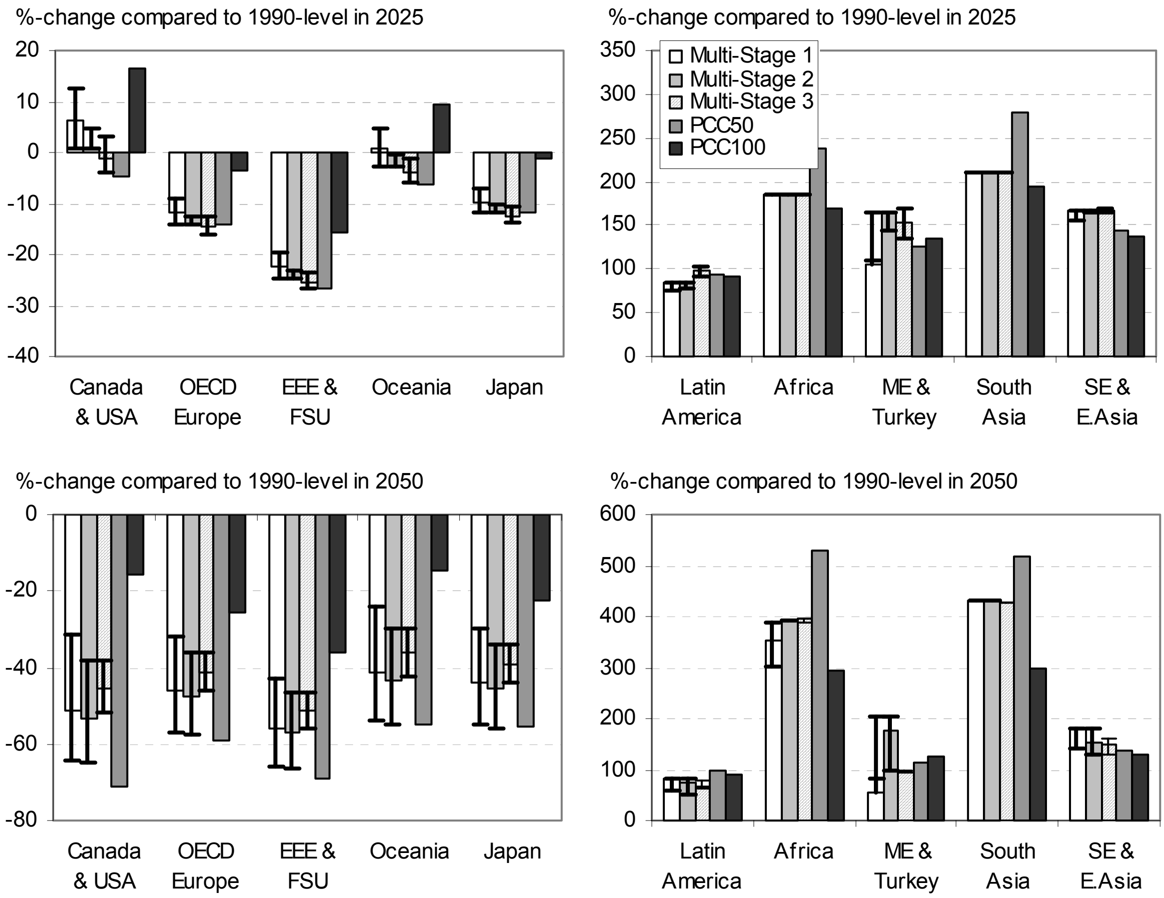


Figure 4.4: Robustness of results for the MS variants under the S650e profile.

5 All results of the S550e and S650e profiles compared

We will now compare the results of all MS and PCC variants for the two different emission profiles. Figure 5.1 shows the relative outcomes resulting from the MS and PCC under the S550e and S650e profiles for the various regions in the short and long term. The approaches resulting in relatively the least emission reductions (or largest emission allowances) are indicated in grey. The approaches resulting in the relatively largest emission reductions (or smallest emission allowances) are indicated in black. White indicates an intermediate position.

From these results it can be concluded that changing from the S550e to the S650e emission profile significantly influences the relative reduction efforts under the MS variants and the PCC50 variant. Only the relative reductions under the PCC100 variant for both the Annex I regions and non-Annex I regions remain unaffected. For the low-income non-Annex I countries, the change from the S550e profile to the S650e profile has the largest influence on the relative reductions resulting from the various approaches. Under the S650e profile, the large number of excess emission allowances (even in the long term) occurs for the PCC50 variant, making the latter more favourable than the MS variants.

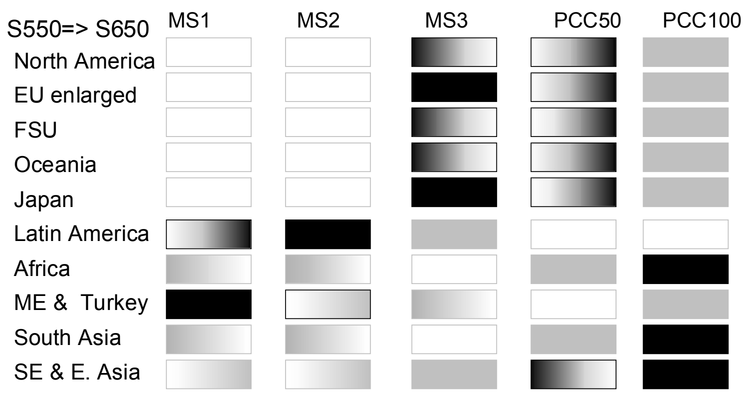


Figure 5.1: Regional relative scores for the MS and PCC reference variants by 2025 under the S550e profile (left-hand side bars) and the S650e profile (right-hand side bars).

5.1 Pros and cons of the Multi-Stage and Per Capita Convergence approaches

In the previous sections we analysed and compared the implications of the Multi-Stage and Per Capita Convergence variants quantitatively. Here, we will evaluate the pros and cons of the three MS variants and the PCC variants qualitatively.

The Multi-Stage variants

First, all variants have in common the CR-index threshold for entering the emission-limitation stage. This threshold looks for a middle road somewhere between the principle of need (justifying that countries are being exempted) and the desirability of early entrance of developing countries into the emission-limitation stage. It allows for an easier adjustment of the overall stringency of the regime if needed[10]. Moreover, it also allows for a more cost-effective global emission control via emission trading (compared to the CDM mechanism). Early participation can be attractive for the developing countries if emission trading results in net benefits. For this to work in practice, however, countries will need sufficient institutional and technical capacity, in particular, concerning the monitoring of national emissions. This is likely to be a key limit in early participation of developing countries in emissions trading.

Regarding the emission-limitation stage, the main difference between the MS variants is the dynamic intensity targets in MS 1 (dynamic threshold) and MS 2 (double CR), and the prescribed emission growth limits in the MS 3(transition path) variant. The simulation results show that the MS 3 approach allocates more emissions to the developed non-Annex I regions than the MS 1 and MS 2 variants. Nevertheless, the dynamic intensity targets of MS 1 and MS 2 have the advantage of accounting for baseline uncertainty on economic growth. Since developing countries experience particularly large fluctuations in economic performance, they are likely to be more willing to adopt dynamic than fixed targets. At the same time, intensity targets have drawbacks as well (Müller et al., 2001; Van Vuuren et al., 2002). They introduce uncertainty about environmental effectiveness and complicate the measurement of the target itself, and ultimately also the use of the emission-trading instruments. However, as they generally provide more certainty about economic costs, it would seem that intensity targets provide a better chance than fixed targets to involve developing countries at an early stage[11].

An advantage of the MS 3 approach is that it creates a rather smooth transition from the emission-limitation stage to the emission-reduction stage. The other MS approaches may result in a still more drastic shift from increasing emissions in the emission-limitation stage to decreasing emissions in the emission-reduction stage. However, the fixed transition pathways make the MS 3 variant less flexible and can lead to large Annex I emission reductions. Another drawback of the MS 3 approach is that it is based on a rather artificial (dimensionless) identity: the transition constant. It is neither directly related to (per capita) emissions (responsibility) nor to income (capability). From a policy point of view the abstract nature of the TC makes it less suitable for negotiations[12].

The main difference between MS 1 and MS 2 is the use of a dynamic threshold versus a fixed threshold for the emission-reduction stage (CR-index). The dynamic world-average per capita emission threshold can result in early entrance of relatively poor country with high per capita emission levels (Southern and Northern Africa, Middle East & Turkey) in the emission-reduction stage, leading to relatively large emission reductions and disproportional burdens. On the other hand, it rewards Annex I action, provides an

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[10] It is expected that adjusting the threshold levels once adopted will be more difficult than adjusting the stringency of emission limitation and reduction targets.

[11] Some of the drawbacks may be overcome through more sophisticated arrangements, such as dual-intensity targets (Kim and Baumert, 2002), indexed absolute targets (Philibert and Pershing, 2001) or including clauses to deal with risks resulting from situations of economic recession.

[12] However, the Multi-Stage 3 approach may still be workable when negotiations focus on the principle of relating the length of the transition period to per capita emission levels, and derive the TC level from negotiations on the overall stringency of emission control desired.

incentive for non-Annex I countries to keep below this threshold and makes the regime more robust for future adjustment of climate targets. The double Capability-Responsibility index approach (MS 2) tends to give a more evenly distribution of emission reductions across the non-Annex I regions, because it accounts for both per capita emissions and per capita income.

Finally, the results show that the use of per capita emissions as burdens-sharing key in all MS variants can lead to (relatively) large emission reduction burdens for regions with relatively high per capita emissions, notably Oceania, USA/Canada, FSU and Middle East & Turkey already in the short term, and Northern and Southern Africa in the long term. In the design of Multi-Stage systems, it may thus be necessary to allow for adjustment factors in the burden-sharing key, or a change of the burden-sharing key used to avoid disproportional burdens and make these regimes acceptable for all Parties.[13]

The Per Capita Convergence variants
The PCC approach is based on a compromise between two opposing equity principles: sovereignty and egalitarian. The balance between the two principles is largely determined by the convergence year. Due to the reduction in the global emissions over time, the convergence year not only determines the relative share of Annex I and non-Annex I in total emissions, but also the cumulative distribution of absolute emissions over time (Müller, 1999).

