Evaluation of the Copenhagen Accord: Chances and risks for the 2°C climate goal

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PBL publication number 500114018

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Abstract

In December 2009, an important United Nations climate change conference (COP15) took place in Copenhagen, Denmark. This conference resulted in the Copenhagen Accord, which forms the basis for further negotiations in Cancun, Mexico, later this year. As part of the Copenhagen Accord, industrialised countries have submitted greenhouse gas emission reduction targets for 2020 and developing countries have submitted actions for reducing greenhouse gas emissions. This report presents an overview of: i) the global emission implications of all these submissions; ii) the abatement cost implications; iii) the implications for meeting the 2°C climate goal, specified in the Copenhagen Accord, iv) the main risks that could increase the existing emissions gap towards 2°C, and v) the available options to close the emissions gap towards 2°C.

The country submissions for emission reduction could result in a decrease of the global emission level in 2020 from 56 Gt CO_2 eq to about 49 to 50 Gt CO_2 eq, against limited costs. For meeting the 2°C climate goal, it is estimated that a global emission level of 44 to 46 Gt CO_2 eq is necessary in 2020. Therefore, although the submissions are expected to lead to substantial emission reductions, higher reductions are necessary in order to maintain a reasonable chance of reaching the 2°C climate goal. Several options are identified that could decrease emissions by a further 4 Gt CO_2 eq, which would close the emissions gap completely. However, there are also various reasons why the emission reductions resulting from the country submissions could turn out to be much lower and, in fact, could result in almost no reductions at all.

Keywords: Reduction pledges, nationally appropriate mitigation actions (NAMAs), emissions gap, two degree target, abatement costs, emissions trading, emission surplus, UNFCCC, climate change

Contents

Summary

In December 2009, an important United Nations climate change conference (COP15) took place in Copenhagen, Denmark. This conference resulted in the Copenhagen Accord, which forms the basis of further negotiations in Cancun, Mexico, later this year. As part of the Copenhagen Accord, Annex I Parties (industrialised countries) and Non-Annex I Parties (developing countries) have submitted reduction proposals (pledges) and mitigation actions to the UNFCCC secretariat. This report analyses the implications of all these reduction pledges and mitigation actions of the seven major Non-Annex I Parties (China, India, Brazil, Indonesia, Mexico, South Africa and South Korea). The analysis focuses on the following questions:

- What are the emission reduction targets, comparability and abatement costs of current Annex I country pledges to the Copenhagen Accord?
- What are the reduction targets and costs of the mitigation action plans submitted by the seven major emerging economies to the Copenhagen Accord?
- Are the Copenhagen Accord pledges and mitigation plans compatible with meeting the long-term 2°C climate target specified in the Copenhagen Accord? If not, what is the emissions gap in the trajectory to keep global temperature rise to below 2°C? What are feasible options to narrow the emissions gap towards 2°C? And what are risks that the gap may widen?

The calculations used in this report are based mainly on the FAIR[1] model which has been used in conjunction with the IMAGE land use model and TIMER energy model. The results of other studies (Ecofys including updates, European Climate Foundation, UNEP) have been used for comparison.

Reduction targets, comparability and costs of Annex I pledges

Most Annex I countries have submitted an unconditional pledge and a more ambitious pledge that is mainly conditional on other countries pledging comparable reductions. The unconditional ("low") pledges would result in a total Annex I emission reduction target of 4 to 18% below 1990 levels by 2020. The conditional ("high") pledges amount to a reduction target of 9 to 21%. The large range in reduction targets is mainly due to uncertainty in the land use and forestry rules and the use of surplus emission allowances or assigned amount units (AAUs), often referred to as 'hot air', of Russia and Ukraine (see Table S.1).

The land use and forestry rules for the current Kyoto commitment period state that individual countries can choose to include greenhouse gas fluxes from forest management (with a cap on accruing emissions allowances), cropland management, grazing land management and re-vegetation. The rules for the post-2012 commitment period are still under negotiation. In this report, we assume that land use and

1 The model names in this section are acronyms. FAIR = Framework to Assess International Regimes for the differentiation of commitments; IMAGE = Integrated Model to Assess the Global Environment; TIMER = The IMage Energy Regional model.

Impact of including allowance increases from land use and forestry rules and new surplus of AAUs for Russia and Ukraine for the Annex I emission and reduction targets for the low and high pledge scenario — **Table S.1**

Annex I	Emission target (Gt CO2 eq[v])	Reduction target below 1990 (%)
Excluding allowances from land use and forestry rules, Including new surplus AAUs	16.5 – 15.5	12 – 18
Including allowances from land use and forestry rules, Including new surplus AAUs	16.9 – 16.0	10 – 15
Excluding allowances from land use and forestry rules, Excluding surplus AAUs	15.5 – 14.8	18 – 21
Including allowances from land use and forestry rules, Excluding surplus AAUs	15.8 – 15.2	16 – 19
Excluding allowances from land use and forestry rules, Including new and Kyoto surplus AAUs	17.7 – 16.7	6 – 11
Including allowances from land use and forestry rules, Including new and Kyoto surplus AAUs	18.1 – 17.1	4 – 9

[v] Carbon dioxide equivalent (CO_2 eq) is a unit that combines all Kyoto greenhouse gases (carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6). It is based on the global warming potential (GWP) and uses the warming associated with carbon dioxide as the benchmark. More specifically, CO_2 eq emissions are GWP-weighted sum of six Kyoto greenhouse gas emissions, excluding land use CO_2.

forestry rules are likely to result in an additional emission allowance of 2.5% of 1990 Annex I emissions (estimates in other studies vary from 1 to 9% of 1990 Annex I emissions). Including allowances from land use and forestry rules to achieve the emission targets would decrease the reduction level by 2.5% of 1990 Annex I emissions.

Another uncertainty concerns the use of surplus AAUs by Russia and Ukraine. The reduction pledges of Russia and Ukraine are well above their baseline emissions, which means that they will receive surplus AAUs. If these AAUs are forfeited (not used), the Annex I reduction target would be 3 to 6% higher than in the case of trading these AAUs. However, banking and use of surplus AAUs from the first commitment period would decrease the reduction level by 6 to 7%, towards a reduction target range of 4 to 11% below 1990 levels.

According to the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment report (AR4), Annex I emission reduction targets of 25 to 40% below 1990 levels in 2020 would be consistent with stabilising long-term levels of greenhouse gas concentration levels at 450 ppm CO_2 equivalent[2] This concentration level has a reasonable chance (50%) of avoiding an increase in global average temperature of more than 2°C. Even in the high pledge scenario (assuming all high reduction pledges are implemented, excluding allowance increases from land use and forestry rules and no trading of surplus AAUs), this range will not be met (Table S.1).

The Copenhagen Accord pledges have been compared with the reduction targets calculated from different comparable effort-sharing approaches (for example, equal marginal abatement costs for all countries) in an earlier study (den Elzen et al., 2009a). This comparison has shown that the high pledges of the EU, Japan and Australia are in line with the comparable effort reduction range to meet the 25-40% Annex I reduction target. The pledge of the USA seems less ambitious if financing emission reduction from deforestation in developing countries is not included. The pledges of Canada and especially Russia and Ukraine are less ambitious than this range.

Average abatement costs for Annex I countries – even when excluding Russia and Ukraine – are correspondingly low. These costs are about 0.2% of GDP in 2020 for the high pledge scenario (reduction target of 21% below 1990 levels), if restricted emissions trading is allowed. This implies that at least two-thirds of emission reductions for all Annex I countries needs to be achieved domestically ('restricted emissions trading'). However without emissions trading and the use of the Clean Development Mechanism (CDM), costs are projected to be 0.4% of GDP in 2020. This estimate assumes substantial international financing of abatement costs in Non-Annex I countries (about 30% of total Annex I abatement cost is earmarked for international financing).

2 CO_2 equivalence expresses the radiative forcing of other anthropogenic forcing agents in terms of the equivalent CO_2 concentration that would result in the same level of forcing. In this paper, the definition of CO_2 eq concentrations includes the Kyoto greenhouse gases, tropospheric ozone and sulphur aerosols.

This means that 50% of the total abatement costs for Brazil, Indonesia, Mexico and South Africa are financed internationally. Australia and New Zeeland will have the highest costs of about 0.5% of GDP with restricted emissions trading and 0.9% of GDP without emissions trading. In such a scenario, Ukraine and Russia could still make significant profits from selling *new* surplus AAUs, even if they do not bank the AAUs from the first commitment period and they help in financing abatement costs in Non-Annex I countries. The costs for Canada are below the Annex I average, which corresponds to their relative low ambitious pledge.

The above indicates that the reduction levels of Russia, Ukraine and Canada would need to increase to keep their reduction targets comparable with other Annex I countries. However, these cost projections depend heavily on assumptions with regard to policy choices, such as limited use of surplus AAUs (no banking of Kyoto surplus AAUs and only 25% use of new surplus AAUs) in order to maximise the gains for Russia and Ukraine. Moreover, the cost estimates are uncertain and depend on many model assumptions, such as baseline emission projections (without climate policy), and marginal abatement cost estimates.

Reduction and costs implications of mitigation actions by the seven major emerging economies

The mitigation action plans submitted to the Copenhagen Accord by the seven largest emitting emerging economies responsible for more than two-thirds of total Non-Annex I emissions in 2020 have been estimated. According to our analysis, these mitigation action plans could reduce emissions by approximately 11 to 14% below their baseline emissions.

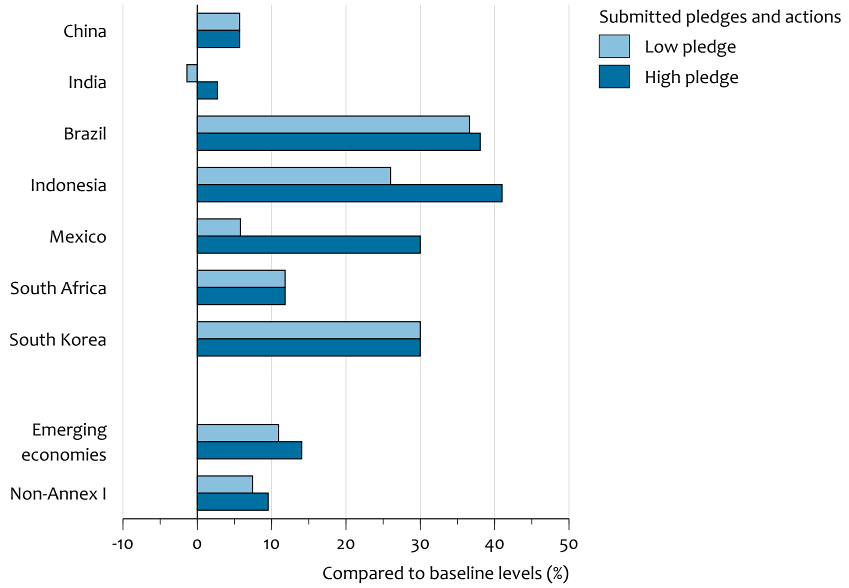
This range is due to the conditionality of the pledges of Brazil, Indonesia, Mexico and South Africa on international support. Without such support, reduction targets will be at the low end of this range and with financial support at the high end of the range. If all other Non-Annex I countries follow their baseline emissions, then the group of Non-Annex I countries would be 7 to 10% below baseline emissions. A 15 to 30% reduction below baseline emissions is consistent with a 450 ppm CO_2 eq target (den Elzen and Höhne, 2008). Thus, the mitigation action plans seem insufficient to meet the 2°C target.

The uncertainty in the projected emission levels of the seven major emerging economies in 2020 based on their submitted actions is larger than suggested by the 11 to 14% below baseline range. The main reason is that China and India have set emission intensity targets (emission reduction per unit of GDP). For China, this is in combination with a non-fossil energy target and a forest target.[3] It implies that the emission reduction target depends heavily on actual developments in baseline emissions and GDP growth.

3 More specifically, China will endeavour to lower its carbon dioxide emissions per unit of GDP by 40–45% by 2020 compared to the 2005 level, increase the share of non-fossil fuels in primary energy consumption to around 15% by 2020, and increase forest coverage by 40 million ha and forest stock volume by 1.3 billion m^3 by 2020 on 2005 levels. India has submitted a 20-25% reduction in greenhouse gas emission intensity per unit of GDP by 2020 compared to 2005 levels (excluding agricultural emissions).

Reduction targets compared to baseline levels of emerging economies, 2020 **Figure S.1**

Greenhouse gas emissions, including CO_2 from land use



The estimated reduction targets of the mitigation action plans in relation to baseline emissions of the emerging economies are presented in Figure S.1. Calculated absolute emission reductions as a result of the intensity targets of China and India are expected to be low. Their national climate plans are not included here because these are not part of their submissions (see the section on options to narrow the gap).

The abatement costs for the seven emerging economies, for which we analysed mitigation action plans, are about 0.15 to 0.20% of GDP for the low and high pledge scenario, respectively. This assumes that about 50% of abatement costs of South Africa, Korea, Indonesia, Brazil and Mexico are financed by Annex I countries. However, these costs are very uncertain.

There are large differences in total costs between countries because of national circumstances, reductions targets and other factors. The costs as proportion of GDP are estimated to be low for countries with relatively low reduction targets, notably China and India. For Korea, Indonesia, Brazil and Mexico costs are expected to be relatively high even with substantial international financial support.

Options to narrow the 2°C gap and the risks of widening the gap

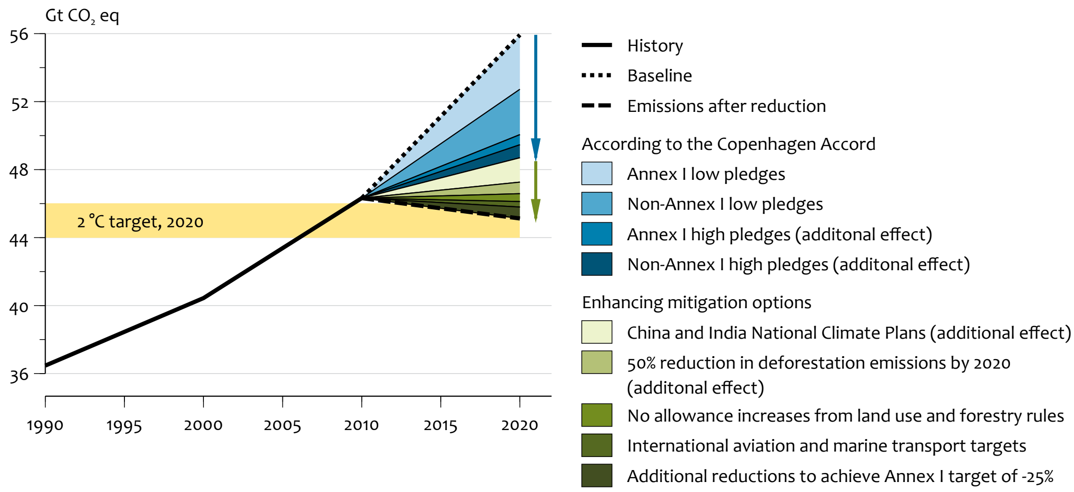
Whether or not the 2°C target will be met depends partly on the emission level in 2020, but much more on the cumulative emissions over the next decades. In other words, the emission trajectory after 2020 largely determines whether the 2°C climate target will be met. According to mitigation scenario studies (e.g., Rao et al., 2010; van Vuuren et al., 2010), an emission level of 44 to 46 Gt CO_2 eq in 2020 seems to be consistent with an emission trajectory that has a reasonable chance of meeting the 2°C target. The Copenhagen Accord pledges of Annex I and emerging economies would lead to a global emission level in 2020 of about 48.7 to 50.1 Gt CO_2 eq. Thus, there is a gap of about 2.7 to 6.1 Gt CO_2 eq in staying on an emission pathway consistent with meeting the 2°C target (see Figure S.2).