The analysis has shown that the results of the PCC approach are strongly dependent on the convergence year chosen and the global emission profiles. An 'early' convergence year (2050) combined with a stringent global emission constraint (S550e profile) can result in high emission reductions for Annex I regions. When combined with a less stringent global emission constraint (S650e profile), it can result in substantial amounts of excess emissions. On the other hand, a 'late' convergence year (2100) combined with a stringent global emission constraint (S550e profile) can result in substantial emission limitations for the low-income non-Annex I regions. When combined with a less stringent global emission constraint (S650e profile), a 'late' convergence year can result in allowing some Annex I regions (USA/Canada, Oceania) to still increase their emissions in the short term, while non-Annex I regions already have to limit their emissions. If this is to be avoided, there needs to be a match between the convergence year and stabilisation profile. However, it is not easy beforehand to set the proper convergence year when there is uncertainty about long-term climate goals and baseline emission levels.

The pros and cons of the MS and PCC variants compared
The PCC approach's main strengths are its clear concept, the certainty that it provides regarding the environmental effectiveness of the regime and developing country participation, and cost-effectiveness resulting from global participation in emission trading. At the same time, the early participation of especially the least developed countries causes many implementation problems. These countries lack the institutional capacities to properly implement policies and monitor emissions. This in turn will make them illegible to participate in emissions trading. Another drawback of the approach is that it can result in surplus emissions that increase abatement costs for Annex I and richer developing regions and result in large financial transfers. Neither does the approach take any national circumstances into account. Finally, the resource-sharing concept is likely to meet principal

[13] One option to be further explored would be to relate not only the thresholds, but also the burden-sharing key, to both per capita emissions (responsibility) and per capita income (capability) to reach a more balanced distribution among all Parties.

policy objections from some key developed countries (like the USA) that do not adhere to a top-down regulation of global commons and the concept of rights Some of these problems can be remedied, like by inclusion of national adjustment factors and/or regional allocations of emissions (allowing for a regional redistribution under emission bubbles) and by restriction of the illegibility of emission trading of the least developed countries in relation to the certainty about emission levels (to avoid overselling) [14].

The strengths of the MS approach are its linkages and balanced coverage of different equity principles (capability, responsibility and egalitarian) and its flexible concept, with types and levels of commitments adjusted to development levels and offering room for negotiation. In this way a balance is struck between early participation of developing countries and adjustment to countries capacities to take on and implement commitments. Moreover, the approach is well compatible with the UNFCCC and KP, Its main weaknesses are the large reductions for Annex I countries with high per capita emissions (particularly under stringent emission profiles) and the need to divide the group of developing countries (G77/China). Another weakness is the complications resulting from the use of intensity targets, and this approach's limited ability to adjust to more stringent targets over time (particularly in the MS2 and MS3 variants). Adopting another burden-sharing key (like per capita income) or even a mix of criteria could reduce the first weakness. The problems with the intensity targets might be remedied by allowing developing countries either to trade only after the commitment period (ex-post) or by adopting a dual-intensity target approach (Kim and Baumert, 2002) that would further reduce economic uncertainty.

Table 5.1: Pros and cons of the Multi-Stage and Per Capita Convergence approaches

	Pros	Cons
Multi-Stage	• Approach covers different equity principles • Flexible concept for adjusting commitments to national capabilities and offering room for negotiation • Compatible with KP/UNFCCC	• Intensity targets reduce certainty about environmental effectiveness and complicate implementation • Large reductions for Annex I countries with high per capita emissions • Need to divide the developing countries into groups
Per Capita Convergence	• Certainty about DC participation • Certainty about environmental effectiveness • Clear concept • High cost-effectiveness due to for full participation	• Implementation problems for LDCs • Risk of surplus emissions resulting in extra costs for Annex I / middle-income DCs • Political resistance against resource- sharing concept • No accounting for national circumstances

[14] In principle, the PCC approach could be detached from the egalitarian concept of equal human entitlements to the use of global commons, by providing countries allowances instead of rights but this seems hard to conceive given the ideological origins of the concept.

6 Conclusions

In this report we have described and analysed the implications of a number of alternative Multi-Stage (MS) and Per Capita Convergence (PCC) approaches for the differentiation of future climate commitments under two alternative global emission profiles for stabilising greenhouse gas concentrations at 550 and 650 ppmv CO_2-equivalent.

A major new element of the new MS variants is the CR-index as a first threshold for adopting intensity targets for the non-Annex-I regions instead of a single capability oriented threshold, i.e. per capita income. The analysis shows that a CR-threshold tends to results into an earlier participation of low-income countries, in particular of those that have relatively high per capita emission levels (such as Southern Africa).

A low first participation threshold for the intensity target stage resulting into an early participation of low-income countries, has several advantages: (1) fast extending the global emission trading market; (2) less leakage to non-participating countries; (3) more spill-over of technology and (4) more flexibility in adjusting to possible more stringent future climate targets. Early adoption of intensity targets may be made attractive when the effort required is related to per capita income levels (very small efforts, while gaining from emission trading). However, setting the first threshold too low may at the same time result in implementation problems as emission and economic monitoring and verification capabilities may not allow for meeting the eligibility requirements for participation in emission trading.

The analysis of the three MS variants shows that:

- For all Annex I countries in 2025, the reductions in assigned amounts of at least 30-55% compared to the 1990 levels are necessary to achieve the 550-ppmv target and 10-20% for the 650-ppmv target. In 2050, the reductions are at least 70% (S550e) and 40% (S650e).
- Among the MS variants, MS 3 results in the largest reductions in the short term for Annex I, due to the late entry of the middle- and high-income non-Annex I regions.
- The region South-East & East Asia (including China) plays a key role in the Annex I emission reductions. An early entry of this region in the emission-reduction stage results in lower reductions for the other participating regions (i.e. Annex I regions), since the total reduction needed to achieve the global emission profiles is now shared with a larger group of countries.
- Participation of the major middle- and high-income non-Annex I countries in reductions is needed before 2025 (S550e) and 2050 (S650e). For S550e, this implies that countries will start to participate at significant lower per capita income levels than for Annex I under the Kyoto Protocol.
- With respect to the emissions for non-Annex I regions, the results of the Multi-Stage variants are quite sensitive to particular assumptions, such as participation thresholds and the global emission profile. No general conclusion for this group as a whole can be drawn. For the S550e profile, the MS 3 variant tends to result in fewer reductions for the more middle- and high-income non-Annex I regions, while for the low-income non-Annex I regions, the MS 2 variant requires the least efforts. For the S650e profile, the results of the different variants in the short term (2025) are quite similar due to the late participation of most non-Annex I regions.
- Finally, the robustness analysis shows that the future emission reductions of the three MS variants depend just as much on the MS variant chosen as on the exact parameters used. The most important parameters are the threshold levels.

The main findings for the Per Capita Convergence variants:

- The results of the PCC approach are strongly dependent on the convergence year chosen and the global emission profiles.
- An ‘early’ convergence year (2050) combined with a stringent global emission constraint (S550e profile) can result in high emission reductions for Annex I regions, while when combined with a less stringent global emission constraint (S650e profile), this can result in substantial amounts of excess emissions. On the other hand, a ‘late’ convergence year (2100) combined with a stringent global emission constraint (S550e profile) can result in substantial emission limitations for the low-income non-Annex I regions; when combined with a less stringent global emission constraint (S650e profile), it can result in allowing some Annex I regions (USA/Canada, Oceania) to continue to increase their emissions in the short term when non-Annex I regions need to limit their emissions as well.
- If this is to be avoided, there needs to be a match between the convergence year and stabilisation profile. However, it is not easy beforehand to set the proper convergence year when there is uncertainty about long-term climate goals and baseline emission levels.

When we compare the MS variants and the PCC variants, the main findings are that:

- For the Annex I regions, the differences in emission allowances between per capita convergence by 2050 and the MS variants are relatively small. Only the 2100 convergence regime is an exception, leading to the lowest reduction efforts.
- For the more developed non-Annex I regions, the convergence approaches can lead to substantial emission limitations reductions under the S550e profile, especially for the SE & E Asia region (including China). For the middle- and high-income non-Annex I regions (Latin America, Middle East & Turkey and SE & E. Asia), the MS 3 variant is more attractive in the short term than the PCC variants. This is because their per capita emissions are higher than those of the low-income non-Annex I regions and close to the world average. In the long term, the differences between these two approaches are small.
- For the least developed non-Annex I regions, the convergence of 2050 approaches are generally more attractive than the MS variants because their allowable emission levels are larger than their baseline emissions. However, a 2100 convergence leads to the highest efforts.

In addition to the quantitative analysis we also evaluated the strengths and weaknesses of the specific Multi-Stage and Per Capita Convergence variants, and of the two approaches in general. From this analysis we can conclude that:

- The CR-index threshold in the new Multi-Stage approach results in a more balanced transition of developing countries into the emission limitation states than per capita income only. The double Capability-Responsibility index approach (MS 2) also tends to give an evenly distribution of emission reductions across the non-Annex I regions, but the fixed thresholds makes it less flexible to adjust to more stringent future climate policies than the dynamic world average threshold (MS 1).
- The transition pathway approach in MS3 secures a smooth transition toward the emission reduction stage, but is even less flexible than the double CR-index (MS 2) and results into high Annex I burdens under stringent stabilisation profiles.
- The per capita emission burden-sharing key in all MS variants leads to (relatively) large emission reduction burdens for regions with relatively high per capita emissions that can be disproportional and unacceptable. The burden-sharing key will have to be adjusted to better account for different national circumstances.

- For a balanced distribution of emission reductions, avoiding excess emissions, there needs to be a match between the convergence year and stabilisation profile. As shown in this study, with a 'proper' match the results of the PCC approach do not have to be very different from a MS approach. However, it is not easy beforehand to set the proper convergence year when there is uncertainty about long-term climate goals and baseline emission levels.
- The PCC and MS approaches both have their strengths and weaknesses. Overall, the MS approach better fits in with the current approach taken under the KP and the UNFCCC and seems to provide a more flexible, technically feasible and politically acceptable approach for differentiating future commitments than the PCC approach. However, the PCC approach may provide more certainty about sufficiently early developing country participation that is needed to meet stringent climate policy goals and more flexibility for policy adjustments. Moreover, there are options for remedying some of the problems related the approach.
- Both the MS and PCC approach will have to be further refined to be able to deal with different national circumstances and to avoid disproportional burdens.

Because the MS schemes include the possibility of different types of commitments for regions with different levels of wealth and intensity of emissions, they are probably considered as good candidates for the long-term international post-Kyoto climate architecture that will have to be developed soon. It is a flexible concept that is able to strike a balance between providing structure and leaving room for negotiation. The concept allows for an incremental, but rule-based broadening and deepening of mitigation commitments. In this way, it could open new and clear pathways for addressing the critical issue of the participation of non-Annex I Parties in an international climate regime. At the same time, the approaches need to be analysed further, including for exploration of more acute burden-sharing keys but also for the study of the conditions of negotiation and practical implementation of the MS schemes.

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Appendix A: The S550e and S650e emission profiles

The IMAGE S550e and S650e profiles result in a stabilisation of CO_2-equivalent concentration at 550 and 650 ppmv. These levels correspond with levels of stabilisation of atmospheric CO_2 -oncentrations at about 450 and 550 ppmv, respectively (Eickhout et al., 2003).

For the short term (up to 2012), the profiles incorporate: (i) the implementation of the Annex I Kyoto Protocol targets, (ii) a revenue maximising level of banking of surplus emissions by the Former Soviet Union (FSU) and Eastern Europe and (iii) adoption of the greenhouse gas intensity target for the USA (-18% between 2002-2012) (Van Vuuren et al., 2002; White-House, 2002). These assumptions are important in defining the initial situation for the analysis (i.e. the regional emission levels by 2012). Non-Annex I countries are assumed to follow their baseline emissions until 2012.

The range of the expected temperature rise associated with different emission profiles depends on the uncertainty about the climate sensitivity, which is defined as the equilibrium global temperature increase over pre-industrial level that would result from a doubling in CO_2-equivalent concentrations. The Intergovernmental Panel on Climate Change (IPCC) estimates the range of this climate sensitivity between 1.5 °C and 4.5°C, with a median value of 2.5°C. From this uncertainty range it follows that the S550e profile will result in a global mean temperature increase below 2°C for a low to median value of the climate sensitivity. The S650e profile only stays below this level if the value of the climate sensitivity is at the low end of the range. This means that this profile is less likely to meet a ‘less than 2°C increase in temperature’ target. If the climate sensitivity is high, this target will not be met in either profile.

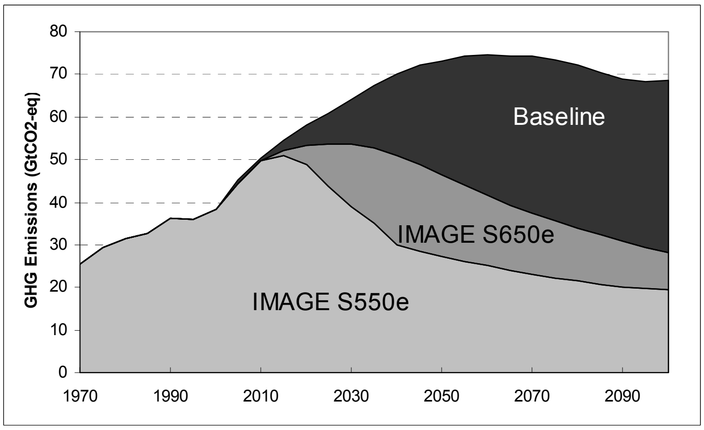

Figure A.1. Global emission profiles for stabilising GHG concentrations at 550 and 650 ppmv (Eickhout et al., 2003).

Figure A.1 shows the emission profiles and indicate that the global GHG emission levels can still increase to 20% above 1990 levels in 2025 under the S550e profile, but that this implies already a substantial reduction of 30% compared to baseline levels. In 2050, the emissions have to be reduced strongly, not only compared to baseline level (65%), but also compared to 1990 levels: about 15%. For S650e reductions compared to the baseline in 2025 are smaller (15%). GHG emission levels can still be 50% above 1990 by 2050 under S650e, but compared to the baseline, they need to be reduced by about 35% (see also Tabel A.1 and A.2).

Table A.1: World CO_2-equivalent emissions for the reference and IMAGE S550e profile

	Reference scenario (Gt CO_2)	IMAGE S550e profile (Gt CO_2)	Emission reduction burden (as %-baseline emissions)
1990	31.7	31.7	0%
1995	32.9	32.9	0%
2000	35.2	35.2	0%
2005	39.3	39.4	0%
2010	43.9	43.7	-1%
2015	48.1	43.5	-10%
2020	52.7	42.5	-19%
2025	56.7	38.5	-32%
2030	60.6	34.5	-43%
2035	64.3	30.9	-52%
2040	68.8	27.4	-60%
2045	72.1	26.6	-63%
2050	74.9	26.9	-64%

Table A.2: World CO_2-equivalent emissions for the reference and IMAGE S650e profile

	CPI baseline scenario (Gt CO_2)	IMAGE S550e profile (Gt CO_2)	Emission reduction burden (as %-baseline emissions)
1990	31.7	31.7	0%
1995	32.9	32.9	0%
2000	35.2	35.2	0%
2005	39.3	39.4	0%
2010	43.9	43.7	0%
2015	48.1	45.0	-6%
2020	52.7	47.3	-10%
2025	56.7	48.7	-14%
2030	60.6	49.4	-19%
2035	64.3	48.9	-24%
2040	68.8	49.3	-28%
2045	72.1	47.6	-34%
2050	74.9	46.9	-37%

Appendix B The Multi-Stage 1 results for the S550e profile

MS 1:

- Participation threshold stage 2 (intensity targets): CR = 5
- Linear de-carbonisation rate
- Participation threshold stage 3 (emission reduction): 100% of world average per capita emissions
- Burden-sharing regime based on per capita emissions

Table B.1: Overview of the total and per capita emission allowances, as well as the changes compared to 1990 and baseline emission levels.

2025	Absolute emission level				Reduction compared to		
Regions	1990 $MtCO_2$	Reference $MtCO_2$	Target $MtCO_2$	Target per capita tCO_2/cap yr	Baseline level %	1990 level %	1990 per capita %
USA	6487	8732	3987	12.3	-54	-39	-52
Canada	587	815	350	9.3	-57	-40	-56
OECD Europe	4390	4803	2894	7.6	-40	-34	-35
Eastern Europe	1338	1267	848	7.2	-33	-37	-34
FSU	5033	5013	2672	9.0	-47	-47	-48
Oceania	526	802	360	9.1	-55	-32	-54
Japan	1301	1617	889	7.4	-45	-32	-30
Central America	661	1436	1076	4.6	-25	63	0
South America	1465	3361	2056	4.5	-39	40	-10
Northern Africa	346	930	822	4.0	-12	138	37
sub-Saharan Africa	1170	3377	3239	2.8	-4	177	24
ME & Turkey	1173	3875	1964	5.2	-49	67	-15
South Asia	1826	5677	5615	3.0	-1	208	87
South-East & East Asia	5361	14960	11757	5.1	-21	119	62
World	31664	56666	38529	4.9	-32	22	-18

2050	Absolute emission level				Reduction compared to		
Regions	1990 $MtCO_2$	Reference $MtCO_2$	Target $MtCO_2$	Target per capita tCO_2/cap yr	Baseline level %	1990 level %	1990 per capita %
USA	6487	8838	1379	3.9	-84	-79	-85
Canada	587	816	144	3.6	-82	-75	-83
OECD Europe	4390	4821	1297	3.7	-73	-70	-68
Eastern Europe	1338	1339	385	3.7	-71	-71	-66
FSU	5033	5305	1081	4.0	-80	-79	-77
Oceania	526	883	154	3.4	-83	-71	-83
Japan	1301	1548	402	3.6	-74	-69	-66
Central America	661	2221	787	2.9	-65	19	-37
South America	1465	5345	1236	2.3	-77	-16	-53
Northern Africa	346	1396	813	3.2	-42	135	11
sub-Saharan Africa	1170	6261	4031	2.6	-36	245	12
ME & Turkey	1173	6010	1134	2.3	-81	-3	-62
South Asia	1826	9702	6895	3.2	-29	278	98
South-East & East Asia	5361	20450	7185	2.9	-65	34	-7
World	31664	74935	26922	3.0	-64	-15	-50

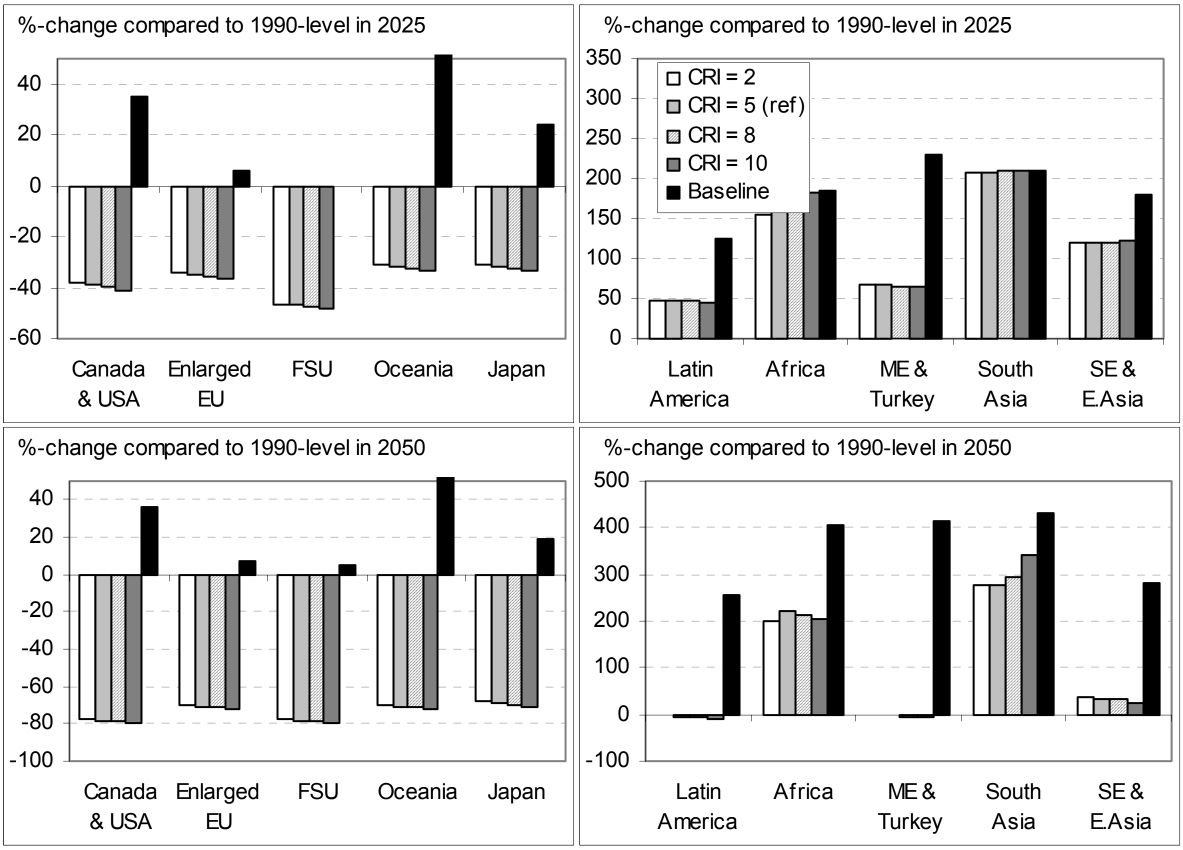

Figure B.1: Percentage change in the anthropogenic CO_2-equivalent emission allowances relative to the 1990-level for the CR sensitivity analyses for the variant MS 1 in the target years 2025 and 2050 for the S550e profile.