The main risks for widening the emission gap are as follows. Firstly, the reduction target for the USA may be lower if the climate bill fails to pass or is weakened by the Senate. This may trigger lower pledges from other countries, leading to a maximum of 2.8 Gt CO_2 eq increase in emissions. It assumes that the USA returns to 2005 levels, Japan to 17% below 2005 levels, and low pledge reduction levels of the other countries. Secondly, there is the risk of higher allowance increases from land use and forestry rules, leading to a 1.2 Gt CO_2 eq increase. Thirdly, offset emissions could be double counted, with emission reductions included by both the developed country reporting having paid for, and by the developing country reporting having reduced. This creates a risk of 1.3 Gt CO_2 eq. Finally, use of Kyoto surplus AAUs could increase emissions by 1 Gt CO_2 eq. Taking into account all the risks explored in this study, the total emission level could be close to baseline emissions.

However, a combined set of options could also result in an additional 2.9 Gt CO_2 eq emission reduction, largely closing the 2020 emissions gap for 2°C. First of all, enhancement of mitigation action for China and India according to their domestic climate policy (not part of their submissions to the Copenhagen Accord) could lead to further reductions estimated at around 1.4 Gt CO_2 eq. Other options include: i) reducing emissions from deforestation by 50% below 2005 levels by 2020; ii) excluding allowance increases from land use and forestry rules; and iii) reducing international bunker emissions by 10 and 20% below 2005 levels for respectively international aviation and marine transport. Implementation of these additional measures would result in an overall Annex I reduction level of 21% below 1990 levels and an overall Non-Annex I reduction level of 15% below

Impact of pledged reductions and enhancing mitigation options — Figure S.2

Global greenhouse gas emissions, including CO_2 from land use and excluding surplus AAUs



baseline levels. According to den Elzen and Höhne (2008), a reduction of 25 to 40% below 1990 levels and 15 to 30% below baseline emissions for Annex I and Non-Annex I as a group, respectively, is compatible with meeting the 2°C target. Non-Annex I countries as a group are just inside this range. In order for Annex I countries to meet this range, they would need to decrease emissions by at least a further 0.7 Gt CO_2 eq by 2020. This would lead to a global emission level of 45.1 Gt CO_2 eq (Figure S.2).

1 Introduction

The 15th Conference of the Parties (COP15) and the 5th Conference of the Parties serving as the Meeting of the Parties to the Kyoto Protocol[1] (COP/MOP5) in Copenhagen marked the culmination of two years of negotiations under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC) and the Bali Action Plan[2]. The purpose of the negotiations was to ultimately create a comprehensive, legally-binding international treaty to replace the Kyoto Protocol when it expires in 2012.

Even though the final Copenhagen Accord drafted under the UNFCCC in 2009 recognises that considerable emission reductions are required to limit global warming to 2°C, it did not result in legally binding reduction targets for greenhouse gas emissions.

Other important issues have not settled, such as quantified goals for emission reduction from deforestation and forest degradation (REDD). Clear agreements have not been reached on how financial support – USD 30 billion for the period 2010-2012 and USD 100 billion a year by 2020 – for adaptation and mitigation measures in developing countries will be provided. Instead for mitigation, a bottom-up approach to setting targets has been agreed. Annex I Parties[3] commit to implementing emission reduction targets – pledges – for 2020 and Non-Annex I Parties (the developing world) commit to implementing mitigation actions. Parties were requested to submit these targets and actions to the UNFCCC Secretariat by 31 January 2010, as part of the Copenhagen Accord.

As of March 2010, many Annex I and Non-Annex I Parties including all major emitting countries had submitted reduction pledges and action plans for 2020. Determining the effect of these pledges and actions on the total emission reduction target is not straightforward. This is because of differences in base year emissions on which the reduction targets are defined in the pledges for Annex I countries, and because of different formulations of action plans of the Non-Annex I countries. Non-Annex I countries have made pledges in terms of detailed domestic actions, overall intensity targets, some combined with additional measures, and often including additional clauses, such as dependence on international finance, technology, and capacity-building support by developed countries.

This report analyses the pledges submitted by Annex I Parties and the mitigation action plans of the seven major emerging economies (China, India, Brazil, Indonesia, Mexico, South Africa and South Korea). For those Annex I countries that have not yet submitted their proposals, the reduction proposals officially announced before the Copenhagen negotiations were used. Our analysis focuses on the following policy questions:

- What is the reduction contribution and comparability of current Annex I reduction pledges? (Chapter 2)
- What is the reduction contribution of the mitigation actions of the seven major emerging economies submitted to the Copenhagen Accord? (Chapter 3)
- What are the abatement costs for Annex I and Non-Annex I countries under different future developments in emissions trading and the Clean Development Mechanisms (CDM)? Who are the buyers and sellers of carbon credits and what is the price of these credits? (Chapter 4)
- Are the Copenhagen pledges and mitigation plans compatible with meeting the long-term 2°C climate target? If not, what is the emissions gap to keep temperature rise below 2°C? What are the options to narrow the 2°C emissions gap? And what are risks of widening the gap? (Chapter 5)
- How robust are the above results? (Chapter 6)

The calculations in this report are mostly based on the FAIR model (den Elzen et al., 2008) which was used in conjunction with the IMAGE land use model (Bouwman et al., 2006) and TIMER energy model (van Vuuren et al., 2007). The TIMER model was used in determining the reductions from the action plans of the major Non-Annex I countries.

1 The protocol adopted in 1997 under UNFCCC negotiations includes commitments (Kyoto targets) by developed countries for emission reductions against base year emission levels. These reductions are to be reached at the end of the Kyoto commitment period in 2012.

2 Adopted at the Conference of the Parties to the UNFCCC of December 2007 (http://unfccc.int/files/meetings/cop_13/application/pdf/cp_bali_action.pdf)

3 Annex I Parties of the Kyoto Protocol consist of the 1997 list of the industrialised countries and the emerging market economies of Central and Eastern Europe.

2

Emission reduction targets from current Annex I pledges

Key findings

- As of March 2010, the low and high pledges for reduction of greenhouse gas emissions of Annex I countries (including the USA) are estimated to lead to a total reduction target of 12 to 18% below 1990 levels, respectively. This is below the 25 to 40% range (below 1990 levels) reported by IPCC to be consistent with scenarios stabilising at 450 ppm CO_2 equivalent.
- Russia and Ukraine submitted pledges above baseline or business-as-usual (BAU) emissions. If these surplus assigned amount units (AAUs) are forfeited (not used), the Annex I reduction target would increase to 18 to 21% below 1990 levels. But allowance increases from land use and forestry rules could reduce the total reduction target by 2.5% and use of Kyoto surplus AAUs by 6 to 7%.
- Comparison of the pledges with the calculated reduction targets from various approaches that account for the "comparability criteria" show the high pledges of the EU, Japan, Switzerland, Oceania and Norway to be comparable with the 25 to 40% range mentioned by IPCC. The USA pledge seems to be less ambitious, unless financing emission reduction from deforestation in developing countries is included. Based on comparability criteria, the pledges of Canada and especially of Russia and Ukraine are less ambitious.

2.1 Copenhagen Accord pledges and announcements

The Annex I countries had announced their national reduction targets for 2020 in the preparation for the Copenhagen negotiations. Recently, most Annex I countries have formally submitted their emission reduction targets for 2020 to the UNFCCC, in the context of the Copenhagen Accord.[1] The formal notifications largely reflect national positions set out in the last year. Some countries have made both a high pledge that is conditional on the pledges of other countries, and a low pledge that is unconditional. Other countries have made only one pledge, which is either conditional or not, or is unclear on this issue. Furthermore, the pledges relate to different base years. All pledges against the emission levels for 1990 and 2005 are presented in Table 2.1. A complete overview of the original pledges and their conditionality is presented in Appendix A. For countries that have only made a conditional pledge such as Japan, we have assumed that this pledge is valid for both the low and high pledge scenario.

Table 2.1 and Appendix A show that the European Union (EU) Heads of State and Government have confirmed their long-standing pledge of a 20% cut on 1990 levels, and of 30% cut if other Annex I countries make comparable commitments. The USA pledged to cut greenhouse gas emissions by 17% on 2005 levels under an international climate agreement, but their commitment is contingent on passing legislation at home. Japan pledged a 25% reduction target relative to 1990 levels, subject to the establishment of a fair and effective international framework in which all major economies participate. Canada matched the pledge by the USA to reduce emissions by 17% relative to 2005 levels, which is less ambitious than their earlier pledge. The pledges of Russia, Ukraine and Belarus are below 1990 levels, but far above the 2005 levels.

1 See http://unfccc.int/home/items/5264.php

Annex I country reduction pledges to the Copenhagen Accord **Table 2.1**

	Greenhouse gas emissions in Mt CO_2 eq (excluding land use CO_2)		Low pledge		High pledge	
	1990	2005	Reduction target below 1990	Reduction target below 2005	Reduction target below 1990	Reduction target below 2005
Australia	416	525	−13%	10%	11%	29%
Belarus	129	77	5%	−58%	10%	−50%
Canada	592	731	−3%	17%	−3%	17%
Croatia	31	30	5%	2%	5%	2%
EU27	5 573	5 119	20%	13%	30%	24%
Iceland	3	4	30%	36%	30%	36%
Japan	1 270	1 358	25%	30%	25%	30%
New Zealand	62	77	10%	28%	20%	36%
Norway	50	54	30%	35%	40%	44%
Russian Federation	3 319	2 118	15%	−33%	25%	−18%
Switzerland	53	54	20%	21%	30%	31%
Ukraine	926	418	20%	−77%	20%	−77%
United States	6 084	7 107	3%	17%	3%	17%
Kazakhstan	300	223	10%	−21%	10%	−21%
Total Annex I	**18 808**	**17 895**	**12%**	**8%**	**18%**	**14%**

Source: Based on submissions to the Copenhagen Accord (http://unfccc.int/home/items/5264.php) as reported by March 2010, except for Ukraine, which is based on an earlier submission (http://unfccc.int/resource/docs/2009/awg7/eng/misc01.pdf). Pledges differ in scope and conditionality (see Appendix A).

The aggregated reduction target by 2020 of all Annex I pledges ranges from 12 to 18% relative to the 1990 level. This would be insufficient to stabilise concentrations at 450 ppm CO_2 eq, according to the IPCC AR4 range of 25 to 40% below 1990 levels (den Elzen and Höhne, 2008; Gupta et al., 2007). These figures are quite robust compared to the total reduction target range of other studies (Catalyst project (European Climate Foundation, 2010); Climate Action Tracker: www.climateactiontracker.org (Höhne et al., 2009b); UNEP Climate Pledge Tracker: www.unep.org/climatepledges (Stern, 2009; Stern and Taylor, 2010)).

All studies report almost the same Annex I reduction target range of 12 to 18-19% below 1990 levels. However, the baseline emissions of the studies differ from each other, partly because our study includes the impact of the economic crisis, which is excluded from other studies. But because the reduction targets are relative to a base year in the past, baseline emissions do not affect target emission levels.

Two other major uncertainties that can influence the reduction target level are discussed.

The first uncertainty relates to the land use and forestry rules. The reduction targets in Table 2.1 exclude allowance increases from land use and forestry rules. The land use and forestry rules for the current Kyoto commitment period state that individual countries can choose to include greenhouse gas fluxes from forest management (with a cap on accruing emissions allowances), cropland management, grazing-land management and re-vegetation. The rules for the post-2012 commitment period are still under negotiation. Some countries have indicated whether their targets include or exclude debits and credits accounting for land use and forestry, but others are vague on this point. In this report, we assume that land use and forestry rules are likely to result in an additional emission allowance of 2.5% of 1990 Annex I emissions, which amounts to 0.45 Gt CO_2 eq (estimates in literature vary from 1 to 9% of 1990 Annex I emissions).[2] In practice, this would decrease the reduction level by 2.5% of 1990 Annex I emissions, leading an overall Annex I reduction target of 10 to 15% below 1990 levels (see Table 2.2). [3] An assessment of the effect of higher allowance increases from land use and forestry rules is included in Chapter 5.

The second uncertainty concerns the use of surplus AAUs or hot air, notably from Russia and Ukraine. As the reduction pledges for 2020 of Russia and Ukraine are above their baseline emission projection, these will generate new surplus AAUs. The targets in Table 2.1 include these new surplus AAUs. If these surplus AAUs are forfeited or not used, the Annex I reduction target will increase to 18 to 21% below 1990 levels (0.7 and 1.0 Gt CO_2 eq, Table 2.2). Furthermore, we assume that surplus AAUs[4] from the first commitment period

2 Emissions from land use and forestry are highly uncertain and emission estimates from various sources are often not consistent. These emissions may constitute a significant share of the emissions for some Annex I countries. The inclusion of land use and forestry in a more elaborated approach could have a significant impact on the range of reduction pledges in this study, particularly for those countries with large forest areas, such as the United States, Canada, Australia, New Zealand and Russia.

3 Land use and forestry measures tend to remove CO_2 and thus decrease the atmospheric CO_2 built up. However, it cannot be guaranteed that the accounted land use and forestry adjustments reflect real, additional and permanent changes — there is no way to ensure that carbon stored in a planted forest or in agricultural soils will not be subsequently released.

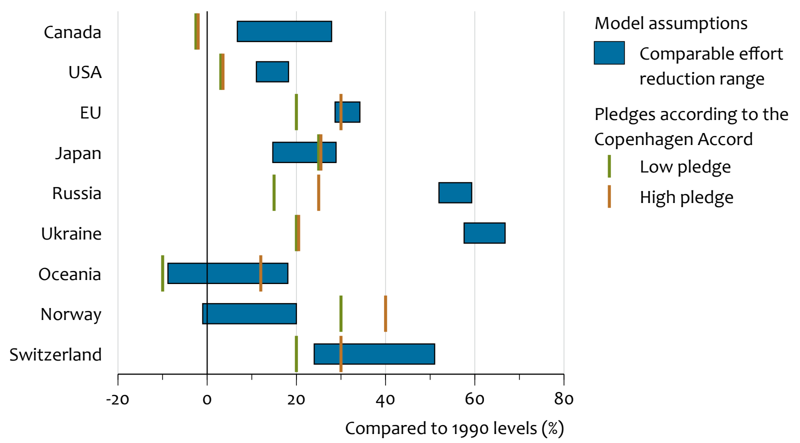
4 The surplus AAUs in the first Kyoto commitment period (1990-2012) originates from the economic downfall in the 'Economies in transition'. These are the nations emanated from the dissolution of the Soviet Union in the 1990s, and former Eastern Bloc states that are now part of the European Union. All of these nations experienced a major economic decline after the abolishment of the communist system at the end of the 20th century. As a result, these Economies in Transition will easily meet their Kyoto target of zero emission growth by the end of the 1990-2012 period, even without installing specific emission reduction policies. In some of

Impact of including allowance increases from land use and forestry rules and new surplus of AAUs for Russia and Ukraine for the Annex I emission and reduction targets for the low and high pledge scenario **Table 2.2**

	Emission target (Gt CO2 eq)	Reduction target below 1990 (%)
Excluding allowances from land use and forestry rules, Including new surplus AAUs	16.5 – 15.5	12 – 18
Including allowances from land use and forestry rules, Including new surplus AAUs	16.9 – 16.0	10 – 15
Excluding allowances from land use and forestry rules, Excluding surplus AAUs	15.5 – 14.8	18 – 21
Including allowances from land use and forestry rules, Excluding surplus AAUs	15.8 – 15.2	16 – 19
Excluding allowances from land use and forestry rules, Including new and Kyoto surplus AAUs	17.7 – 16.7	6 – 11
Including allowances from land use and forestry rules, Including new and Kyoto surplus AAUs	18.1 – 17.2	4 – 9

Comparable effort reduction targets compared to pledges of Annex I countries, 1990 – 2020 **Figure 2.1**

Greenhouse gas emissions, excluding CO_2 from land use



The comparable effort ranges given assume an aggregated Annex I reduction target of 30% below 1990. Source: adapted from den Elzen et al. (2009a).

of the Kyoto Protocol cannot be banked and used. Surplus AAUs from the five-year Kyoto period amounts to 13 Gt CO_2 eq (Russia: 7.2; Ukraine: 3.1; and EU Member States: 2.8 - see den Elzen et al., 2009c). It represents about 6.5% of 1990 Annex I emissions if consumed for compliance purposes at a constant rate over the period 2013-2023[5]. If Kyoto surplus AAUs are banked, and there would be no restrictions on the sale of AAUs; the total reduction level of Annex I would therefore decrease by about 6.5% to a total reduction level of 6 to 11% (see den Elzen et al., 2009c).