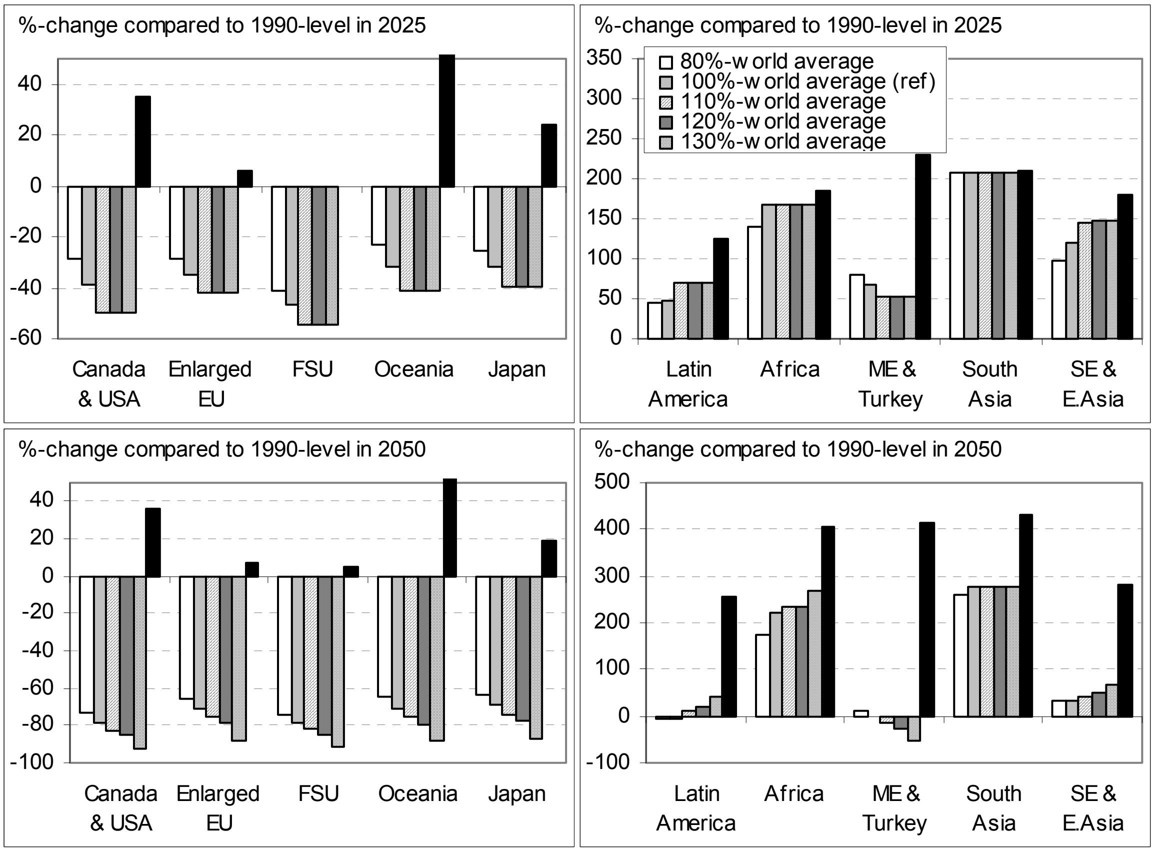

Figure B.2: Percentage change in the anthropogenic CO_2-equivalent emission allowances relative to the 1990-level for the world-average per capita threshold-sensitivity analyses for the variant MS 1 in the target years 2025 and 2050 for the S550e profile.

Appendix C The Multi-Stage 2 results for the S550e profile

MS 2 variant

- Participation threshold stage 2 (intensity targets): CR = 5
- Linear de-carbonisation rate
- Participation threshold stage 3 (emission reduction): CR = 12
- Burden-sharing regime based on per capita emissions

Table C.1: Overview of the total and per capita emission allowances, as well as the changes compared to 1990 and baseline emission levels.

2025	Absolute emission level				Reduction compared to		
Regions	1990 MtCO$_2$	Reference MtCO$_2$	Target MtCO$_2$	Target per capita tCO$_2$/cap yr	Baseline level %	1990 level %	1990 per capita %
USA	6487	8732	4287	13.2	-51	-34	-48
Canada	587	815	369	9.9	-55	-37	-53
OECD Europe	4390	4803	3015	7.9	-37	-31	-32
Eastern Europe	1338	1267	881	7.5	-30	-34	-31
FSU	5033	5013	2808	9.4	-44	-44	-46
Oceania	526	802	380	9.6	-53	-28	-52
Japan	1301	1617	925	7.7	-43	-29	-27
Central America	661	1436	948	4.0	-34	43	-11
South America	1465	3361	2109	4.6	-37	44	-7
Northern Africa	346	930	822	4.0	-12	138	37
sub-Saharan Africa	1170	3377	3239	2.8	-4	177	24
ME & Turkey	1173	3875	2025	5.4	-48	73	-12
South Asia	1826	5677	5615	3.0	-1	208	87
South-East & East Asia	5361	14960	11105	4.8	-26	107	53
World	31664	56666	38529	4.9	-32	22	-18

2050	Absolute emission level				Reduction compared to		
Regions	1990 MtCO$_2$	Reference MtCO$_2$	Target MtCO$_2$	Target per capita tCO$_2$/cap yr	Baseline level %	1990 level %	1990 per capita %
USA	6487	8838	1309	3.7	-85	-80	-85
Canada	587	816	138	3.4	-83	-77	-84
OECD Europe	4390	4821	1232	3.6	-74	-72	-69
Eastern Europe	1338	1339	365	3.5	-73	-73	-68
FSU	5033	5305	1024	3.8	-81	-80	-78
Oceania	526	883	147	3.2	-83	-72	-84
Japan	1301	1548	382	3.4	-75	-71	-67
Central America	661	2221	572	2.1	-74	-13	-54
South America	1465	5345	1199	2.3	-78	-18	-55
Northern Africa	346	1396	891	3.6	-36	158	21
sub-Saharan Africa	1170	6261	5370	3.4	-14	359	49
ME & Turkey	1173	6010	1102	2.3	-82	-6	-63
South Asia	1826	9702	6921	3.2	-29	279	99
South-East & East Asia	5361	20450	6269	2.6	-69	17	-19
World	31664	74935	26922	3.0	-64	-15	-50

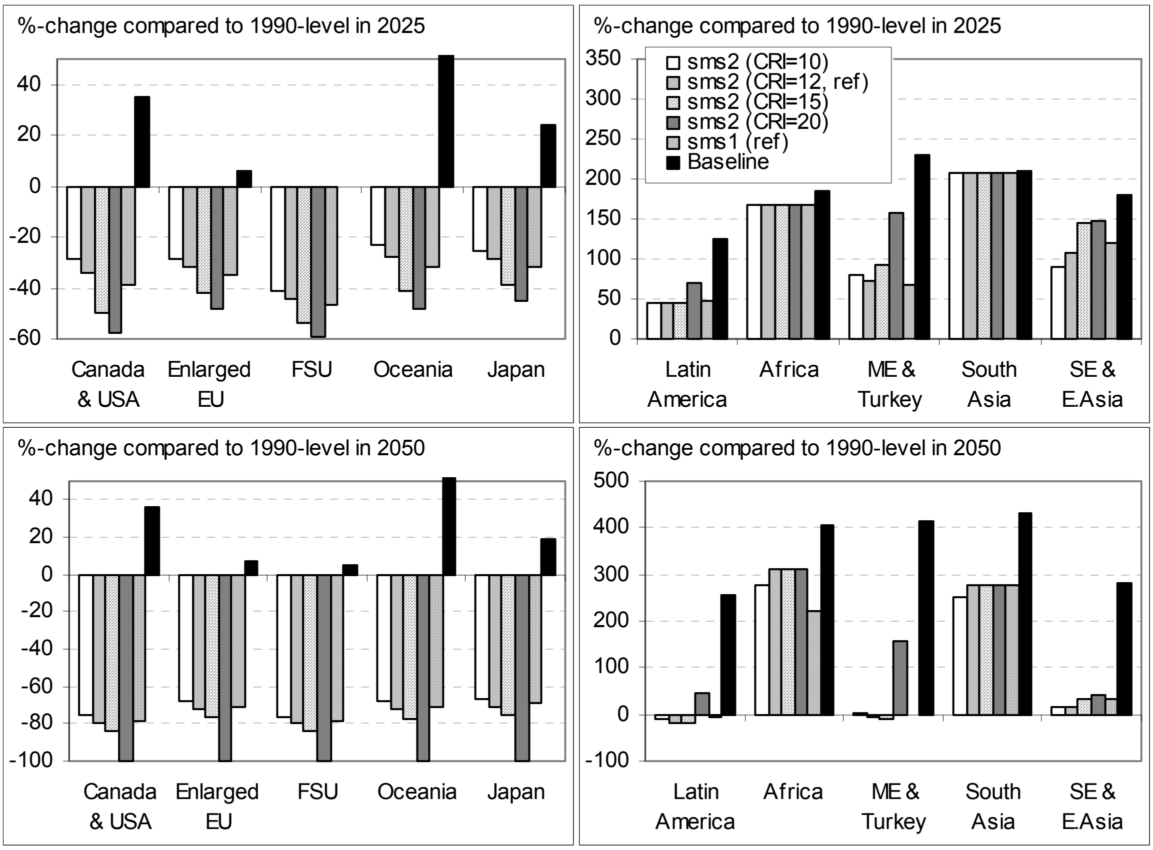

Figure C.1: Percentage change in the anthropogenic CO_2-equivalent emission allowances relative to the 1990-level for the CR sensitivity analyses for the variant MS 2 (for comparison also MS 1 reference variant is included) in the target years 2025 and 2050 for the S550e profile.

Appendix D The Multi-Stage 3 results for the S550e profile

MS 3 variant

- Participation threshold stage 2 (intensity targets): CR = 5
- Stabilisation period (TC = 70)
- Participation threshold stage 3 (emission reduction): at the end of the stabilisation period
- Burden-sharing regime based on per capita emissions

Table D.1: Overview of the total and per capita emission allowances, as well as the changes compared to 1990 and baseline emission levels.