2.1 Comparability of Annex I pledges

Den Elzen et al. (2009a; 2010a) analysed the comparability of the Copenhagen Accord pledges, which is a major condition of the high pledges of many Annex I countries. Reduction targets were calculated according to fundamentally different comparable effort-sharing approaches for the individual Annex I countries to meet an aggregated Annex I reduction target of 30% below 1990 levels. In Figure 2.1, these comparable reduction targets are compared with the reduction targets resulting from the Annex I pledges given in Table 2.1.

Figure 2.1 shows that the stringency of the pledges of individual countries differs, and sometimes substantially, when compared to the results from the effort-sharing approaches of den Elzen et al. (2009a). The pledges of only a few countries are in line with the comparable effort reduction range, notably those of Norway and Japan. For the pledges of Switzerland, EU and Oceania (Australia and New Zealand), only the ambitious variant is in line with the comparable effort range. For the USA, the current pledge is less ambitious than the comparable effort range calculated by Elzen et al. (2009a), unless financing of emission reduction from deforestation in developing countries is included. Canada's pledge falls short of the comparable effort range. The pledges of Russia and Ukraine are above their baseline emission projection, and thus involve no real mitigation action (see Footnote 9). Applying the current rules to their pledge, Russia would receive significantly more allowances than needed. The land use and forestry rules and banking could even increase the surplus allowances for Russia.

these countries such as Ukraine, emissions even declined by as much as 60% on 1990 levels. For Russia, the maximum decline was about 40%. Den Elzen et al. (2009c) have presented an analysis and discussion of the environmental, financial and negotiation consequences of various strategies of dealing with surplus AAUs.

5 Based on similar calculations of the European Commission (2009b) and den Elzen et al. (2009c), assuming that the surplus AAUs under the Kyoto Protocol are consumed for compliance purposes at a constant rate over the period 2013-2023. More specifically, a total of 1.3 Gt CO_2 AAUs (= 13 / 10) would be available each year up to 2020.

3

Emission reduction targets in submitted mitigation action plans of emerging economies

Key findings

- The mitigation action plans submitted to the Copenhagen Accord by the seven largest emitting Non-Annex I countries are estimated to reduce emissions by approximately 11 to 14% below their baseline or business-as-usual (BAU) emissions in 2020. The range is due to the conditionality on international support of the pledges of Brazil, Indonesia, Mexico and South Africa. Without such support, reduction targets will be at the low end of this range and with financial support, at the high end.
- If all other Non-Annex I countries follow the BAU, then the group of Non-Annex I countries would be about 7 to 10% below BAU emissions (including land use CO_2). This is insufficient given the estimated 15 to 30% reduction target below baseline emissions needed to reach the long-term target for greenhouse gas concentration of 450 ppm CO_2 eq.
- As China and India have set unconditional carbon intensity targets, the emission target level resulting from the reduction proposals depends heavily on BAU emissions and GDP growth. However, our study and other studies conclude that the absolute reductions below BAU emissions from the intensity targets of China and India may well be low, about 6% and 3%, respectively.

3.1 Copenhagen Accord mitigation action plans

In March 2010, many Non-Annex I Parties had submitted their national mitigation action plans (NAMAs) to the UNFCCC secretariat[1]. This report focuses on the seven largest-emitting Non-Annex I countries with NAMAs (all emerging economies), which represent more than two-thirds of total Non-Annex I emissions (including land use CO_2) in 2020. Of these seven economies, Brazil, Indonesia, Mexico, South Africa and South Korea have pledged their reductions in terms of a percentage below BAU emissions. The other two, China and India, have announced a carbon intensity improvement (emission reduction per unit of income). This implies that their emission reduction target depends heavily on both the projected emissions and income levels.

Other developing countries have submitted actions, but it is rather uncertain whether these actions lead to reduction targets compared to BAU emissions. Moreover, their share in total Non-Annex I emissions is very small. The NAMAs of these countries have been excluded from the analysis. Furthermore, the national climate policies of China and India that are not part of their submissions to the Copenhagen Accord have not been taken into account (see Chapter 5).

The mitigation action plans for 2020 of the major emerging economies are as follows:

- China pledges i) to reduce CO_2 emissions per unit of GDP by 40 to 45% relative to 2005; ii) to increase non-fossil fuels in primary energy consumption to around 15%; and iii) to increase forest coverage by 40 million ha and forest stock volume by 1.3 billion m^3 relative to 2005 levels.
- India pledges to reduce emissions per unit of economic output by 20 to 25% relative to 2005 levels.
- Brazil pledges to reduce emissions by 36 to 39% relative to BAU. Measures to achieve this include increasing energy efficiency, improving agriculture techniques, increasing

1 See http://unfccc.int/home/items/5265.php.

Outcome of the Copenhagen Accord mitigation action plans of the seven largest emitting emerging economies and emissions from other Non-Annex I countries (For details, see Appendix B)

Table 3.1

2020	BAU emissions ($Gt\ CO_2\ eq$)		Pledged target ($Gt\ CO_2\ eq$)			
Country	**Central**		**Low pledge**		**High pledge**	
	This study	**Other studies***	**This study**	**Other studies***	**This study**	**Other studies***
China	13.8	(12.4, 13.9)	13.0	(11.9, 13.0)	13.0	(11.5, 13.0)
India	3.4	(3.0, 4.4)	3.4	(3.3, 5.3)	3.3	(3.3, 4.4)
Brazil (including land use CO_2)	2.4	(2.3, 2.7)	1.5	(1.5, 1.7)	1.5	(1.5, 1.7)
Mexico (including land use CO_2)	0.9	(0.9, 1.1)	0.8	(0.8, 0.8)	0.6	(0.6, 0.6)
South Africa	0.6	(0.6, 0.7)	0.5	(0.5, 0.5)	0.5	(0.4, 0.5)
South Korea	0.9	(0.8, 0.9)	0.7	(0.6, 0.7)	0.7	(0.6, 0.7)
Indonesia (including land use CO_2)	2.5	(2.5, 2.8)	1.8	(1.8, 2.1)	1.5	(1.5, 1.7)
Total seven emerging economies	**24.5**	(22.9, 25.0)	**21.8**	(20.8, 22.5)	**21.0**	(19.5, 21.2)
Other Non-Annex I countries	9.8	(9.8, 13.2)	9.8	(9.8, 12.2)	9.8	(9.8, 12.2)
Land use CO_2 emissions outside Brazil, Indonesia and Mexico	1.7		1.7		1.7	
Total Non-Annex I	**36.0**	(34.4, 38.2)	**33.3**	(32.3, 34.2)	**32.6**	(30.5, 33.4)

* Ecofys (Moltmann et al., 2009; Höhne et al., 2009a); Catalyst project (European Climate Foundation, 2010); UNEP Climate Pledge Tracker (Stern, 2009; Stern and Taylor, 2010)

hydropower capacity, increasing use of biofuels and renewable energy, and finally REDD measures.

- South Africa commits to reduce emissions by 34% relative to BAU. In addition to this 2020 target, the country pledges a 42% reduction target by 2025. These reductions are compared to a national reference scenario with "unconstrained growth". The reductions presented in this study are lower (Figure 3.1) because of lower baseline emissions (including autonomous efficiency improvements). The pledge is conditional on financial resources, transfer of technology and capacity building support by developed countries.
- South Korea, Mexico (both 30%) and Indonesia (26 to 41%) have submitted reductions pledges relative to their BAU emissions. The pledges of Mexico and Indonesia are conditional on international support.

Some of these countries including Brazil, China, India and Mexico have also announced detailed climate action plans for emission reduction targets or have set out specific policies. In these cases, plan implementation partly depends on the extent to which these policies require international financial support.

The effects of the mitigation action plans of the seven largest emerging economies on emission reduction targets is presented in Table 3.1. As the uncertainties of the effect are large, the results are presented as a range, based on most of the present available studies[2]. Appendix B provides a detailed analysis of how these reduction targets are calculated in the various studies for the three most important countries in terms of emissions - China, India and Brazil.

2 The following studies include an analysis of the emission reductions of the Copenhagen pledges and mitigation actions of the major Non-Annex I countries: Ecofys (Moltmann et al., 2009; Höhne et al., 2009a); Catalyst-project (European Climate Foundation, 2010); UNEP Climate Pledge Tracker (Stern, 2009; Stern and Taylor, 2010). Other studies have analysed the actions for individual Non-Annex I countries (see Appendix C)

The high pledges result in an emission target of about 14% and the low pledges an emission target of 11% below BAU for the seven major emerging economies combined (see Figure 3.1). These countries are responsible for more than two-thirds of emissions of all Non-Annex I countries. This means that the target for all Non-Annex I countries combined, assuming that all other Non-Annex I countries do not reduce emissions, is 10 to 7% below BAU levels. The difference between the high and low pledges is due to the reduction pledges of Brazil, Indonesia, Mexico and South Africa being partly conditional on international support. Without such support, the total pledge of the emerging economies could be close to the low-end range, and with support close to the high-end range.

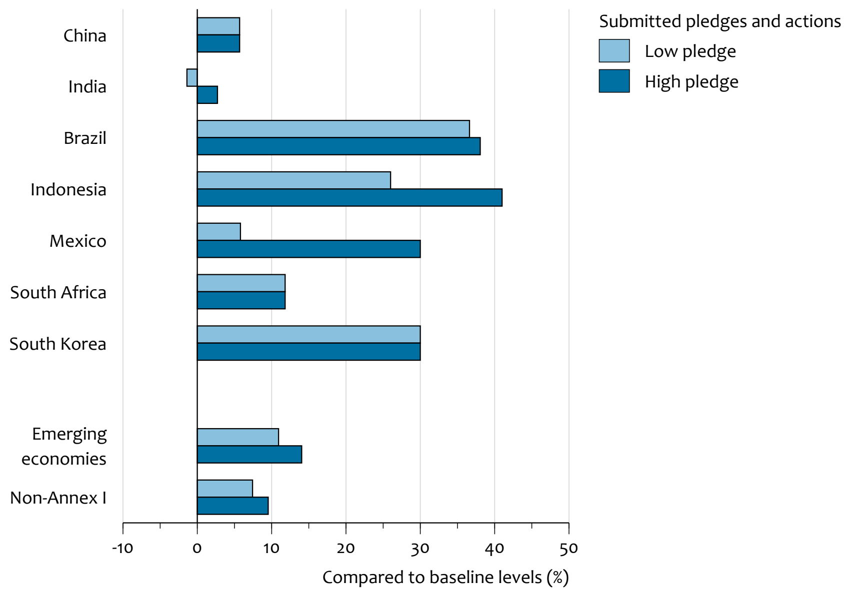
With regard to the reduction level of individual countries, Brazil, Mexico, South Korea and Indonesia have provided quite ambitious climate action plans. According to most studies, the emission reductions of the pledges of China and India are relatively small, 3 and 6%, respectively (see Chapter 5 for the effect of additional national climate policies of China and India). In addition, other Non-Annex I countries have made reduction pledges that are not further analysed in this report.

The total projected emission level resulting from the high mitigation action plans of the seven emerging economies is 19.3 to 21.2 $Gt\ CO_2\ eq$. This wide range is mainly due to uncertainties in the BAU emission levels, especially for China and India, and the conditionality on international funding of the pledges of Brazil, Mexico and South Africa. The emission target level of all Annex I countries as a whole would then be 30.5 to 33.4 $Gt\ CO_2\ eq$ (assuming other Non-Annex I countries do not reduce emissions).

A comparison of the above reduction targets in 2020 with the range of 15 to 30% needed to achieve the 2°C target (den Elzen and Höhne, 2008) is not straightforward because this range is based mainly on the IPCC Special Report on Emission Scenarios (SRES). The BAU scenarios considered here are at the high end of the SRES scenarios. Consequently, a reduction

Reduction targets compared to baseline levels of emerging economies, 2020 **Figure 3.1**

Greenhouse gas emissions, including CO_2 from land use



of 15 to 30% below this high BAU may not be sufficient, unless reductions occur elsewhere. In addition, the 15 to 30% range is an average value for all Non-Annex I countries and the reductions required by individual countries may not be within this range.

Information on the calculation of the emission reduction targets of the individual countries provided in Table 3.1 is presented in the following sections.

3.2 China

China's emissions accounted for approximately 30% of all Non-Annex I emissions in 1990 and this share is projected to grow to 40% by 2020. China proposed three actions under the Copenhagen Accord:

1. To lower carbon dioxide emissions per unit of GDP by 40 to 45% by 2020 compared to the 2005 level;
2. To increase the share of non-fossil fuels in primary energy consumption to around 15% by 2020;
3. To increase forest coverage by 40 million ha and forest stock volume by 1.3 billion m^3 by 2020 on 2005 levels.

In addition to these actions, China is planning additional climate policies. As these policies are not part of the submission to the Copenhagen Accord, their effect is not discussed here. These policies are analysed in Chapter 5 because they could contribute to narrowing the gap towards meeting the 2°C target.

3.2.1 This study

The implications of the announced carbon intensity target for emission reductions are difficult to assess because they depend heavily on future GDP growth and on whether reductions are relative to GDP in terms of purchasing power parity (PPP) or market exchange rates (MER) (see Box 3.1 and 3.2, respectively). In our reference scenario, China is assumed to have strong continued economic growth of on average 8% per year in the period 2005 to 2020.

Our analysis suggests the intensity target will only substantially slow the rate of emissions growth below BAU if China's average GDP growth falls below the level of the last decade. China's target for non-fossil energy supply is projected to overlap with the intensity target. Their combined effect is calculated as the maximum of the reduction contributions of both individual targets. This is a conservative estimate because meeting the intensity target could also lead to additional energy efficiency improvements compared to BAU developments. This could further increase the combined effect. According to our calculations, the projected final reduction below BAU emissions is 6% (see Table 3.3).

3.2.2 Comparison with other studies

The full range of estimates from various models is presented in Table 3.3. For this study, Ecofys has updated their analysis for calculating the reductions from China's submitted actions of the Climate Action Tracker (www.climateactiontracker.org). Details on the calculation are presented in the Appendix B.

The range of BAU emission projections across the various studies is 12.4 to 13.9 Gt CO_2 eq in 2020. These estimates take into account all greenhouse gases, including CO_2 emissions from land use. The considerable range stems from the use of different models, future growth rates, and inclusion of different policies (an official national BAU scenario from China is not available). The additional reduction contributions of the separate measures listed in Table 3.3 also depend on the order in which measures and targets are implemented.

The impact of the greenhouse gas intensity target (the first action listed in their submission to the Copenhagen Accord)

Box 3.1. Methodology for calculation of reduction targets used in this study

This study analysed the effect of the mitigation actions submitted to the Copenhagen Accord by the seven major emerging economies. These mitigation actions can consist of intensity targets (China and India), targets related to energy use and forest cover (China), or reduction targets below BAU emissions. Two key elements in the calculations are BAU emissions and reduction target estimates.

1. Baseline or BAU emissions

We used BAU emissions of energy- and industry-related greenhouse gases from the TIMER energy model and the land use related non-CO_2 greenhouse gases from the IMAGE land use model for all seven emerging economies, except for South Africa. For South Africa, the baseline emissions (unconstrained growth) of the Long Term Mitigation Scenarios study (Scenario Building Team, 2007) were used because this study was the basis for the mitigation actions submitted by South Africa. Land use CO_2 emissions are only included for Brazil, Indonesia and Mexico where these emissions contribute an important share of the national emissions. National estimates were used for Brazil and Mexico. For Indonesia, BAU land use CO_2 emissions were estimated based on constant 2005 emissions from external data sources (CAIT tool of the World Resource Institute, Wetlands International, 2009).

2. Reduction target estimates

The reductions for Brazil, China and India, were estimated using the TIMER energy model, which also takes account of the technical feasibility of specific actions. Where data or estimates were not available, national reduction estimates from their submissions were used to give a full picture of the effect of commitments, such as REDD and non-CO_2 greenhouse gas emission reductions, and from the Catalyst study (European Climate Foundation, 2010), such as for forest management for China. For Mexico, South Africa, South Korea and Indonesia, the proposed reduction target percentage below BAU emissions was applied to our BAU emissions.