2025	Absolute emission level				Reduction compared to		
Regions	1990 MtCO$_2$	Reference MtCO$_2$	Target MtCO$_2$	Target per capita tCO$_2$/cap yr	Baseline level %	1990 level %	1990 per capita %
USA	6487	8732	3486	10.7	-60	-46	-58
Canada	587	815	314	8.4	-61	-46	-60
OECD Europe	4390	4803	2660	7.0	-45	-39	-40
Eastern Europe	1338	1267	782	6.7	-38	-42	-39
FSU	5033	5013	2419	8.1	-52	-52	-53
Oceania	526	802	324	8.2	-60	-38	-59
Japan	1301	1617	820	6.8	-49	-37	-35
Central America	661	1436	1152	4.9	-20	74	8
South America	1465	3361	2705	5.9	-20	85	19
Northern Africa	346	930	828	4.0	-11	139	38
sub-Saharan Africa	1170	3377	3114	2.7	-8	166	19
ME & Turkey	1173	3875	2222	5.9	-43	89	-4
South Asia	1826	5677	5007	2.7	-12	174	67
South-East & East Asia	5361	14960	12694	5.5	-15	137	74
World	31664	56666	38529	4.9	-32	22	-18

2050	Absolute emission level				Reduction compared to		
Regions	1990 MtCO$_2$	Reference MtCO$_2$	Target MtCO$_2$	Target per capita tCO$_2$/cap yr	Baseline level %	1990 level %	1990 per capita %
USA	6487	8838	1551	4.4	-82	-76	-83
Canada	587	816	160	3.9	-80	-73	-81
OECD Europe	4390	4821	1435	4.1	-70	-67	-64
Eastern Europe	1338	1339	425	4.1	-68	-68	-63
FSU	5033	5305	1206	4.4	-77	-76	-75
Oceania	526	883	170	3.7	-81	-68	-81
Japan	1301	1548	445	4.0	-71	-66	-62
Central America	661	2221	748	2.7	-66	13	-40
South America	1465	5345	1628	3.1	-70	11	-38
Northern Africa	346	1396	619	2.5	-56	79	-16
sub-Saharan Africa	1170	6261	3712	2.3	-41	217	3
ME & Turkey	1173	6010	1367	2.8	-77	16	-54
South Asia	1826	9702	5634	2.6	-42	209	62
South-East & East Asia	5361	20450	7824	3.2	-62	46	1
World	31664	74935	26922	3.0	-64	-15	-50

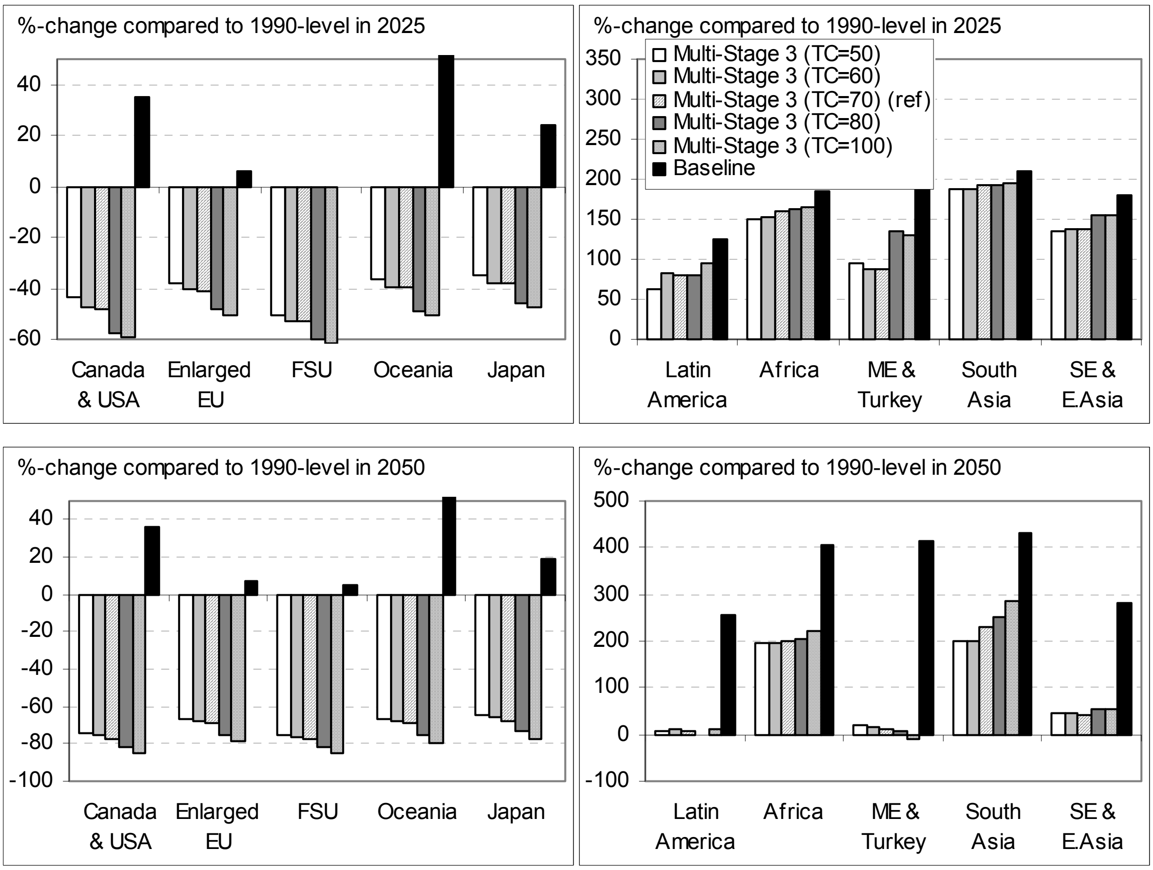

Figure D.1: Percentage change in the anthropogenic CO_2-equivalent emission allowances relative to the 1990-level for the TC-sensitivity analyses for the variant MS 3 in the target years 2025 and 2050 for the S550e profile.

Appendix E The PCC results for the S550e profile

Per capita convergence 2050 (PCC50 variant)

- Linear per capita convergence by 2050;

Table E.1: Overview of the total and per capita emission allowances for the PCC50 variant, as well as the changes compared to 1990 and baseline emission levels.

2025	Absolute emission level				Reduction compared to		
Regions	1990 $MtCO_2$	Reference $MtCO_2$	Target $MtCO_2$	Target per capita tCO_2/cap yr	Baseline level %	1990 level %	1990 per capita %
USA	6487	8732	4950	15.2	-43	-24	-40
Canada	587	815	380	10.1	-53	-35	-52
OECD Europe	4390	4803	2979	7.8	-38	-32	-33
Eastern Europe	1338	1267	869	7.4	-31	-35	-32
FSU	5033	5013	2831	9.5	-44	-44	-45
Oceania	526	802	390	9.8	-51	-26	-51
Japan	1301	1617	911	7.6	-44	-30	-28
Central America	661	1436	1014	4.3	-29	53	-5
South America	1465	3361	2243	4.9	-33	53	-1
Northern Africa	346	930	752	3.7	-19	117	25
Sub-Saharan Africa	1170	3377	3314	2.9	-2	183	27
ME & Turkey	1173	3875	2094	5.5	-46	78	-9
South Asia	1826	5677	5482	2.9	-3	200	82
South-East & East Asia	5361	14960	10318	4.5	-31	92	42
World	31664	56666	38529	4.9	-32	22	-18

2050	Absolute emission level				Reduction compared to		
Regions	1990 $MtCO_2$	Reference $MtCO_2$	Target $MtCO_2$	Target per capita tCO_2/cap yr	Baseline level %	1990 level %	1990 per capita %
USA	6487	8838	1048	3.0	-88	-84	-88
Canada	587	816	122	3.0	-85	-79	-86
OECD Europe	4390	4821	1037	3.0	-78	-76	-74
Eastern Europe	1338	1339	311	3.0	-77	-77	-73
FSU	5033	5305	818	3.0	-85	-84	-83
Oceania	526	883	137	3.0	-85	-74	-85
Japan	1301	1548	334	3.0	-78	-74	-72
Central America	661	2221	819	3.0	-63	24	-34
South America	1465	5345	1580	3.0	-70	8	-40
Northern Africa	346	1396	751	3.0	-46	117	2
Sub-Saharan Africa	1170	6261	4735	3.0	-24	305	31
ME & Turkey	1173	6010	1449	3.0	-76	23	-51
South Asia	1826	9702	6473	3.0	-33	255	86
South-East & East Asia	5361	20450	7310	3.0	-64	36	-6
World	31664	74935	26922	3.0	-64	-15	-50

Per capita convergence 2100 (PCC100 variant)

- Linear per capita convergence by 2100;

Table E.2: Overview of the total and per capita emission allowances for the PCC100 variant, as well as the changes compared to 1990 and baseline emission levels.

2025	Absolute emission level				Reduction compared to		
Regions	1990 $MtCO_2$	Reference $MtCO_2$	Target $MtCO_2$	Target per capita tCO_2/cap yr	Baseline level %	1990 level %	1990 per capita %
USA	6487	8732	6070	18.7	-30	-6	-27
Canada	587	815	446	11.9	-45	-24	-44
OECD Europe	4390	4803	3351	8.8	-30	-24	-25
Eastern Europe	1338	1267	968	8.3	-24	-28	-25
FSU	5033	5013	3289	11.0	-34	-35	-37
Oceania	526	802	456	11.5	-43	-13	-42
Japan	1301	1617	1019	8.5	-37	-22	-20
Central America	661	1436	970	4.1	-32	47	-9
South America	1465	3361	2251	4.9	-33	54	-1
Northern Africa	346	930	669	3.3	-28	93	11
Sub-Saharan Africa	1170	3377	2563	2.2	-24	119	-2
ME & Turkey	1173	3875	2178	5.8	-44	86	-5
South Asia	1826	5677	4274	2.3	-25	134	42
South-East & East Asia	5361	14960	10025	4.4	-33	87	38
World	31664	56666	38529	4.9	-32	22	-18

2050	Absolute emission level				Reduction compared to		
Regions	1990 $MtCO_2$	Reference $MtCO_2$	Target $MtCO_2$	Target per capita tCO_2/cap yr	Baseline level %	1990 level %	1990 per capita %
USA	6487	8838	3170	9.1	-64	-51	-64
Canada	587	816	248	6.1	-70	-58	-71
OECD Europe	4390	4821	1877	5.4	-61	-57	-53
Eastern Europe	1338	1339	545	5.3	-59	-59	-52
FSU	5033	5305	1782	6.5	-66	-65	-62
Oceania	526	883	258	5.7	-71	-51	-72
Japan	1301	1548	577	5.2	-63	-56	-51
Central America	661	2221	727	2.7	-67	10	-42
South America	1465	5345	1578	3.0	-70	8	-40
Northern Africa	346	1396	568	2.3	-59	64	-23
Sub-Saharan Africa	1170	6261	2866	1.8	-54	145	-21
ME & Turkey	1173	6010	1515	3.1	-75	29	-49
South Asia	1826	9702	4161	1.9	-57	128	19
South-East & East Asia	5361	20450	7049	2.9	-66	31	-9
World	31664	74935	26922	3.0	-64	-15	-50

Appendix F The Multi-Stage 1 results for the S650e profile

MS 1 variant

- Participation threshold stage 2 (intensity targets): CR = 12
- Linear de-carbonisation rate
- Participation threshold stage 3 (emission reduction): 120% of world average per capita emissions
- Burden-sharing regime based on per capita emissions

Table F.1: Overview of the total and per capita emission allowances, as well as the changes compared to 1990 and baseline emission levels.