Box 3.2. The impact of MER versus PPP on the calculated reductions for China and India from their proposed emission intensity targets

China and India have pledged targets in terms of emission intensity targets which is expressed as an improvement in the ratio of emissions to output (corrected for inflation). The intensity target that both countries will use for evaluation is based on the local currency. However, international evaluations such as our study are usually based on international currencies. In general, two types of methods are used to create international income series: 1) conversion of income figures based on market-exchange rates (MER); and 2) conversion of income figures based on purchasing-power-parity (PPP). The first method uses the exchange rates of a single year to express income in terms of US dollars[a]. The second method corrects for the observation that many products are much cheaper in low-income than in high-income countries and uses an exchange rate based on the average price of a set of products (PPP). The latter is seen as a better metric for comparison across countries but data are more uncertain.

In the context of long-term scenarios, a discussion is whether growth rates measured in MER or PPP-based metrics are equal (see van Vuuren and Riahi, 2006). Some have argued that both are coupled to local growth estimates. Others have indicated that the metrics value different parts of the economy in different ways and thus also lead to different growth rates. In that case, PPP-based growth for developing countries will be lower than MER-based growth figures. This is also consistent with the fact that the gap between developing countries and developed countries is smaller based on PPP.

Intensity indicators are also influenced by the choice of either PPP or MER. A PPP-based estimate for a developing country starts at a lower level and decreases more slowly with time (if PPP-based growth is lower). Evaluation of the China and India targets thus depends on whether the PPP or MER figures are assumed to be correct and on the assumptions of relative growth rates between these metrics. This is illustrated in Table 3.2. The pledged targets of India and China are relatively ambitious in terms of PPP-based figures but are very close to baseline for MER figures.

Impact of PPP and MER on the calculated reductions for China and India from their proposed emission intensity targets — **Table 3.2**

Country		Emission intensity target of 40% (China) or 20% (India): Reduction (Gt CO_2)	(rel. to BAU)	Emission intensity target of 45% (China) or 25% (India): Reduction (Gt CO_2)	(rel. to BAU)	BAU energy/industry CO_2 emissions (Gt CO_2)	decrease in CO_2 intensity
China	MER	–0.4	–4%	0.5	5%	10.8	42%
	PPP	2.9	28%	3.5	34%	10.8	16%
India	MER	–0.0	–2%	0.1	4%	2.2	22%
	PPP	0.3	14%	0.4	19%	2.2	7%

a All prices and costs in this report are expressed in 2005 USD.

Emissions of China under BAU and after application of Copenhagen Accord mitigation actions **Table 3.3**

China	Emissions after reduction ($Gt\ CO_2\ eq$)	
	This study	Overview of all studies*
BAU	13.8	12.4 – 13.9
+ Lower CO_2 emissions per unit of GDP by 40–45% by 2020 relative to the 2005 level	13.3 – 14.2	11.7 – 14.2
+ Increase the share of non–fossil fuels in primary energy consumption to around 15% by 2020	13.1	11.6 – 13.1
+ Increase forest coverage by 40 million ha and forest stock volume by 1.3 billion m^3 by 2020 relative to 2005 levels	13.0	11.5 – 13.0

* Ecofys (Moltmann et al., 2009; Höhne et al., 2009a); Catalyst project (European Climate Foundation, 2010); the Chinese Energy Research Institute (ERI, 2009); World Energy Outlook 2009 (IEA, 2009); and this study. UNEP Climate Pledge Tracker (Stern, 2009; Stern and Taylor, 2010) has been excluded because this study analysed the national climate policy of India (not part of their submission).

Emissions of India under BAU and after application of Copenhagen Accord mitigation actions **Table 3.4**

India	Emissions after reduction ($Gt\ CO_2\ eq$)	
	This study	Overview of all studies*
BAU	3.4	3.0 – 4.4
+ Lower the greenhouse emissions per unit of GDP by 20 to 25% by 2020 relative to the 2005 level (excluding agricultural emissions)	3.3 – 3.4	3.0 – 5.3

* Ecofys (Moltmann et al., 2009; Höhne et al., 2009a); Catalyst project (European Climate Foundation, 2010); the TERI in Climate Modelling Forum (2009); World Energy Outlook 2009 (IEA, 2009); and this study. UNEP Climate Pledge Tracker (Stern, 2009; Stern and Taylor, 2010) is excluded here as this study analyses the national climate policy of India (not part of their submission).

is difficult to assess. Absolute emission reductions in 2020 depend on the assumed GDP growth rate up until 2020. Our best estimate of emissions after the application of the target is 11.7 to 14.2 Gt CO_2 eq. For most studies, this means little to no reductions compared to BAU emissions.

The second action of China, increasing the share of non-fossil fuels, leads to a decrease in absolute emissions to 11.6 to 13.1 Gt CO_2 eq. This target is an improvement over BAU for all studies and reduces emissions by between 0.1 and 1.1 Gt CO_2 eq in addition to the intensity target.

The effect of the forestry target is comparatively small and adds only about 0.1 Gt CO_2 eq emission reductions. Thus, China's emission target after all actions submitted to the Copenhagen Accord is 11.5 to 13.0 Gt CO_2 eq in 2020.

3.3 India

India is projected to have the second highest emission level of all Non-Annex I countries in 2020. India proposes under the Copenhagen Accord to unilaterally reduce the emissions intensity of its GDP by 20 to 25% by 2020 on the 2005 level. Emissions from the agriculture sector are not part of the assessment of emissions intensity target. In addition to this target submitted to the Copenhagen Accord, India is planning further climate policies. The effect of these measures is discussed in Chapter 5.

3.3.1 This study

According to our study, the intensity target does not result in a significant reduction in emissions. The target leads to a maximum reduction of only 3% below BAU. In our reference scenario, India is assumed to have strong continued economic growth on average of 5.5% per year in the period 2005-2020.

3.3.2 Comparison with other studies

The full range of BAU emissions in 2020 across studies is 3 to 4.4 Gt CO_2 eq in 2020 (Table 3.4). All studies included all greenhouse gases and CO_2 emissions from land use and there is a large range of estimates. Assumptions used in the different models and particularly future growth rates vary widely, as an official BAU scenario from India is not available.

All studies indicate that India's intensity target will not lead to substantial emission reductions. Only two studies report that a 25% intensity target could lead to some reduction of up to 0.3 Gt CO_2 eq below BAU or even an increase compared to BAU. Thus, our best estimate of the absolute emission target after the application of the intensity target is 3 to 5.3 Gt CO_2 eq, which covers the full BAU range.

3.4 Brazil

Brazil anticipates that a package of measures "will lead to an expected reduction target of 36.1 to 38.9% regarding the projected emissions of Brazil by 2020". Brazil proposes this assumption under the Copenhagen Accord based on the implementation of the following measures:

- Reduction in Amazon deforestation

Emissions of Brazil under BAU and after application of the Copenhagen Accord mitigation actions **Table 3.5**

Brazil	Emissions after reduction ($Gt\ CO_2\ eq$)	
	This study	Overview of all studies*
BAU	2.4	2.3 – 2.7
+ Reduction target of around 36–39% relative to BAU by 2020	1.5–1.55	1.5 – 1.7

* Ecofys (Moltmann et al., 2009; Höhne et al., 2009a); Catalyst project (European Climate Foundation, 2010); UNEP Climate Pledge Tracker (Stern, 2009; Stern and Taylor, 2010); the national scenario; World Energy Outlook 2009 (IEA, 2009); and this study

- Reduction in "Cerrado" deforestation
- Restoration of grazing land
- Integrated crop-livestock system
- No–till farming
- Biological N_2 fixation
- Increase in energy efficiency
- Increase in use of biofuels
- Increase in energy supply by hydroelectric power plants
- Increase in use of alternative energy sources
- Replacement of coal from deforestation with coal from planted forests

3.4.1 This study

We evaluated the energy reductions from the above measures using the TIMER energy model and our own BAU greenhouse gas emissions. The agriculture and REDD targets are based on those reported in Brazil's mitigation actions submitted to the Copenhagen Accord. The TIMER BAU was extended with IMAGE agricultural emissions and the deforestation emissions were based on national data. The energy emissions are only about 20% of the total emissions and because the analysis gave only small reduction differences for energy-related measures compared to the pledged reductions, the final reduction target is close to the pledged reduction targets and equal to 36 to 38% below BAU.

3.4.2 Comparison with other studies

The full range of BAU emissions in 2020 across studies is 2.3 to 2.7 Gt CO_2 eq in 2020 (Table 3.5). For Brazil, an increase in forestry emissions is important because these are responsible for the largest share of the country's emissions. An official BAU scenario from Brazil was made available with the reduction pledge. Its BAU for forestry is the highest of all studies.

Brazil provides absolute emission reduction estimates for the different measures. Other studies come to different conclusions, also resulting from the fact that most assessments were made before Brazil made its pledge. Our best estimate of the absolute emission target after the application of the Copenhagen Accord mitigation actions is 1.5 to 1.7 Gt CO_2 eq, with quite good agreement between the studies. The most important reductions come from the forestry sector. The proposed package leads to substantial reduction targets below BAU according to all studies.[3]

3.5 Indonesia

In a press release dated 27 September 2009, Indonesia announced the potential to reduce greenhouse gas emissions by as much as 60% by 2030, with the right mixture of domestic policies and international support. This is based on a study by the National Climate Change Council Indonesia (DNPI). After the COP15, the Indonesian Government sent two letters to the UNFCCC to announce their mitigation actions. In the first letter, they presented actions that will lead to 26 to 41% CO_2 eq emission reductions. In the second letter, only the 26% target is mentioned, and this is stated to be a voluntary mitigation action. The remaining part is conditional on international finance. The main two CO_2 emission sources in Indonesia are deforestation and peat land emissions and consequently, the highest abatement potential is also in these sectors.

The 26% and 41% reduction targets were applied to the TIMER/IMAGE BAU where CO_2 emissions from deforestation were added from the World Resource Institute's Climate Analysis Indicators Tool (CAIT; www.cait.wri.org) and the peat land emissions from Wetlands International (2009). The results are shown in Table 3.6. The impact of the reduction proposal has been assessed in various studies. Based on these studies, the reductions lead to an emission target range of 1.5 to 1.7 Gt CO_2 eq (see Table 3.6).

3.6 Mexico

Mexico recently increased its 2020 target from 20 to 30% emission reduction against BAU, but made the reduction conditional on international financing. The submission to the Copenhagen Accord contains two parts. In the first unconditional step, Mexico pledges a reduction of 51 Mt CO_2 eq by 2012 relative to BAU, stated in the Special Climate Change Program 2009[4]. This detailed plan includes a set of nationally appropriate mitigation and adaptation actions to be undertaken in all relevant sectors in line with an overall strategy to reduce emissions by 50% by 2050. Second, Mexico aims to reduce greenhouse gas emissions up to 30% below BAU, but conditional on adequate financial and technological support from developed countries as part of a global agreement. Mexico is assumed to reduce 21% domestically and the remaining 9% is to be achieved with international funding, which is based on the UNEP Climate Pledge Tracker (www.unep.org/climatepledges). In terms of emission reduction on 2005 levels, the 30% reduction target below BAU means a 20% increase for Mexico. Mexico's target is expected to be

3 Brazil's Copenhagen submission is very comprehensive and only very limited additional measures are planned or implemented, mainly in the waste sector. These reductions could add another 0.1 Gt CO_2 eq.

4 www.semarnat.gob.mx/queessemarnat/politica_ambiental/cambioclimatico/Documents/pecc/090828_PECC.Capitulos_DOF.pdf

Emissions of Indonesia under BAU and after application of the Copenhagen Accord mitigation actions

Table 3.6

Indonesia	Emissions after reduction ($Gt CO_2$ eq)	
	This study	Overview of all studies*
BAU	2.5	2.5 – 2.8
+ Unconditional low pledge: 26% emission reduction relative to BAU by 2020	1.8	1.8 – 2.1
+ Conditional high pledge: 41% emission reduction relative to BAU by 2020	1.5	1.5 – 1.7

* Catalyst project (European Climate Foundation, 2010); UNEP Climate Pledge Tracker (Stern, 2009; Stern and Taylor, 2010); and this study.

Emissions of Mexico under BAU and after application of Copenhagen Accord mitigation actions

Table 3.7

Mexico	Emissions after reduction ($Gt CO_2$ eq)	
	This study	Overview of all studies*
BAU	0.9	0.9 – 1.1
+ Unconditional low pledge: 51 $MtonCO_2eq$ emission reduction by 2012	0.8	0.8 – 0.8
+ Conditional high pledge: 30% emission reduction relative to BAU by 2020	0.6	0.6 – 0.6

* Ecofys (Moltmann et al., 2009); Catalyst project (European Climate Foundation, 2010) UNEP Climate Pledge Tracker (Stern, 2009; Stern and Taylor, 2010); the national study of Mexico (SEMARNAT, 2009); and this study.

Emissions of South Africa under BAU and after application of Copenhagen Accord mitigation actions

Table 3.8

South Africa	Emissions after reduction ($Gt CO_2$ eq)	
	This study	Overview of all studies*
BAU	0.6	0.6 – 0.7
+ Conditional pledge: 34% emission reduction relative to BAU by 2020	0.5	0.4 – 0.5

* Ecofys (Moltmann et al., 2009); Catalyst project (European Climate Foundation, 2010); UNEP Climate Pledge Tracker (Stern, 2009; Stern and Taylor, 2010); the national study Long-term Mitigation Scenarios (Scenario Building Team, 2007); and this study.

achieved mainly by changes in the energy sector for instance, switching to gas-fired plants and waste-related gas initiatives.

In this study, the 30% reduction pledged was applied to the TIMER/IMAGE BAU where land use CO_2 emissions were added from the national BAU (Special Climate Change Program 2009). The results are shown in Table 3.7 together with the BAU emission range in other studies, which is between 0.9 and 1.1 Gt CO_2 eq. This range can be explained by differences in assumed growth rates of future emissions. The emission target level after implementing the conditional high pledge mitigation actions for all studies is around 0.6 Gt CO_2 eq.

3.7 South Africa

The main source of emissions in South Africa is the coal-intensive power sector. The country's reduction pledge of 34% below BAU is expected to be achieved mainly through changes in the energy sector. The 34% commitment is conditional on international financing and technology support. This pledge is based on their nationally appropriate mitigation action plan that also states that before 2025, emissions will peak and remain at that level for approximately a decade, and thereafter decline in absolute terms.

In 2007, South Africa provided a comprehensive study of long-term mitigation pathways (Scenario Building Team, 2007) and options up to 2050. This served as a basis for their mitigation action submission. We used the BAU emission estimates from the Government's Long-Term Mitigation Scenarios. Moltmann (2009) interpreted their emissions for the unconstrained growth scenario as the reference level, and deducted from that 34% in 2020 (see Table 3.8). The resulting emission target level is 0.5 Gt CO_2 eq, which represents only a 12% reduction below the baseline emissions in this study. The estimate of the project Catalyst (European Climate Foundation, 2010) of 0.4 Gt CO_2 eq forms the lower end of the range of all studies, but is likely not compatible with South Africa's proposal of peaking in emissions between 2020 and 2025.

3.8 South Korea

South Korea pledges to the UNFCCC a 30% reduction below BAU in 2020, which is a 4% emission reduction on 2005 levels. South Korea intends to reach this target by increasing energy efficiency, renewable energy use and nuclear power capacity. The 30% reduction in the Copenhagen Accord pledge was applied to the TIMER/IMAGE BAU and resulted in a target of 0.7 Gt CO_2 eq in 2020 (see Table 3.9). Based on different studies of the Copenhagen Accord pledges, the emission target range for South Korea is 0.6 to 0.7 Gt CO_2 eq.

Emissions of South Korea under BAU and after application of Copenhagen Accord mitigation actions

Table 3.9

South Korea	Emissions after reduction ($Gt\ CO_2\ eq$)	
	This study	Overview of all studies*
BAU	0.9	0.8 – 0.9
+ Uncoditional pledge: 30% emission reduction relative to BAU by 2020	0.7	0.6 – 0.7

* Ecofys (Moltmann et al., 2009); Catalyst project (European Climate Foundation, 2010); UNEP Climate Pledge Tracker (Stern, 2009; Stern and Taylor, 2010); the national study of South Korea (see http://www.greengrowth.go.kr); and this study.