2025	Absolute emission level				Reduction compared to		
Regions	1990 MtCO$_2$	Reference MtCO$_2$	Target MtCO$_2$	Target per capita tCO$_2$/cap yr	Baseline level %	1990 level %	1990 per capita %
USA	6487	8732	7010	21.6	-20	8	-16
Canada	587	815	519	13.9	-36	-12	-34
OECD Europe	4390	4803	3874	10.1	-19	-12	-13
Eastern Europe	1338	1267	1115	9.5	-12	-17	-13
FSU	5033	5013	3835	12.9	-24	-24	-26
Oceania	526	802	530	13.4	-34	1	-33
Japan	1301	1617	1176	9.8	-27	-10	-7
Central America	661	1436	1213	5.2	-16	83	13
South America	1465	3361	2703	5.9	-20	85	19
Northern Africa	346	930	930	4.5	0	169	55
sub-Saharan Africa	1170	3377	3377	3.0	0	189	29
ME & Turkey	1173	3875	2414	6.4	-38	106	5
South Asia	1826	5677	5677	3.0	0	211	89
South-East & East Asia	5361	14960	14278	6.2	-5	166	96
World	31664	56666	48651	6.2	-14	54	3

2050	Absolute emission level				Reduction compared to		
Regions	1990 MtCO$_2$	Reference MtCO$_2$	Target MtCO$_2$	Target per capita tCO$_2$/cap yr	Baseline level %	1990 level %	1990 per capita %
USA	6487	8838	3151	9.0	-64	-51	-65
Canada	587	816	293	7.2	-64	-50	-66
OECD Europe	4390	4821	2375	6.9	-51	-46	-41
Eastern Europe	1338	1339	694	6.7	-48	-48	-39
FSU	5033	5305	2124	7.8	-60	-58	-55
Oceania	526	883	309	6.8	-65	-41	-66
Japan	1301	1548	731	6.6	-53	-44	-38
Central America	661	2221	1209	4.4	-46	83	-3
South America	1465	5345	2632	5.0	-51	80	0
Northern Africa	346	1396	1224	4.9	-12	254	67
sub-Saharan Africa	1170	6261	5614	3.6	-10	380	55
ME & Turkey	1173	6010	1832	3.8	-70	56	-38
South Asia	1826	9702	9702	4.5	0	431	179
South-East & East Asia	5361	20450	15031	6.2	-27	180	94
World	31664	74935	46922	5.2	-37	48	-13

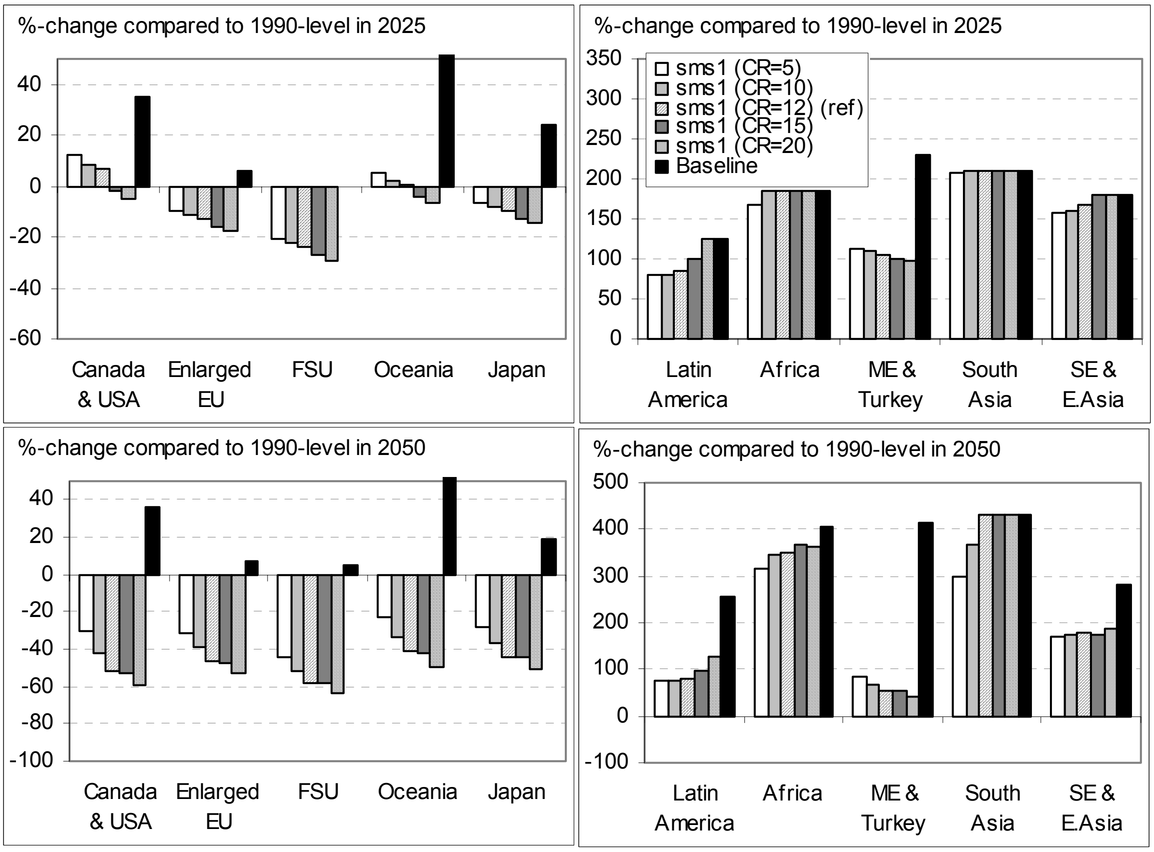

Figure F.1: Percentage change in the anthropogenic CO_2-equivalent emission allowances relative to the 1990-level for the CR sensitivity analyses for the variant MS 1 in the target years 2025 and 2050 for the S650e profile.

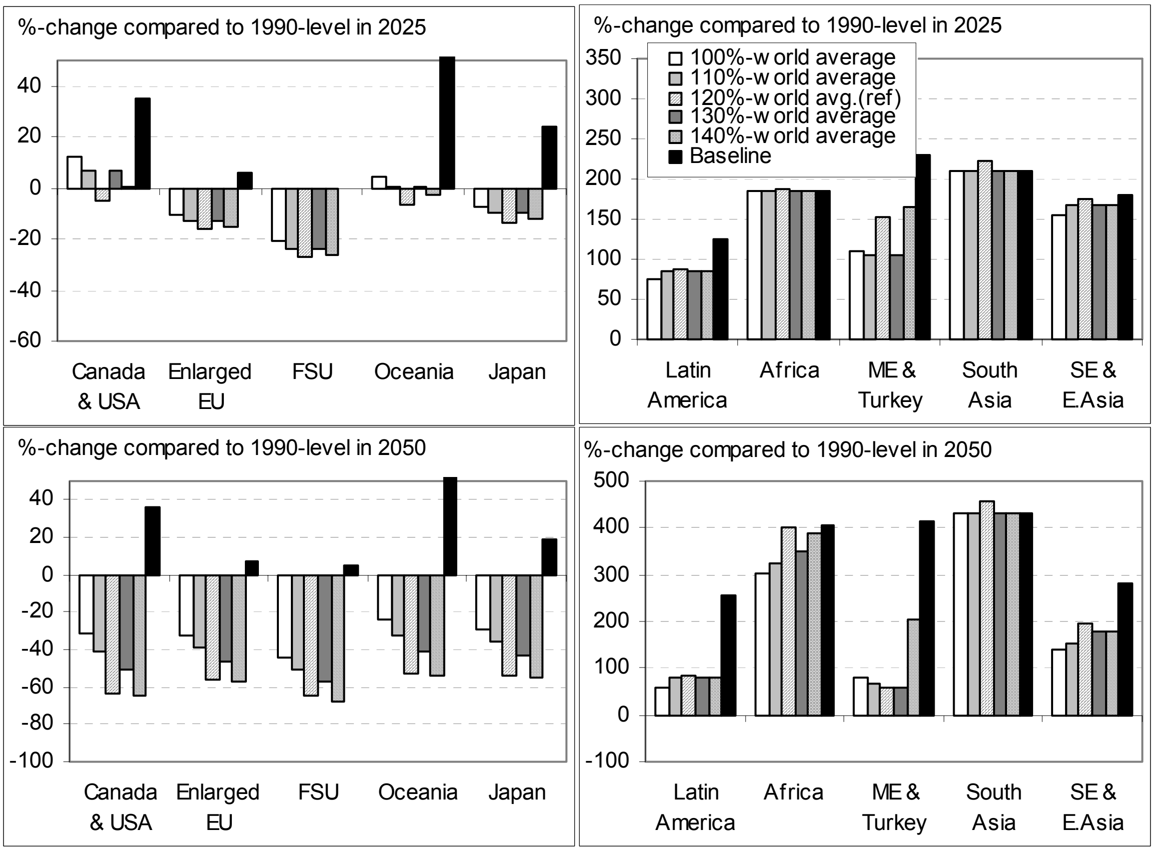

Figure F.2: Percentage change in the anthropogenic CO_2-equivalent emission allowances relative to the 1990-level for the world-average per capita threshold-sensitivity analyses for the variant MS 1 in the target years 2025 and 2050 for the S650e profile.

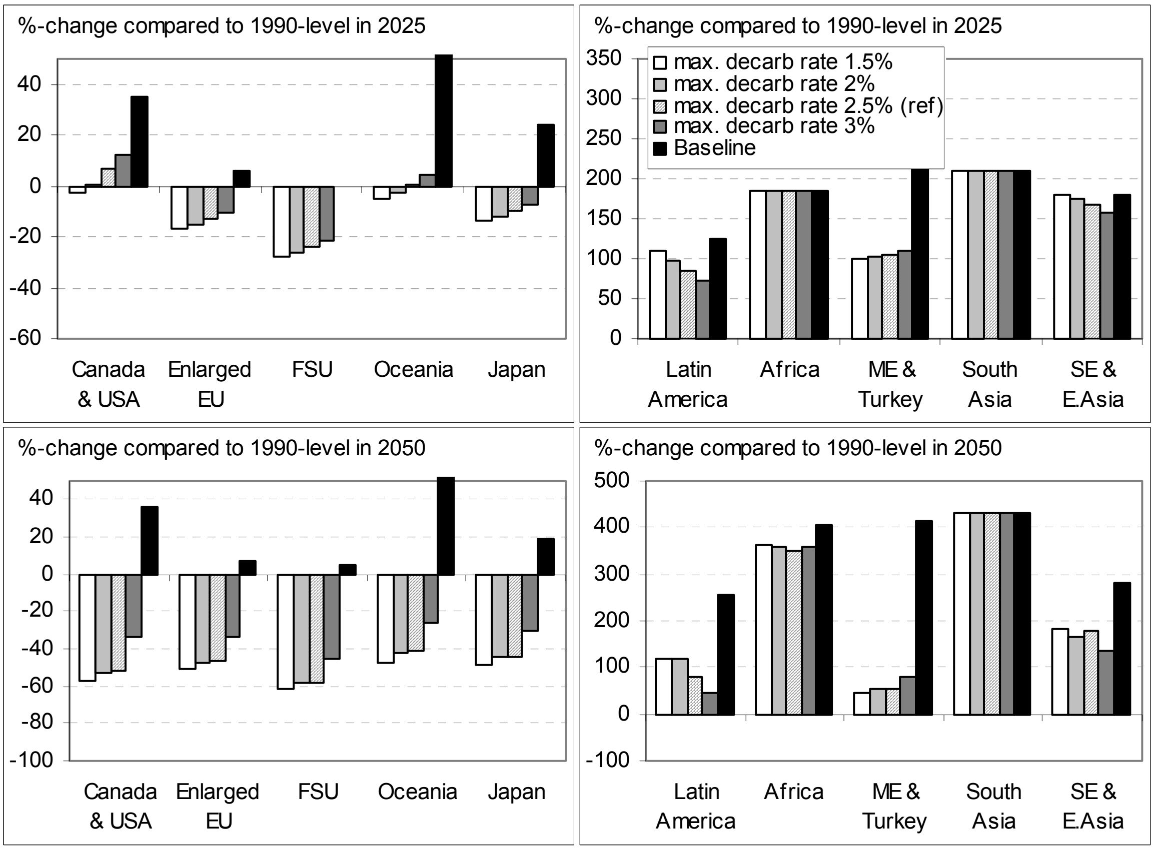

Figure F.3: Percentage change in the anthropogenic CO_2-equivalent emission allowances relative to the 1990-level for the sensitivity analyses for the rate of de-carbonisation for the variant MS 1 in the target years 2025 and 2050 for the S650e profile.

Appendix G The Multi-Stage 2 results for the S650e profile

MS 2 variant

- Participation threshold stage 2 (intensity targets): CR = 12
- Linear de-carbonisation rate
- Participation threshold stage 3 (emission reduction): CR = 20
- Burden-sharing regime based on per capita emissions

Table G.2: Overview of the total and per capita emission allowances. as well as the changes compared to 1990 and baseline emission levels.

2025	Absolute emission level				Reduction compared to		
Regions	1990 $MtCO_2$	Reference $MtCO_2$	Target $MtCO_2$	Target per capita tCO_2/cap yr	Baseline level %	1990 level %	1990 per capita %
USA	6487	8732	6624	20.4	-24	2	-20
Canada	587	815	500	13.4	-39	-15	-37
OECD Europe	4390	4803	3775	9.9	-21	-14	-15
Eastern Europe	1338	1267	1089	9.3	-14	-19	-15
FSU	5033	5013	3710	12.4	-26	-26	-28
Oceania	526	802	511	12.9	-36	-3	-35
Japan	1301	1617	1147	9.5	-29	-12	-10
Central America	661	1436	1213	5.2	-16	83	13
South America	1465	3361	2703	5.9	-20	85	19
Northern Africa	346	930	930	4.5	0	169	55
sub-Saharan Africa	1170	3377	3377	3.0	0	189	29
ME & Turkey	1173	3875	3118	8.3	-20	166	35
South Asia	1826	5677	5677	3.0	0	211	89
South-East & East Asia	5361	14960	14278	6.2	-5	166	96
World	31664	56666	48651	6.2	-14	54	3

2050	Absolute emission level				Reduction compared to		
Regions	1990 $MtCO_2$	Reference $MtCO_2$	Target $MtCO_2$	Target per capita tCO_2/cap yr	Baseline level %	1990 level %	1990 per capita %
USA	6487	8838	3013	8.6	-66	-54	-66
Canada	587	816	282	6.9	-65	-52	-67
OECD Europe	4390	4821	2310	6.7	-52	-47	-43
Eastern Europe	1338	1339	675	6.5	-50	-50	-41
FSU	5033	5305	2057	7.5	-61	-59	-57
Oceania	526	883	298	6.5	-66	-43	-67
Japan	1301	1548	711	6.4	-54	-45	-39
Central America	661	2221	1209	4.4	-46	83	-3
South America	1465	5345	2498	4.7	-53	71	-5
Northern Africa	346	1396	1224	4.9	-12	254	67
sub-Saharan Africa	1170	6261	6241	4.0	0	434	73
ME & Turkey	1173	6010	3222	6.7	-46	175	9
South Asia	1826	9702	9702	4.5	0	431	179
South-East & East Asia	5361	20450	13477	5.5	-34	151	74
World	31664	74935	46922	5.2	-37	48	-13

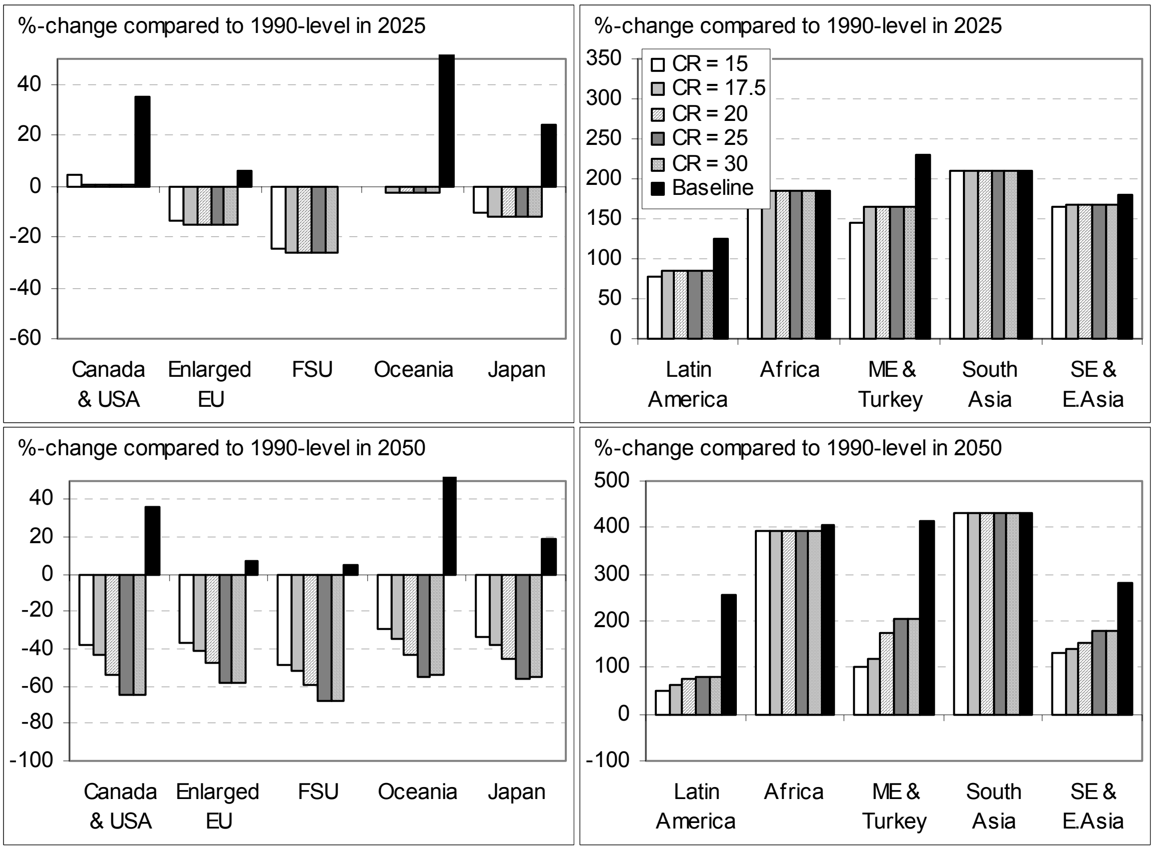

Figure G.1: Percentage change in the anthropogenic CO_2-equivalent emission allowances relative to the 1990-level for the CR sensitivity analyses for the variant MS 2 in the target years 2025 and 2050 for the S650e profile.

Appendix H The Multi-Stage 3 results for the S650e profile

MS 3 variant
- Participation threshold stage 2 (intensity targets): CR = 12
- Stabilisation period (TC = 30)
- Participation threshold stage 3 (emission reduction): at the end of the stabilisation period
- Burden-sharing regime based on per capita emissions

Table H.1: Overview of the total and per capita emission allowances, as well as the changes compared to 1990 and baseline emission levels.