Abatement costs and impact on international carbon market

4

Key findings

- Total abatement costs consist of the sum of domestic abatement costs, the costs or revenues from emissions trading, CDM and Joint Implementation (JI), and international financial transfers for financing abatement costs (including costs of REDD) in Non-Annex I countries.
- If Annex I countries are assumed to achieve at least two-thirds of their target through domestic emission reductions, total abatement costs for those countries as a group, excluding Ukraine and Russia, is about 0.11 to 0.20% of GDP in 2020 for the low and high pledge scenario, respectively. The costs increase to 0.23 and 0.37% if all Annex I reduction targets must be achieved domestically. For the high pledge scenario, 20% of these costs consist of financial transfers for financing abatement costs of Non-Annex I countries.
- The total abatement cost for the seven major Non-Annex I economies is about 0.11 to 0.19% of GDP for the low and high pledge scenario, respectively. Again, this assumes that part of the abatement cost is financed by Annex I countries.
- There are large differences in total costs between countries. Ukraine and Russia may still make significant profits from selling *new* surplus AAUs. The cost as proportion of GDP is very low for China and India. For Korea, Indonesia, Brazil and Mexico, costs are expected to be relatively high, even with substantial financial support.

4.1 Key assumptions

This chapter presents total abatement costs consisting of domestic abatement costs, emissions trading flows and financial transfers earmarked for financing abatement costs in Non-Annex I countries. These costs result from the reduction pledges of Annex I countries and mitigation actions of the emerging economies submitted to the Copenhagen Accord.

The projected reductions and costs were calculated with the FAIR 2.3 model and are based on marginal abatement cost (MAC) curves and reduction targets. Full use has been made of flexible Kyoto mechanisms, such as emissions trading, and cost-effective distribution of reductions over the different greenhouse gases and different sources, excluding REDD.

REDD measures are excluded from the carbon market, and are assumed to be financed 50% domestically and 50% by Annex I countries. The model uses aggregated permit demand and supply curves derived from MAC curves for the different regions, gases and sources from the energy model TIMER and land use model IMAGE. The permit demand and supply curves are used to determine the equilibrium permit price ('carbon price') on the international trading market, its buyers and sellers, and the resulting domestic and external abatements and costs for each region (see Appendix D). All prices and costs in this report are expressed in 2005 US dollars.

The FAIR 2.3 model is an improved version of the same model used in the analysis by den Elzen et al. (2009b). The main improvements include better calibration of the energy-related baseline emissions in the updated TIMER model; better representation of technological change with regard to non-CO_2 emission reduction options, and inclusion of inertia in reducing non-CO_2 emissions (see Appendix D).

Below, an explanation is given of how our cost estimates need to be interpreted and the differences between direct abatement costs (used in this study) and macroeconomic costs. Subsequently, the assumptions for the key factors influencing abatement costs are discussed, namely emissions trading, international financing of abatement costs of emerging economies, baseline emissions and how to deal with land use, land use change and forestry emissions. The main model assumptions for the costs calculations are presented in Box 4.1.

Abatement costs

Abatement costs have been calculated on the basis of marginal abatement cost curves, which indicate the costs of reducing an additional emission unit. These costs constitute one measure of the cost of climate policy. They capture the direct costs of abatement action but not the macroeconomic implications of these costs. For instance, crowding out of private consumption or investment due to increased government spending on abatement is not accounted for, nor are terms of trade effects due to emissions trading.

Studies/models use different cost metrics to describe the costs of climate policy. Both partial and general equilibrium models use direct abatement costs or increases in energy system costs. In addition, macroeconomic costs measured as GDP or consumption losses are used in general equilibrium models (den Elzen et al., 2007; Hof et al., 2009).

The abatement costs approach is relatively simple and focuses on the direct cost factor: additional costs for energy and abatement technology. Studies have shown that these direct costs correlate strongly with macroeconomic costs (van Vuuren et al., 2009a). Macroeconomic costs are more comprehensive, as they also capture indirect effects within the economy. They are also more uncertain because they also depend on distribution effects, revenue recycling and the impacts on other investments (Hourcade and Shukla, 2001; Morita and Robinson, 2001). An important indirect impact may occur via altering investment patterns. Some studies indicate that abatement action may lead to crowding out of more productive investments and thus less economic growth. Other studies claim that climate policies could lead to more investments and even increase economic growth (Hourcade and Shukla, 2001).

A similar issue exists with respect to tax revenue recycling, which can influence macroeconomic costs based on the efficiency of re-investment. An overview of GDP impacts at a global scale in different models is available from Edenhofer et al. (2006). Macroeconomic costs for different scenarios in the WorldScan model are discussed by Lejour et al. (2006). While abatement costs may be a good proxy for the total direct costs of climate policy in case of global policies, differences between macroeconomic cost measures and abatement costs may become more important if all parties do not participate in climate policy (see for instance, Lasky, 2003).

Emissions trading and pledges scenarios

The key factors for projecting abatement costs are how much countries have to reduce domestically (the extent to which emissions trading is allowed) and related to this how to deal with surplus AAUs of Russia and Ukraine. While results could strongly depend on the assumptions chosen, two possible variants were analysed:

1. *Restricted emissions trading and CDM scenario.* All individual Annex I countries are assumed to achieve at least two-thirds[1] of their target, after using credits for land use and forestry (see below), through domestic emission reductions. The remainder of their target could be achieved by either the purchase of surplus AAUs from Russia/Ukraine using JI in these countries, or implementing CDM projects in Non-Annex I countries ('off-setting').

   In theory, emissions trading between Annex I countries is allowed. But this will not occur in practice (except for Russia and Ukraine) because reducing emissions above the domestic target is more expensive than using CDM projects. To avoid double-counting of emission reductions, reductions from CDM projects are fully to the benefit of the donor country and the costs are fully to the burden of the donor country. This means that the emission reductions in Non-Annex I countries are the sum of their domestic target and off-setting reductions by CDM projects.

   We further assume that Russia and Ukraine maximise their profits from selling surplus AAUs from the first commitment period 2008-2012, and new period 2012-2020. They also maximise the gains from JI projects by using an 'optimal banking strategy' consisting of limiting the supply of AAUs in the market, thus raising the carbon price and optimising their financial revenues (see also den Elzen et al., 2009c).

2. *No emissions trading scenario*. All countries meet their reduction targets domestically – again with the potential to use credits for land use and forestry – without emissions trading and CDM. Possible new surplus AAUs can neither be traded nor used.

For both variants, we assume that banked surplus AAUs from the first commitment period cannot be sold. The results of a third and more theoretical variant that assumes no minimum level of domestic emission reductions (full emissions trading variant) are provided in Chapter 6, as part of analysing the robustness of results. Furthermore, we assume that either all countries implement their unconditional pledges (low pledge scenario), or all countries implement their conditional pledges (high pledge scenario).

Financing of abatement costs of emerging economies

For the low pledge scenario, 50% of the abatement costs of Brazil and South Africa are assumed to be financed by Annex I countries. For the high pledge scenario, Annex I countries are assumed to finance 50% of the total abatement costs of Brazil, South Africa and Mexico[2]. For Indonesia, the difference

1 Based on 1) the domestic target of the European emissions trading system, 2) the announcement of the Japanese Government that Japan does at least 60% domestically, and 3) the domestic abatement ambition of the anticipated USA energy and climate legislation.

2 The associated costs are more or less the same under the assumption that one-third of the total emission reduction is financed, internationally with the external finance for the more expensive policy measures. This is based on the conditional and unilateral pledges of Indonesia and Mexico.

in abatement costs between the high and low pledge is internationally financed. For India, China and South Korea, no international financing was assumed. The costs are shared between Annex I countries proportional to their GDP.

Baseline

The baseline incorporates the effects of the economic crisis (see Appendix D). The present economic crisis is likely to significantly affect the post-2012 carbon market. Less economic activity will result in lower emissions and lower projected baseline emissions, thus making it less costly to meet pledged emission reduction targets. The projected baseline emissions in 2020 for Annex I countries have been lowered by 7% as compared with pre-crisis analysis. The results of a baseline without economic crisis are provided in Chapter 6 as part of the analysis of the robustness of results.

Land use

We assume a fund-based financing mechanism for REDD in developing countries. The baseline emissions from deforestation in developing countries were used as well as the marginal abatement cost curves of REDD from the OSIRIS project (Busch et al., 2009), using the Global Forestry Model (G4M) from IIASA (Kindermann et al., 2008; Kindermann et al., 2006; Rokityanskiy et al., 2007). Based on the Copenhagen Accord mitigation actions of some emerging economies (Brazil, Mexico and Indonesia), we derived the emission reductions from REDD below baseline, and used this as basis for the costs and reductions calculations. As our own baseline differs from the baseline of G4M, the reductions were corrected to match the interpretation of the action plan. Although we do account for the costs and reductions from REDD for those emerging economies with an action related to this sector, these results are not included in the default

Box 4.1 Main model assumptions for the costs calculations

- ***Costs*** *– The total abatement costs of each scenario are the sum of i) domestic abatement costs calculated on the basis of the national carbon prices and reductions; ii) costs or revenues due to emissions trading, CDM and JI calculated on the basis of the international carbon price and quantity traded; and iii) costs or revenues due to financial transfers for financing abatement costs (including costs of REDD) in Non-Annex I countries. They represent the direct additional costs due to climate policy but do not capture the macroeconomic implications of these costs.*
- ***Carbon market*** *– includes emissions from all sources, except from deforestation emissions.*
- ***REDD*** *– REDD measures in Non-Annex I countries are excluded from the carbon market, and are assumed to be financed 50% domestically and 50% by Annex I countries. The costs for REDD measures for countries that have pledged for REDD financing, such as Brazil and Indonesia, are calculated separately, and do not affect the abatement costs, the carbon price and financial flows of the carbon market. Costs calculations are based on marginal abatement cost curves of REDD from the OSIRIS project (Busch et al., 2009), using the Global Forestry Model (G4M) from IIASA.*
- ***Financing*** *– Annex I countries finance 50% of the total abatement costs (including costs of REDD), through a simple financial transfer to Brazil and South Africa for the low pledge scenario, and to Brazil, Mexico and South Africa for the high pledge scenario. For Indonesia, the costs associated from increasing the reduction target from 26 to 41% will be financed.*
- ***Financial burden sharing*** *– the costs of supporting abatement (including REDD) in Non-Annex I countries will be allocated to Annex I countries in proportion to their GDP.*
- ***Baseline*** *– incorporates the effects of the recent economic crisis.*
- ***Banking*** *– no banking of surplus AAUs from the first commitment period.*
- ***New surplus AAUs*** *– limited in order to maximise the financial gains of Russia and Ukraine.*
- ***Transaction costs*** *associated with the use of the Kyoto mechanisms are assumed to consist of a constant USD 0.55 per tonne CO_2 eq emissions plus 2% of the total costs.*
- ***Starting levels of Annex I emissions in 2010*** *– the Kyoto targets for all Annex I countries (excluding the USA) that have agreed to meet their Kyoto target by their ratification of the Kyoto Protocol. For regions that have emissions well below their Kyoto target or surplus Assigned Amount Units (AAUs), such as Russia and Ukraine region in Annex I, the baseline or reference emissions for 2010 were chosen as a starting point.*
- ***International carbon price*** *are endogenously calculated. In the scenario without emissions trading, there is no international carbon price. In the restricted emissions trading variant, the domestic carbon price may be higher than the international carbon price due to the assumption that two-thirds of the emission reduction target needs to be achieved domestically.*
- ***Land use and forestry rules*** *– Emission allowance increases from land use and forestry rules are included, based on a low estimate of 2.5% of 1990 Annex I emissions (uncertainty range 1 to 9%), about 460 Mt CO_2. The regional estimates are based on the net-net accounting methodology described by the European Commission (2009a) and based on the work of the Joint Research Centre (JRC). This value is similar to the estimate of Rogelj et al. (2010), which is based on the assumptions that the land use and forestry rules remain the same as under the Kyoto Protocol, but with mandatory forest-management accounting and generated allowances capped at 4% of 1990 emissions.*
- ***International emissions trading within Annex I*** *is allowed, but as there are more cost-effective alternatives (CDM, trade in surplus AAUs) it is seldom used in practice.*
- ***Use of offsets*** *is included. But offsets are not used for the countries receiving financing for abatement costs since reducing emissions above their domestic target are higher than the international carbon price.*

Table 4.1

Emission reductions after emissions trading and financial consequences for the low and high pledge scenarios and for the variants restricted and no emissions trading for four world regions

	Emission reductions in 2020		Carbon price*	Total costs**			
	Annex I	Non-Annex I	Global	Annex I excluding Russia & Ukraine	Russia & Ukraine	Seven emerging economies	Rest of Non-Annex I
Scenario	relative to 1990 levels	relative to BAU levels	USD /tCO_2				billion USD (% of GDP)
1. Low pledges							
a. Restricted emissions trading	16%	7%	12	47 (0.11%)	–3 (–0.16%)	18 (0.11%)	–3 (-0.04%)
b. No emissions trading	16%	7%	–	96 (0.23%)	0.1 (0.01%)*	20 (0.13%)	0 (0.0%)
2. High pledges							
a. Restricted emissions trading	18%	10%	17	85 (0.20%)	–7 (–0.40%)	27 (0.17%)	–4 (–0.06%)
b. No emissions trading	19%	10%	–	157 (0.37%)	0.7 (0.04%)	29 (0.19%)	0 (0.0%)

* Carbon price on international carbon market (price of CDM, emissions trading), which is lower than the marginal abatement costs for individual Annex I countries as they are assumed to achieve at least two-thirds of their target through domestic reductions.
** Including financial transfers for international financing of abatement costs of the emerging economies (Brazil, Indonesia, South Africa and Mexico).

calculation and reduction targets. Instead, they are presented separately.

With regard to land use and forestry measures in Annex I countries, some countries have indicated whether their targets include or exclude debits and credits for land use and forestry. As explained in Chapter 2, we have assumed that on average, the emission allowance increases from land use and forestry rules are 2.5% of 1990 Annex I emissions, equal to about 460 Mt CO_2. The regional estimates are based on the net-net accounting methodology described by the European Commission (2009a), and based on the work of the Joint Research Centre (JRC).[3] The costs related to implementation of land use and forestry measures in Annex I countries are assumed to be negligible.

4.2 Cost comparisons of Annex I and Non-Annex I as a group

The emission reductions and abatement costs for the Annex I countries and Non-Annex I countries as a group are presented in Table 4.1. In the no emissions trading variant, surplus AAUs cannot be traded and emission allowance increases from land use and forestry rules are included. This case corresponds to the "Including emission allowances from land use and forestry rules, excluding surplus AAUs" of Table 2.2. Annex I emission reductions in this case are thus 16 to 19% below 1990 levels. The interesting result for the restricted emissions trading variant is that projected emission reductions for Annex I as a group (16% below 1990 levels for the low pledge scenario and 18% below 1990 levels for the high pledge scenario) are slightly lower than their pledge. This is because the restricted emissions trading variant assumes optimal banking and trade of new surplus AAUs in order to maximise the gains of Russia and Ukraine. This implies that a small proportion of the new surplus AAUs are sold in the high pledge scenario, which decreases the Annex I reduction level. For the low pledge scenario, it is optimal to forfeit almost all surplus AAUs (Kyoto and new).

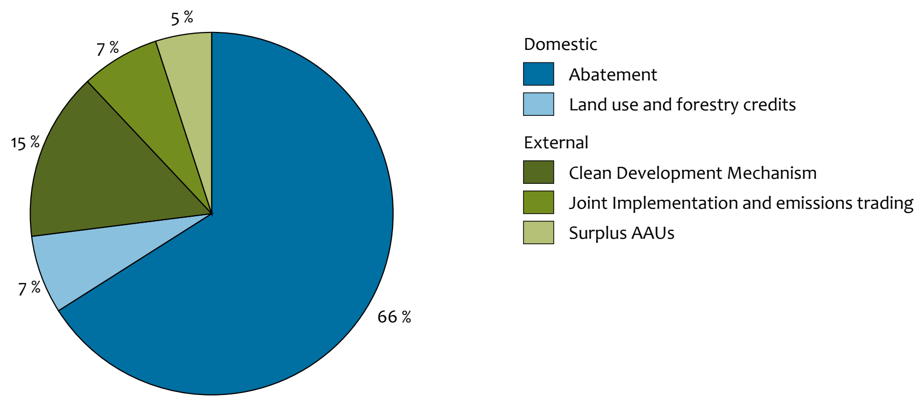
For the low pledge scenario, the average Annex I costs (excluding Russia and Ukraine) are about USD 47 billion (0.11% of GDP) in 2020 for the restricted emissions trading variant and USD 96 billion (0.23% of GDP) for the no emissions trading variant. Russia and Ukraine will profit from selling surplus AAUs in the restricted emissions trading variant, especially in the high pledge scenario. For the seven emerging economies as a group, the costs are about USD 20 billion (0.13% of GDP) for both the restricted emissions trading and no emissions trading variant. The reason that costs are not substantially lower for the restricted emissions trading variant is the very low carbon price.

The very low carbon price can be explained by the low demand for and high supply of emission credits which is caused by several factors. These are the restriction of achieving two-thirds of total emission reductions domestically; the large supply due to the surplus AAUs of Russia and Ukraine (although restricted to only 25% of the surplus AAUs by 2020 due to the optimal banking strategy); and the relatively low pledges. Even though the international carbon price is only USD 12 per t CO_2, many individual countries have to invest in more expensive abatement measures to achieve the two-thirds domestic reduction requirement.

For the high pledge scenario, the total abatement costs increase to USD 85 billion (0.20% of GDP) in the restricted emissions trading variant and USD 157 billion (0.37% of GDP) in the no emissions trading variant for Annex I as a whole (excluding Russia and Ukraine). This includes financial transfers for co-financing abatement costs in Non-Annex I countries, which amounts to USD 18 billion. For the seven emerging economies as a group, total abatement costs

3 JRC provided a spreadsheet-based tool to assess the impact of different land use and forestry rules for the Annex I countries under the Kyoto Protocol based on historic data for the base year 1990 or the base period 1990-1999.

Reduction options to meet Annex I reduction target, 2020 **Figure 4.1**



Contribution of reduction options to meet reduction target of Annex I countries (excluding Russia and Ukraine) for the high pledge scenario with restricted emissions trading.

are about USD 27 billion (0.17% of GDP) for the restricted emissions trading variant and only slightly higher for the no emissions trading variant. The small difference is due again to the low carbon price. How the emission reduction target for Annex I as a group is achieved is shown in Figure 4.1. Only about one-quarter of the target is achieved by emissions trading, of which half is from Russia and Ukraine (JI or buying surplus AAUs) and half through CDM.

4.3 Abatement costs of Annex I countries and regions

4.3.1 Emission reductions

The Copenhagen Accord pledges of the Annex I countries are given for a certain base year (Chapter 2). For projecting abatement costs, the reduction targets compared to BAU are more relevant. These are presented in Figure 4.2, which shows that the pledges of Russia and Ukraine are above their BAU projections. Reduction targets relative to BAU are the highest for the high pledges of Oceania (40% below their BAU emissions), followed by Japan (30%), the high pledge of the EU (24%), the pledges of the USA (23%) and Canada (20%).

Table 4.2 shows how the emission reduction targets for both the high and low pledge scenario are met by the individual Annex I countries and regions (again assuming that two-thirds of the total reduction target has to be met domestically for all individual Annex I countries). The emission reductions needed for the high pledge scenario are 50% higher than the low pledge scenario, mainly due to the large difference between the low and high pledge of the EU, followed by Russia and Oceania. Table 4.2 clearly shows that the total Annex I domestic emission reductions are higher than the total reduction target from the pledges. This is explained by trading of JI credits of Russia and Ukraine.

4.3.2 Abatement costs

Table 4.3 shows the total abatement costs per Annex I country for both the restricted emissions trading variant (two-thirds of reduction after using credits for land use and forestry has to be achieved domestically) and the no emissions trading variant. The costs consist of domestic abatement costs, costs or gains of emissions trading and JI, and costs of financing emission reductions in Non-Annex I countries. For the last category, the assumptions for financing in the low and high pledge scenario need to be considered (see Section 4.1). The financing costs are distributed to Annex I countries in proportion to their GDP.

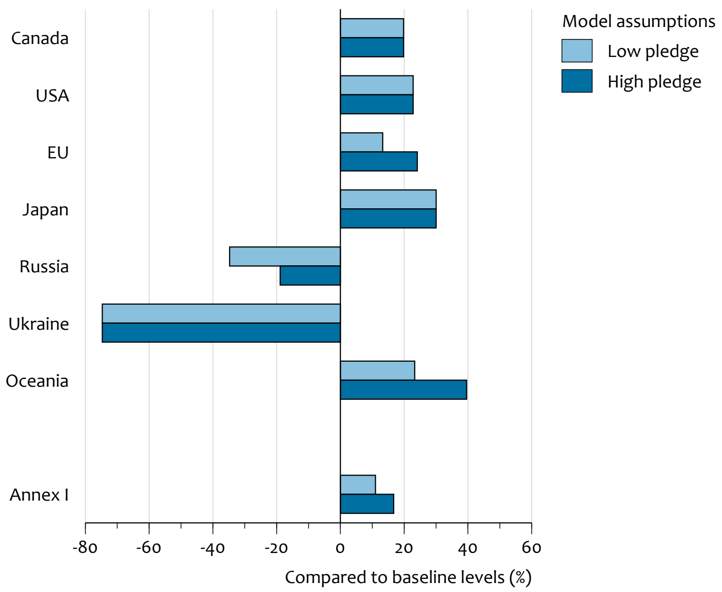
The abatement costs as share of GDP between Annex I countries and regions differ considerably, for both the high and low pledge scenarios, and for the restricted emissions trading and no emissions trading variants (Table 4.3). These differences can be explained by differences in reduction targets and in reduction potentials and GDP. In the low pledge scenario, abatement costs are relatively high especially for Oceania, and to a lesser extent for Japan and the USA. In the high pledge scenario, where in particular the EU has a more ambitious pledge, costs as share of GDP are more equally divided in the restricted emissions trading variant. The notable exceptions are Oceania where costs are much higher, and Canada where costs are much lower. The cost estimate of Oceania, however, depends heavily on land use accounting rules and could be much lower with different rules (also see Chapter 2). Total financing costs are USD 18 billion.

If no emissions trading is allowed and all Annex I reductions have to be achieved domestically, the costs are much higher for all countries except for Canada in the high pledge scenario. A better comparison of relative abatements costs is given in Figure 4.3, which compares the costs as proportion of GDP with the Annex I average. Relative costs are the highest for Oceania in each of the four variants, followed by Japan. For the EU, Ukraine and Russia, relative costs (or gains) depend heavily on whether the high or low pledge is implemented.

Reduction targets compared to baseline levels of Annex I countries, 2020

Figure 4.2

Greenhouse gas emissions, excluding CO_2 from land use



Emission reduction targets and emission reductions in 2020 for Annex I countries (in Mt CO_2 eq, rounded to the nearest 10 Mt)

Table 4.2

Low pledge scenario	1990 level	Baseline emissions 2020	Target 2020	Land use and forestry credits	Total reduction target	Domestic reduction	Emissions trading
Canada	600	770	620	60	90	60	30
USA	6 070	7 630	5 890	140	1 600	1120	490
EU27	5 930	5 470	4 750	80	730	670	70
Japan	1 220	1 310	910	40	350	240	110
Russia	3 480	2 200	2 960	0	–760	0	–200*
Ukraine	1 110	510	880	0	–380	0	–60*
Oceania+	520	770	590	–10	190	130	60
Annex I excluding Russia & Ukraine	14 350	15 950	12 760	320	2 980	2 230	750
Annex I	18 930	18 650	16 600	320	2 730	2 230	500
High pledge scenario							
Canada	600	770	620	60	90	80	150
USA	6 070	7 630	5 890	140	1 610	1140	470
EU27	5 930	5 470	4 150	80	1 240	990	250
Japan	1 220	1 310	910	40	350	240	110
Russia	3 480	2 200	2 610	0	–420	0	–320*
Ukraine	1 110	510	880	0	–380	0	–160*
Oceania+	520	770	460	–10	320	140	180
Annex I excluding Russia & Ukraine	14 350	15 950	12 040	320	3 590	2570	1020
Annex I	18 930	18 650	15 540	320	3 120	2570	540

* Surplus AAUs
\+ Australia and New Zealand

4.4 Abatement costs of Non-Annex I countries

4.4.1 Emission reductions

The emission reduction targets resulting from the mitigation actions submitted to the Copenhagen Accord by Non-Annex I countries have been calculated and are summarised in Figure 4.4. The reduction targets are very uncertain as shown in Chapter 3. These reduction targets exclude land use CO_2 emissions, and therefore the reductions from Brazil and Indonesia are much lower than their reduction targets presented in Chapter 3.

REDD measures are excluded from the carbon market and are calculated separately. These measures do not influence the abatement costs, carbon price, or financial flows of the carbon market. The model calculations for Korea include both

Total abatement costs by source for Annex I regions (in USD million; rounded to the nearest USD 10 million (negative sign indicates benefits))

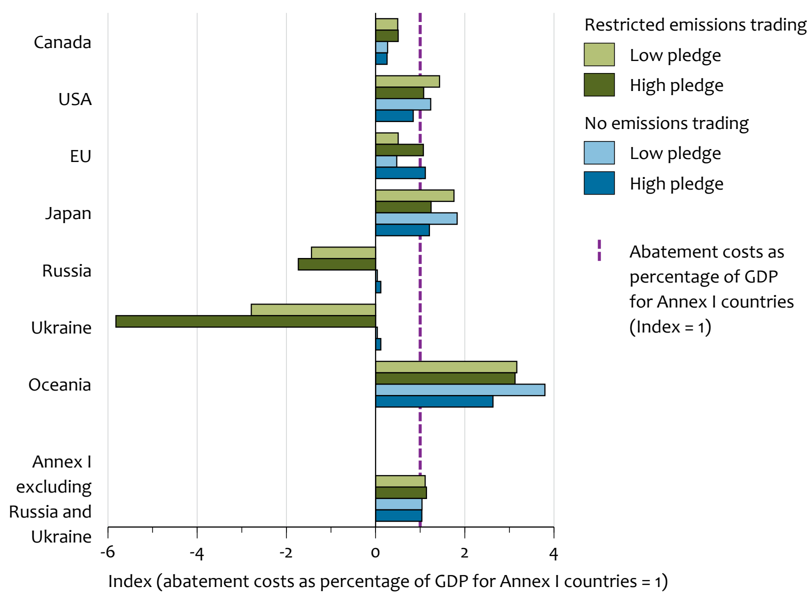
Table 4.3

	Restricted emissions trading					No emissions trading	
Low pledge scenario	**Domestic abatement costs**	**Emissions trading costs/ revenues**	**Financial transfers for financing**	**Total costs**	**Total costs relative to GDP**	**Total costs**	**Total costs relative to GDP**
Canada	270	330	120	720	0.05%	860	0.06%
USA	16 180	6 210	1 410	23 800	0.14%	44 810	0.27%
EU27	6 380	1 010	1 490	8 880	0.05%	18 150	0.10%
Japan	7 400	1 460	450	9 310	0.18%	21 160	0.40%
Russia	0	−2 370	130	−2 230	−0.14%	130	0.01%
Ukraine	0	−700	20	−680	−0.28%	20	0.01%
Oceania+	3 300	760	110	4 170	0.32%	10 920	0.83%
Annex I excluding Russia & Ukraine	33 520	9 760	3 590	46 870	0.11%	95 890	0.23%
Annex I	33 520	6 700	3 740	43 960	0.10%	96 050	0.22%
High pledge scenario							
Canada	420	270	610	1 310	0.09%	1 350	0.09%
USA	16 400	8 180	6 960	31 530	0.19%	50 240	0.30%
EU27	21 260	4 460	7 340	33 060	0.19%	69 980	0.40%
Japan	7 400	2 000	2 220	11 620	0.22%	22 930	0.43%
Russia	0	−5 400	650	−4 750	−0.31%	650	0.04%
Ukraine	0	−2 600	100	−2 500	−1.03%	100	0.04%
Oceania+	3 550	3 150	550	7 260	0.55%	12 430	0.94%
Annex I excluding Russia & Ukraine	49 030	18 060	17 680	84 770	0.20%	156 920	0.37%
Annex I	49 030	10 060	18 440	77 530	0.18%	157 680	0.36%

+Australia and New Zealand

Relative abatement costs for Annex I countries, 2020

Figure 4.3

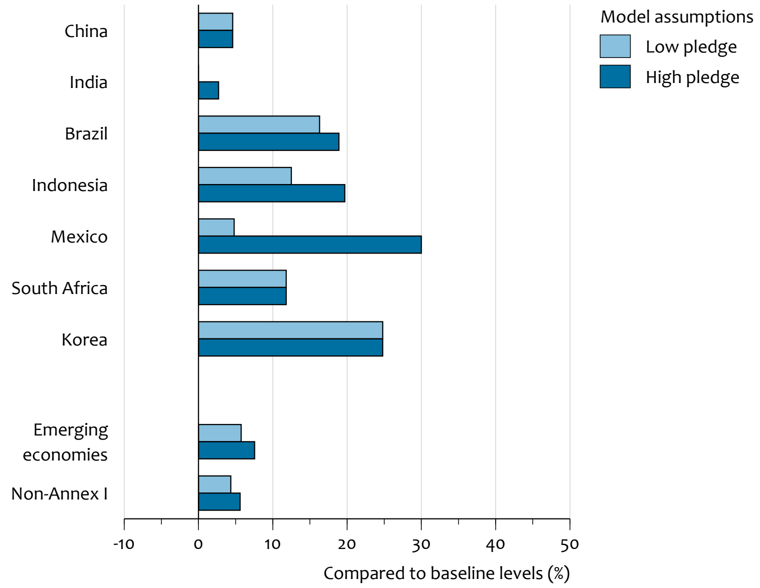


South and North Korea so that the reduction target of Korea is lower than the 30% pledged by South Korea. Our reduction target for South Africa is lower than their Copenhagen pledge of 34% because our BAU emissions for 2020 are lower than the BAU emissions used in their submission.

Figure 4.4 shows large differences between countries in reduction targets, excluding actions to reduce land use CO_2 emissions. Korea has a relatively high reduction target, whereas the reduction level of China and India is very low. Mexico and Indonesia have a large range of emission reduction targets, depending on international support. For Indonesia, we assume that in the high pledge scenario 50% of the difference in costs between the low and high pledge scenario will be financed internationally. We also assume

Reduction targets compared to baseline levels of emerging economies, 2020 **Figure 4.4**

Greenhouse gas emissions, excluding CO_2 from land use



that 50% of the total abatement costs will be provided by international support for Mexico, Brazil and South Africa.

Table 4.4 shows how the countries are expected to achieve their targets. As the mitigation actions submitted by Brazil, Indonesia, Mexico, South Africa and South Korea relate to domestic emission reductions only, their targets are assumed to be achieved domestically (abatement costs are partly paid by Annex I countries). This means that only India and China will serve as host countries for CDM projects. The abatement costs above the domestic targets of these other emerging economies are too high to implement CDM.

The REDD reduction targets are considerable for Indonesia and Brazil. According to our interpretation of the high pledge scenario, these targets are 56% and 62% below deforestation baseline emissions, respectively. In the case of Mexico, REDD is included in the original action plan.

4.4.2 Abatement costs

Total abatement costs for the seven emerging economies analysed are shown in Table 4.5. As can be expected from the wide range in reduction targets (see Figure 4.4), there are large differences in costs between the countries. For the low pledge scenario with restricted emissions trading, costs as proportion of GDP are by far the highest in Korea (about 0.7% of GDP), which is also the country with the most ambitious target. The total costs for Brazil and Indonesia are also substantial, 0.27 and 0.28% of GDP, respectively. For the no emissions trading variant, total costs are equal to those in the restricted emissions trading variant for those countries that achieve their actions domestically.