2025	Absolute emission level				Reduction compared to		
Regions	1990 $MtCO_2$	Reference $MtCO_2$	Target $MtCO_2$	Target per capita tCO_2/cap yr	Baseline level %	1990 level %	1990 per capita %
USA	6487	8732	6497	20.0	-26	0	-22
Canada	587	815	494	13.2	-39	-16	-38
OECD Europe	4390	4803	3749	9.8	-22	-15	-16
Eastern Europe	1338	1267	1082	9.2	-15	-19	-16
FSU	5033	5013	3673	12.3	-27	-27	-29
Oceania	526	802	505	12.7	-37	-4	-36
Japan	1301	1617	1140	9.5	-30	-12	-10
Central America	661	1436	1333	5.7	-7	102	25
South America	1465	3361	2885	6.3	-14	97	27
Northern Africa	346	930	930	4.5	0	169	55
sub-Saharan Africa	1170	3377	3377	3.0	0	189	29
ME & Turkey	1173	3875	2971	7.9	-23	153	29
South Asia	1826	5677	5677	3.0	0	211	89
South-East & East Asia	5361	14960	14337	6.3	-4	167	97
World	31664	56666	48651	6.2	-14	54	3

2050	Absolute emission level				Reduction compared to		
Regions	1990 $MtCO_2$	Reference $MtCO_2$	Target $MtCO_2$	Target per capita tCO_2/cap yr	Baseline level %	1990 level %	1990 per capita %
USA	6487	8838	3538	10.1	-60	-45	-60
Canada	587	816	320	7.9	-61	-46	-63
OECD Europe	4390	4821	2584	7.5	-46	-41	-36
Eastern Europe	1338	1339	754	7.3	-44	-44	-34
FSU	5033	5305	2342	8.6	-56	-53	-51
Oceania	526	883	335	7.3	-62	-36	-63
Japan	1301	1548	794	7.1	-49	-39	-32
Central America	661	2221	1183	4.3	-47	79	-5
South America	1465	5345	2359	4.5	-56	61	-11
Northern Africa	346	1396	1314	5.2	-6	280	79
sub-Saharan Africa	1170	6261	6175	3.9	-1	428	71
ME & Turkey	1173	6010	2295	4.7	-62	96	-22
South Asia	1826	9702	9630	4.5	-1	427	176
South-East & East Asia	5361	20450	13300	5.5	-35	148	72
World	31664	74935	46922	5.2	-37	48	-13

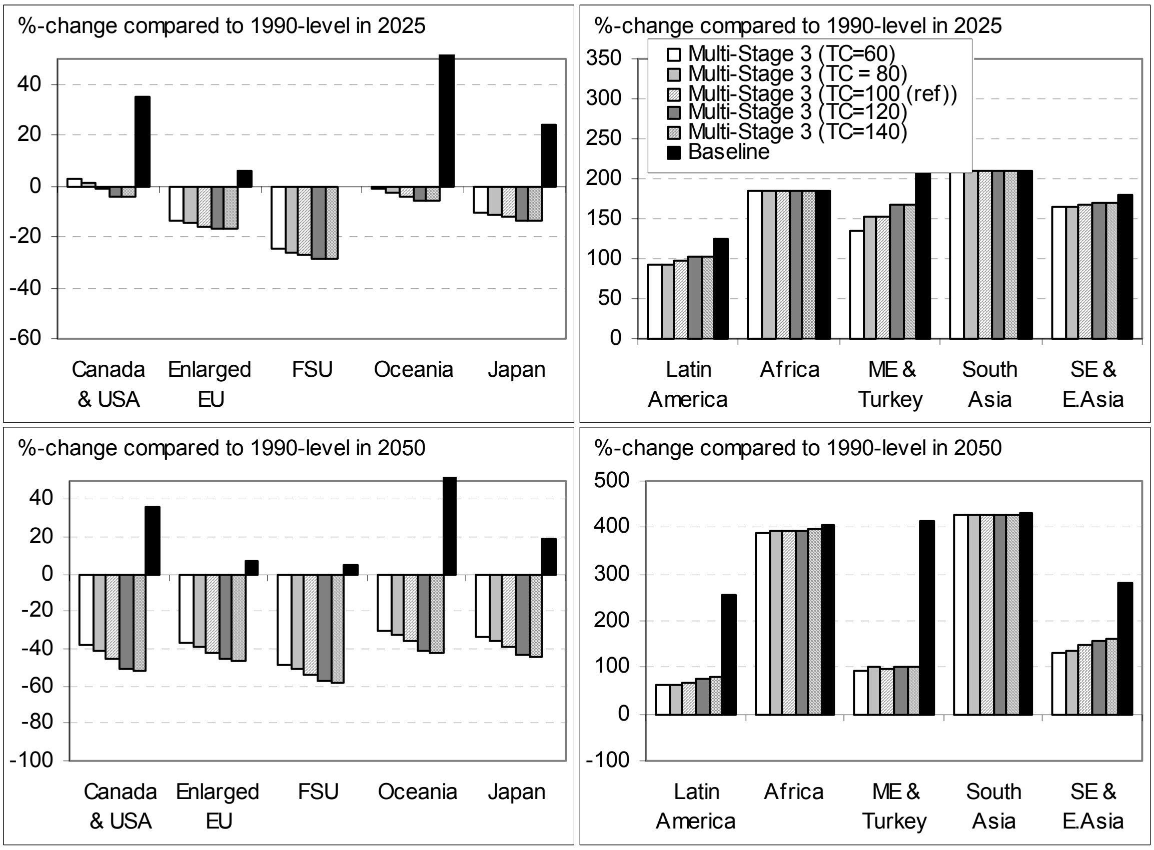

Figure H.1: Percentage change in the anthropogenic CO_2-equivalent emission allowances relative to the 1990-level for the TC-sensitivity analyses for the variant MS 3 in the target years 2025 and 2050 for the S650e profile.

Appendix I The PCC results for the S550e profile

Per capita convergence 2050

- Linear per capita convergence by 2050;

Table I.1: Overview of the total and per capita emission allowances, as well as the changes compared to 1990 and baseline emission levels.

2025	Absolute emission level				Reduction compared to		
Regions	1990 MtCO$_2$	Reference MtCO$_2$	Target MtCO$_2$	Target per capita tCO$_2$/cap yr	Baseline level %	1990 level %	1990 per capita %
USA	6487	8732	6250	19.2	-28	-4	-25
Canada	587	815	480	12.8	-41	-18	-39
OECD Europe	4390	4803	3762	9.9	-22	-14	-15
Eastern Europe	1338	1267	1098	9.4	-13	-18	-14
FSU	5033	5013	3574	12.0	-29	-29	-31
Oceania	526	802	493	12.4	-39	-6	-38
Japan	1301	1617	1151	9.5	-29	-12	-9
Central America	661	1436	1281	5.5	-11	94	20
South America	1465	3361	2832	6.2	-16	93	24
Northern Africa	346	930	950	4.6	2	175	58
Sub-Saharan Africa	1170	3377	4185	3.7	24	258	60
ME & Turkey	1173	3875	2645	7.0	-32	125	15
South Asia	1826	5677	6922	3.7	22	279	130
South-East & East Asia	5361	14960	13028	5.7	-13	143	79
World	31664	56666	48651	6.2	-14	54	3

2050	Absolute emission level				Reduction compared to		
Regions	1990 MtCO$_2$	Reference MtCO$_2$	Target MtCO$_2$	Target per capita tCO$_2$/cap yr	Baseline level %	1990 level %	1990 per capita %
USA	6487	8838	1827	5.2	-79	-72	-80
Canada	587	816	212	5.2	-74	-64	-75
OECD Europe	4390	4821	1807	5.2	-63	-59	-55
Eastern Europe	1338	1339	542	5.2	-60	-59	-52
FSU	5033	5305	1425	5.2	-73	-72	-70
Oceania	526	883	238	5.2	-73	-55	-74
Japan	1301	1548	582	5.2	-62	-55	-50
Central America	661	2221	1427	5.2	-36	116	15
South America	1465	5345	2754	5.2	-48	88	4
Northern Africa	346	1396	1309	5.2	-6	278	78
Sub-Saharan Africa	1170	6261	8252	5.2	32	606	128
ME & Turkey	1173	6010	2525	5.2	-58	115	-14
South Asia	1826	9702	11281	5.2	16	518	224
South-East & East Asia	5361	20450	12739	5.2	-38	138	65
World	31664	74935	46922	5.2	-37	48	-13

Per capita convergence 2100

- Linear per capita convergence by 2100;

Table I.2: Overview of the total and per capita emission allowances, as well as the changes compared to 1990 and baseline emission levels.

2025	Absolute emission level				Reduction compared to		
Regions	1990 $MtCO_2$	Reference $MtCO_2$	Target $MtCO_2$	Target per capita tCO_2/cap yr	Baseline level %	1990 level %	1990 per capita %
USA	6487	8732	7665	23.6	-12	18	-8
Canada	587	815	563	15.0	-31	-4	-29
OECD Europe	4390	4803	4232	11.1	-12	-4	-5
Eastern Europe	1338	1267	1223	10.4	-4	-9	-5
FSU	5033	5013	4153	13.9	-17	-17	-20
Oceania	526	802	576	14.5	-28	9	-27
Japan	1301	1617	1287	10.7	-20	-1	1
Central America	661	1436	1225	5.2	-15	85	14
South America	1465	3361	2842	6.2	-15	94	25
Northern Africa	346	930	845	4.1	-9	144	41
Sub-Saharan Africa	1170	3377	3237	2.8	-4	177	24
ME & Turkey	1173	3875	2750	7.3	-29	134	19
South Asia	1826	5677	5397	2.9	-5	196	79
South-East & East Asia	5361	14960	12659	5.5	-15	136	74
World	31664	56666	48651	6.2	-14	54	3

2050	Absolute emission level				Reduction compared to		
Regions	1990 $MtCO_2$	Reference $MtCO_2$	Target $MtCO_2$	Target per capita tCO_2/cap yr	Baseline level %	1990 level %	1990 per capita %
USA	6487	8838	5526	15.8	-37	-15	-38
Canada	587	816	432	10.6	-47	-26	-50
OECD Europe	4390	4821	3272	9.5	-32	-25	-19
Eastern Europe	1338	1339	949	9.2	-29	-29	-16
FSU	5033	5305	3107	11.4	-41	-38	-34
Oceania	526	883	450	9.9	-49	-14	-50
Japan	1301	1548	1006	9.0	-35	-23	-14
Central America	661	2221	1267	4.6	-43	92	2
South America	1465	5345	2751	5.2	-49	88	4
Northern Africa	346	1396	990	3.9	-29	186	35
Sub-Saharan Africa	1170	6261	4995	3.2	-20	327	38
ME & Turkey	1173	6010	2641	5.5	-56	125	-10
South Asia	1826	9702	7252	3.4	-25	297	108
South-East & East Asia	5361	20450	12286	5.0	-40	129	59
World	31664	74935	46922	5.2	-37	48	-13