The high pledge scenario leads again to the highest costs in Korea, closely followed by Indonesia and Mexico. Since the high pledge scenario implies that there is no room for CDM projects, the no emissions trading variant leads to the same costs except for India and China, who would benefit from emissions trading.

The costs as share of GDP relative to the average costs of the seven countries are presented in Figure 4.5. The high costs for Korea are noteworthy, followed by Indonesia, Mexico (only for the high pledge scenario) and Brazil. The costs of Brazil and Indonesia include the costs of REDD, which are substantial for these two countries.

Emission reduction targets and emission reductions for the seven major emerging economies (in Mt CO_2 eq, rounded to the nearest 10 Mt)

Table 4.4

Low pledge scenario	1990 level	Baseline emissions 2020	Target 2020	Total Reduction	Domestic Reduction	Emissions trading	REDD
Mexico	460	790	750	40	45	–10	10
Brazil	740	1340	1 120	220	220	0	670
China	3 880	13 760	13 230	530	740	–210	0
India	1 410	3 390	3 390	0	60	–60	0
Indonesia	470	1 040	910	130	130	0	520
Korea	460	1 130	850	280	280	0	0
South Africa	440	580	510	70	70	0	0
Total	7 860	22 040	20 770	1 270	1 540	–270	1 200
High pledge scenario							
Mexico	460	790	550	240	240	0	30
Brazil	740	1340	1 090	250	250	0	670
China	3880	13 760	13 230	530	780	–250	0
India	1410	3 390	3 300	90	140	–50	0
Indonesia	470	1 040	830	210	210	0	820
Korea	460	1 130	850	280	280	0	0
South Africa	440	580	510	70	70	0	0
Total	7 860	22 040	20 370	1 660	1 970	–300	1 520

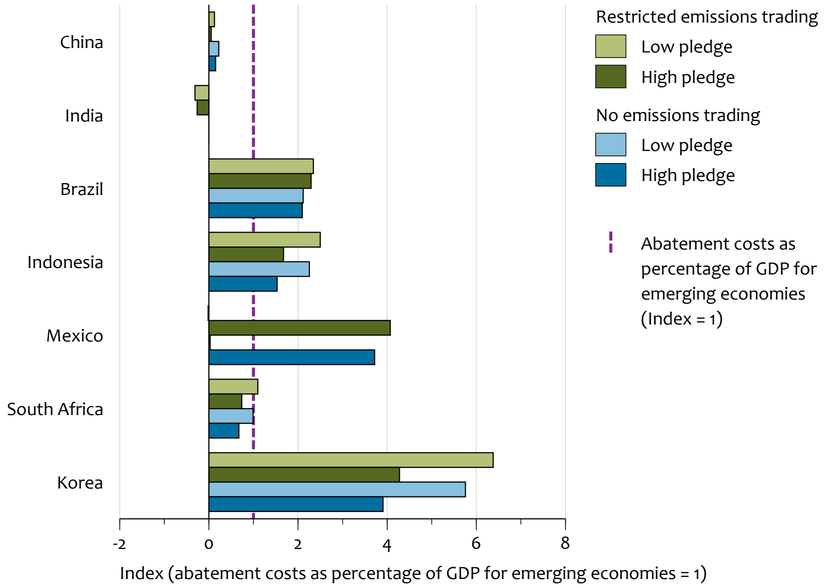
Total abatement costs by source for the seven major emerging economies (in USD million; rounded to the nearest USD 10 million (negative sign indicates benefits))

Table 4.5

	Restricted emissions trading						No emissions trading	
Low pledge scenario	Domestic abatement costs	Costs of REDD abatement	Emissions trading costs/ revenues	Financial transfers for financing	Total costs	Total costs relative to GDP	Total costs	Total costs relative to GDP
Mexico	60	10	–90	0	–20	0.00%	40	0.00%
Brazil	5 080	1 580	0	–3 330	3 330	0.27%	3 330	0.27%
China	3800	0	–2 500	0	1 300	0.01%	2 550	0.03%
India	20	0	–680	0	–660	–0.04%	0	0.00%
Indonesia	1 220	570	0	0	1 800	0.28%	1 800	0.28%
Korea	12 120	0	0	0	12 120	0.73%	12 120	0.73%
South Africa	810	0	0	–410	410	0.12%	410	0.12%
Total	23 120	2 170	–3 270	–3 740	18 280	0.11%	20 260	0.13%
High pledge scenario								
Mexico	16 190	20	0	–8 110	8 110	0.69%	8 110	0.69%
Brazil	8 140	1 580	0	–4 860	4 860	0.39%	4 860	0.39%
China	4 970	0	–4 170	0	800	0.01%	2 550	0.03%
India	40	0	–870	0	–830	–0.04%	0	0.00%
Indonesia	5 540	1 320	0	–5 060	1 800	0.28%	1 800	0.28%
Korea	12 120	0	0	0	12 120	0.73%	12 120	0.73%
South Africa	810	0	0	–410	410	0.12%	410	0.12%
Total	47 820	2 930	–5 040	–18 440	27 270	0.17%	29 850	0.19%

Relative abatement costs for emerging economies, 2020 — Figure 4.5

Abatement costs including international financing



Risks of widening and options for narrowing the gap towards 2°C

5

Key findings

- Whether the 2°C target is met depends to some extent on the emission target level in 2020 but longer term reductions are just as important. According to most studies, an emission level of 44 to 46 Gt CO_2 eq in 2020 is assumed to be in accordance with a 2°C target.
- Copenhagen Accord pledges of Annex I countries and the action plans of the seven major emerging economies would lead to a global emission level in 2020 of about 48.7 to 50.1 Gt CO_2 eq, if new surplus AAUs are forfeited. The gap towards 2°C is thus about 2.7 to 6.1 Gt CO_2 eq. This range takes account of low emission allowance increases from land use and forestry rules.
- The main risks of the high end pledges being watered down are: i) a lowering of the reduction target from the USA if the climate bill fails to pass or is weakened by the Senate. This may trigger lower pledges from other countries, leading to a 2.8 Gt CO_2 eq increase in emissions; ii) double counting of offset emissions, leading to 1.3 Gt CO_2 eq increase in emissions; and, finally iii) using Kyoto surplus AAUs, which would increase emissions by 1.5 Gt CO_2 eq. When all the risks explored in this study are taken into account, the total emission level could be close to baseline emissions.
- A set of options could also result in an additional 2.9 Gt CO_2 eq emission reduction, which would narrow the 2020 emissions gap towards 2°C. These options include: i) enhancing mitigation action for China and India according to their national climate policies (not part of their submissions to the Copenhagen Accord) would lead to further reductions of around 1.4 Gt CO_2 eq; ii) reducing emissions from deforestation by 50% below 2005 levels by 2020; iii) excluding emission allowance increases from land use and forestry rules; and iv) reducing international bunker emissions.

5.1 Copenhagen Accord pledges by 2020 compared to 2°C pathways

As described in Chapter 2, the emission reduction target resulting from the pledges of Annex I countries depends heavily on the emission allowance increases from land use and forestry rules, and on whether the new surplus AAUs for Russia and Ukraine may be used. We have assumed a 2.5% emission allowance increases from land use and forestry rules of the Annex I emission level of 1990. Furthermore, we have assumed that the new surplus AAUs for Russia and Ukraine are *not* used. The later is also supported by our cost calculations in Chapter 4 that show the net financial revenues for Russia and Ukraine are optimal if they forfeit most of their new surplus AAUs, and do not bank the Kyoto surplus emissions. This implies that the emission reduction targets for Annex I countries are 16 to 19% below the 1990 level, leading to an Annex I emission target level of 15.2 to 15.8 Gt CO_2 eq (Table 2.2).

According to our calculations, the total emission reduction target for the Non-Annex I group resulting from the mitigation actions under the Copenhagen Accord is 7 to 10% below BAU emissions. This would lead to an emission target level for the Non-Annex I group of around 33 Gt CO_2 eq.

Emissions resulting from international aviation and shipping are not included in these pledges and are expected to amount to 0.9 Gt CO_2 eq. The total emission level in 2020 resulting from the high pledge scenario would be about 48.7 Gt CO_2 eq

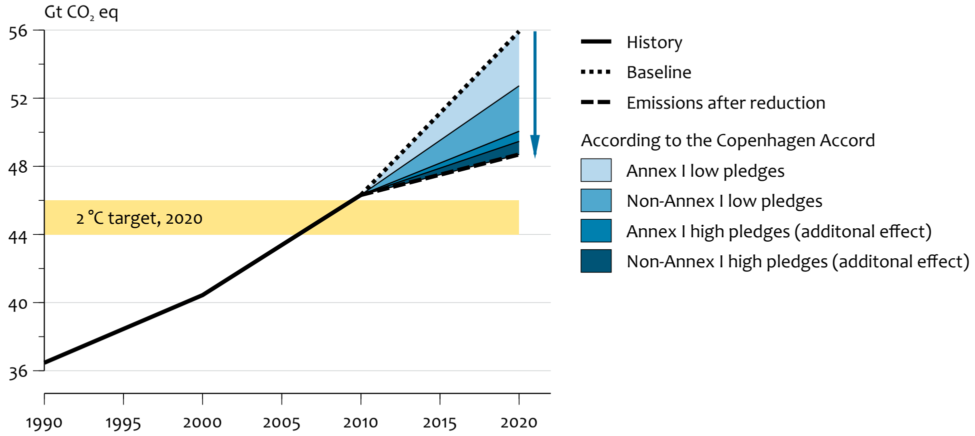
Greenhouse gas emission levels (including land use CO_2, in Gt CO_2 eq) resulting from the reduction pledges of Annex I countries and mitigation actions of Non-Annex I countries under the Copenhagen Accord compared with the reduction level to meet the 2°C target (44 to 46 Gt CO_2 eq) **Table 5.1**

	Annex I (including land use*, excluding new surplus AAUs**)	Non-Annex I	International aviation and maritime	Global	Reduction against baseline levels	2°C emissions gap
Emissions, 1990	18.8	17.2	0.5	36.5	–	–
Baseline emissions, 2020	19.0	36.0	0.9	55.9	–	9.9 – 11.9
Low pledge scenario, 2020	15.8	33.3	0.9	50.1	5.9	4.1 – 6.1
High pledge scenario, 2020	15.2	32.6	0.9	48.7	7.2	2.7 – 4.7

* Includes increase of emission allowances from land use and forestry rules of 0.45 Gt CO_2 eq
** Excludes new surplus AAUs from Russia and Ukraine of 1.0 and 0.7 Gt CO_2 eq for respectively the low and high pledge scenario.

Impact of pledged reductions **Figure 5.1**

Global greenhouse gas emissions, including CO_2 from land use and excluding surplus AAUs



Note: all pledges for reductions are implemented domestically

(Table 5.1 and Figure 5.1). The total emission level resulting from the low pledge scenario would be about 50.1 Gt CO_2 eq.

Since the Copenhagen Accord acknowledges that global temperature should not increase by more than 2°C relative to pre-industrial times, the question is whether a 48.7 Gt CO_2 eq emission level in 2020 is compatible with the 2°C target. This largely depends on the extent to which emissions are reduced after that time because the level of cumulative emissions in the next decades is more important in reaching the 2°C target than the emission level in 2020 (Meinshausen et al., 2009). However, higher 2020 emissions imply that emissions need to be reduced faster after that point in order to achieve the same cumulative emissions. At some point, this will become very costly or even impossible (Bowen and Ranger, 2009; den Elzen et al., 2010b).

UNEP (2010) compiled the results of a number of studies (e.g., Bowen and Ranger, 2009; Lowe et al., 2009; Meinshausen et al., 2009; van Vuuren et al., 2007) to identify robust conclusions on the emission level in 2020 to remain below the 2°C target. UNEP concluded that the range of emissions reported in the studies consistent with a 50% probability of reaching the 2°C target was 40 to 48 Gt CO_2 eq in 2020 (with a reduction target of 40 to 80% below 2000 levels in 2050). Van Vuuren et al. (2009b) analysed more recent mitigation scenarios from the MESSAGE model of the International Institute for Applied Systems Analysis (IIASA) and the IMAGE model of Netherlands Environmental Assessment Agency (PBL; e.g., Rao et al., 2010; van Vuuren et al., 2010). An emission range of 44 to 48 Gt CO_2 eq in 2020 was found to be compatible with a 50% chance of reaching the 2°C target.

Clearly, the high end of this range implies faster emission reductions in the long-term. This is likely to lead to lower short-term costs but higher long-term costs (Bowen and Ranger, 2009; den Elzen et al., 2010b). It is also likely to lead to more risks because of doubts as to whether such rates of change are feasible without incurring prohibitive economic costs (Stern and Taylor, 2010). As a medium assumption, this report takes a central range of 44 to 46 Gt CO_2 eq.

From our analysis of the pledges, we conclude that the low pledge scenario achieves an emission reduction of 5.9 Gt CO_2 eq, leading to a global emission level of 50.1 Gt CO_2 eq in 2020 (Table 5.1). This leaves a gap of about 4 to 6 Gt CO_2 eq to the range required to keep the 2°C degree target within reach. The high pledge scenario would achieve a total reduction of 7.2 Gt CO_2 eq, leaving a gap of about 2.7 to 4.7 Gt CO_2 eq. Given the baseline emissions of 56 Gt CO_2 eq, and thus an overall reduction effort challenge of 10 to 12 Gt CO_2 eq, the high pledge scenario reduces the emissions gap by 55 to almost 80%.

5.2 Risks of widening the emissions gap towards 2°C

The global emission level resulting from all pledges and proposed mitigation actions of the Copenhagen Accord given in Table 5.1 is our interpretation. The various risks that the final pledges could lead to a higher global emission level are summarised in Figure 5.2 (high pledge scenario) and in Table 5.2 (low and high pledge scenario). All together, the risks of lowering the emission reduction target could lead to a global emission target close to BAU emissions. The watering down effects are mostly smaller for the low pledge scenario (see Table 5.2) because the reduction targets below baseline are smaller. Furthermore, the Annex I countries' demand for carbon credits is lower.

The analysis of the effects of watering down focuses on i) risks related to the conditionality of the pledges; and ii) the risks related to offsets (CDM and credits for land use and forestry) and trading of surplus AAUs.

I. Risks related to pledge conditionalities

Risk 1: A lower reduction target for the USA if the climate bill fails may trigger reduction in conditional pledges of other developed and developing countries.

Various high pledges are conditional on an ambitious overall outcome (e.g., EU, Australia, Japan, and New Zealand). The largest uncertainty in the Annex I pledges relates to the climate bill of the USA that proposes reductions of roughly 17% relative to 2005 emissions (see Chapter 2). If the bill is not passed or is weakened by the Senate, lack of comprehensive legislation may fail to trigger contingent pledges (or sticking to low pledges) by other developed and developing countries. This may be the case even though other measures may be able to deliver some, if not all, of the USA pledge (European Climate Foundation, 2010).

It is not certain whether all countries are willing to implement their pledges if the USA climate bill fails to pass or weakened by the Senate. In this study, we have assumed that if the climate bill fails to pass, the USA will lower its emissions target towards 2005 levels. This will cause Japan to lower its reduction target to 15% below 2005 levels (the earlier pledge by Japan). The pledges and mitigation actions of all other countries fall towards the low abatement end. This would lead to a decrease in total reduction of 2.8 Gt CO_2 eq.

The Catalyst project (European Climate Foundation, 2010) has made more pessimistic assumptions, consisting of USA emissions increasing to 7% above 2005 levels, other countries switching to the low pledge scenario, and Japan following the baseline. This would even lead to a decrease in reduction level of 4.3 Gt CO_2 eq.

II. Risks related to offsets and trading surplus AAUs

Risk 2: Using surplus AAUs from Kyoto period

From the first commitment period (2008–2012), around 13 Gt CO_2 eq of surplus AAUs from Russia, Ukraine and Central Europe are expected. We have assumed in our default calculations that these surpluses are not used, but if used they could reduce the reduction level in 2020 by 1.3 Gt CO_2 eq. This represents about 6.5% of 1990 Annex I emissions if consumed for compliance purposes at a constant rate over the period 2013–2023[1]. Our calculations for Kyoto surplus AAUs are comparable with the estimates reported in the Point Carbon report (Point Carbon, 2009). In the risk analysis only Kyoto surplus AAUs from Russia and Ukraine are taken into account, resulting in a 1.0 Gt CO_2eq lower reduction level in 2020.

Another risk related to the Kyoto hot air is that the starting level of emissions in 2013 for Russia and Ukraine is equal to their actual projected emissions. Their Kyoto target is much higher, however. If the Kyoto target is used as starting point for calculating their surplus AAUs (linearly decreasing their pledged targets for 2020) for the 2013–2020 period, this would lower the Annex I reduction by an additional 0.5 Gt CO_2 eq.

The total impact of the surplus AAUs from previous commitment periods on the mitigation effort by 2020 is about 1.5 Gt CO_2 eq, if used entirely to meet the targets and actions described in the Appendices to the Copenhagen Accord. Höhne et al. (2009b) give an estimate of 2 Gt CO_2 eq, and Stern and Taylor (2010) of 1 to 2 Gt CO_2 eq.

Risk 3: Trading of new surplus AAUs

The pledges for 2020 of Russia and Ukraine are above their baseline projection, meaning that new surplus AAUs are generated. If these surplus AAUs are banked and used, the emission reduction would decrease by 0.7 Gt CO_2 eq for the high pledge and 1 Gt CO_2 eq for the low pledge scenario (see also Sections 2.1 and 5.1).

Risk 4: Lenient land use and forestry rules for Annex I countries

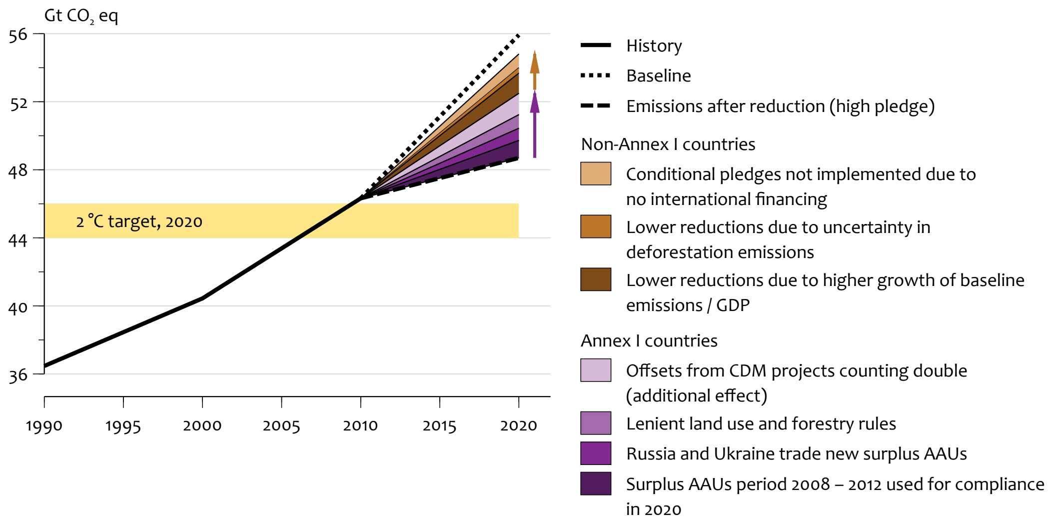
In the default calculations of the pledges, we assume that land use and forestry rules lowers the total reduction level by about 0.45 Gt CO_2 eq, which is about 2.5% of Annex I 1990 emissions. However, lenient land use and forestry rules[2] would lower the reduction level of developed countries by up to 9% of Annex I 1990 emissions (European Commission,

1 Based on similar calculations of the European Commission (2009b) and den Elzen et al. (2009c), assuming that the surplus AAUs under the Kyoto Protocol are consumed for compliance purposes at a constant rate over the period 2013-2023. More specifically, a total of 1.3 Gt CO_2 AAUs (= 13 / 10) would be available each year up to 2020.

2 Kyoto Protocol's land use and forestry rules would be changed to unconstrained "gross net", which would allow countries that have emission removals from land use and forestry measures already in the baseline, without additional effort, to account for them fully. More specifically, option 1 (with 0% discounting for forest management) of Table 9 of the European Commission (2009a) is implemented based on the work of the Joint Research Centre (JRC).

Impact of possible risks of broadening the gap for the high pledge — **Figure 5.2**

Global greenhouse gas emissions, including CO_2 from land use



Impact of the risks that widen the emissions gap towards the 2°C target for the low and high pledge scenario* — **Table 5.2**

Emissions or emission reductions (Gt CO_2 eq)	Low pledge scenario	High pledge scenario
Pledges, total emissions, 2020	50.1	48.7
I. Risks related to conditionality of pledges		
Leaving conditional Annex I targets (Japan, Australia, USA, etc)	1.4	2.8
Pledges, total emissions after watering down, 2020	51.5	51.5
II. Risks related to offsets and trading of surplus AAUs		
Use of surplus AAUs from Kyoto period	1.5	1.5
Russia and Ukraine trade new surplus AAUs	1.0	0.7
Lenient land use and forestry rules for Annex I countries	1.2	1.2
Double-counting of offsets from CDM projects	1.1	1.3
Lower reductions due to higher growth of Non-Annex I BAU emissions/GDP	0.6	1.2
Lower reductions due to uncertainty in deforestation emissions	0.2	0.3
No financial transfers for financing abatement Non-Annex I countries	0.5	0.8
Total decrease in total emission reductions, 2020	4.6*	6.1*
Pledges, total emissions after watering down, 2020	54.8	54.8

* Totals do not add up because of possible overlap between certain risks.

2009a). This would lead to an additional increase in emissions of 1.2 Gt CO_2.

The Climate Action tracker assumes land use and forestry rules to degrade the Annex I reduction level by 5% of Annex I 1990 emissions (about 0.9 Gt CO_2 eq), leading to an additional increase in emissions of 0.45 Gt CO_2 eq.

Risk 5: Offsets from CDM projects counting double

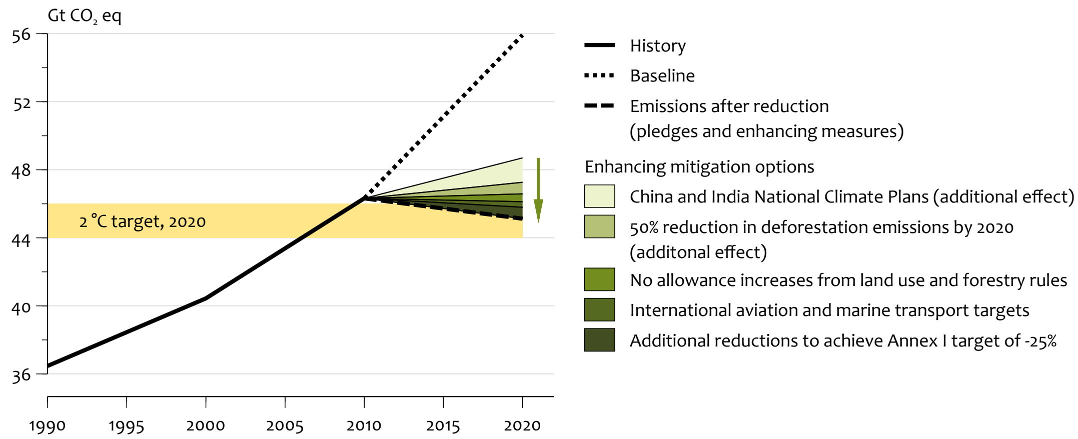
A further uncertainty is the potential double-counting of offsets, which could affect emission reduction by up to 1.3 Gt CO_2eq. In the default calculations, we assumed that reductions from CDM projects are fully to the benefit of the donor country. However, there is a risk of double-counting of these offset emissions, with reductions accounted for by both the developed country reported as having been paid for compliance, and the developing country reported as contributions to meeting their pledges (European Climate Foundation, 2010).

Risk 6: Lower reduction of NAMAs due to high Non-Annex I BAU emissions/GDP

A major uncertainty in estimating emission reduction targets of Non-Annex I countries is that BAU emissions against which the proposals are defined are not mentioned or specified in the submissions to the Copenhagen Accord. There might be a tendency to report high BAU emissions so that the targets can be more easily achieved. To estimate the consequences of this risk, we analysed the effect of a 10% increase of baseline emissions (excluding land use) of the seven major emerging economies, except China and India. These last two countries have an intensity target, which means that the main

Impact of enhancing mitigation options to narrow the gap for the high pledge **Figure 5.5**

Global greenhouse gas emissions, including CO_2 from land use and excluding surplus AAUs



uncertainty is GDP growth. Average economic growth for our baseline scenario is about 8% and 5.5% per year in the period 2005-2020, respectively for China and India. We analysed the effect of a 1.0% higher annual GDP growth rate for both countries, keeping the energy intensity target unchanged and assuming the same relative reductions compared to the new BAU emissions from the non-fossil target. The effect of this higher GDP growth rate is 0.8 Gt CO_2 eq higher emissions by 2020 for China, and 0.1 Gt CO_2 eq higher emissions by 2020 for India.[3] For the other Non-Annex I countries as a whole, emissions are projected to increase by 0.2 for the low pledge scenario and 0.3 Gt CO_2 eq for the high pledge scenario.

Risk 7: Lower reduction of NAMAs due to uncertainty in deforestation emissions

For the deforestation emissions of Brazil and Indonesia, we based the watering down effect on the higher baseline from the G4M model (Kindermann et al., 2008). This results in at least 0.3 Gt CO_2 eq extra emissions.

Risk 8: Lower reduction of NAMAs due to insufficient international financial support

The reduction pledges of Brazil, Indonesia, Mexico and South Africa are partly conditional on international support. Without such support, the reductions may be less. For some countries, such as Mexico and Indonesia, the reductions will be equal to their low pledge, and for other countries these reductions will decrease by 50% as mentioned in Section 4.4. The total pledge of the emerging economies could be reduced from 10 to 7%, leading to an increase in global emissions of 0.8 Gt CO_2 eq. This estimate is a similar to that presented by Stern and Taylor (2010).

5.3 Options for closing the emissions gap towards 2°C

Options to narrow the emissions gap of 2.7 to 4.7 Gt CO_2 eq are assessed. Options for emission reductions have been identified which go beyond the submissions of Annex I and Non-Annex I countries to the Copenhagen Accord. They are based on policy choices that have been discussed in policy documents before Copenhagen. They should not be seen as recommendations but simply as examples.

Option 1: Taking into account national climate policies of China and India

Some developing countries, notably China and India, have domestic climate policies (not part of their submitted mitigation actions) that go further than the mitigation actions under the Copenhagen Accord. According to our interpretation of their climate plans, implementation of these plans would increase their reductions from 6 to 12% below BAU for China and from 3 to 19% below BAU for India (see Box 5.1 and Appendix D). This will reduce global emissions by about 1.4 Gt CO_2 eq. The remaining gap towards 2°C is only 1.3 to 3.3 Gt CO_2 eq.

Option 2: Reducing deforestation by 50% by 2020

Separate policy interventions are currently being discussed under the UNFCCC to prevent deforestation as early as possible. Emissions from land use due to policy interventions against deforestation can be assumed to be declining much faster, leading to 50% reduction by 2020 and zero emissions by 2030. This would increase the reductions by about 0.7 Gt CO_2 eq.

Option 3: No emission allowance increases from land use and forestry rules for Annex I

If it would not be allowed to use land use and forestry credits for the Annex I countries, this would enhance the Annex I reduction by 0.5 Gt CO_2 eq and bring the Annex I reduction target towards 18 to 21% below 1990 levels (also see Section 2.1).

Option 4: Reducing international bunker emissions

The EU has proposed targets for 2020 of a 10% reduction in the international aviation sector and 20% in the international maritime sector relative to 2005 levels. This would result in 0.3 Gt CO_2 eq additional emission reductions.

3 A 2% higher economic growth would lead to 3.2 Gt CO_2 eq higher emissions by 2020 for China, and 0.7 Gt CO_2 eq higher emissions by 2020 for India. A 1% lower economic growth would lead to 1.3 Gt CO_2 eq lower emissions by 2020 for China, and 0.4 Gt CO_2 eq lower emissions by 2020 for India.

Impact of options to narrow the emissions gap towards the 2°C target on the low and high pledge scenario (Gt CO_2 eq)

Table 5.3

Global emissions or emission reductions	Low pledge scenario	High pledge scenario
Pledges, total emissions, 2020	**50.1**	**48.7**
Options to narrow the gap towards 2°C		
Additional reductions from national climate plans, China and India	–1.4	–1.4
50% reduction target of deforestation in 2020	–0.9	–0.7
No emission allowance increases from land use and forestry rules for Annex I	–0.5	–0.5
Aviation and marine transport targets	–0.3	–0.3
Total impact on emissions	–3.1	–2.9
Total emissions after implementation of options	**47.0**	**45.8**
Increase reduction level of Annex I to 25% below 1990 levels		–0.7
Total emissions after implementation of options and increase of Annex I reduction		**45.1**

Box 5.1: Effect of national climate policies of China and India on emissions

China national climate plan

The national climate plan of China contains additional measures that could reduce its emissions further than the measures in the submission to the Copenhagen Accord. These additional measures include:

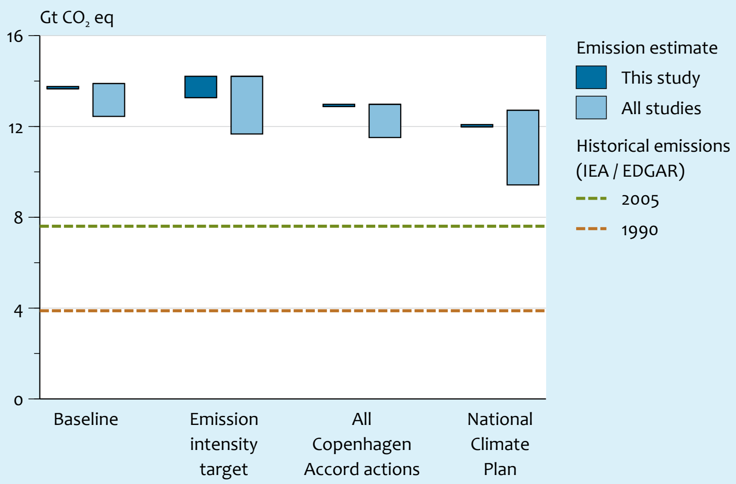
- *Improvement of emission efficiency by 20% from 2005 to 2010 and other energy-related measures;*
- *Development of coal-bed methane industry;*
- *Use of waste for energy;*
- *Maintenance of N_2O emissions from industrial processes at 2005 levels by 2010;*
- *Promotion of low emission rice cultivation;*
- *Promotion of CH_4 reduction from animals.*

Interpretation of reductions from these measures varies widely. The energy-intensity improvement up until 2010 and other energy-related measures can lead to significant reductions (up to 2 Gt CO_2 eq), but according to some studies these measures are already included in the BAU. Also, the formulation of the energy intensity target for 2010 causes additional uncertainty: extrapolation of the target from 2010 to 2020 can be done in different ways (see Appendix B). Our analysis tool, the TIMER model, is developed for long-term analysis and not necessarily reliable for short-term (2020) targets. Many studies have not considered the non-energy related measures, which could add reductions of around 0.3 Gt CO_2 eq. Our study projects that their national plan will result in a decrease in emission level in China from 13 Gt CO_2 eq to 12.1 Gt CO_2 eq. The range in other studies is a reduction from 11.5 to 13.0 Gt CO_2 eq to 9.4 to 12.7 Gt CO_2 eq (see Figure 5.3).

Total emissions after reductions in China, 2020

Figure 5.3

Greenhouse gas emissions, including CO_2 from land use



The total effect of these options could amount to about 2.9 Gt CO_2 eq, as shown in Figure 5.5 and Table 5.3. For the high pledge scenario, this would result in a projected emission level of 45.8 Gt CO_2 eq, which is just within the range of 44 to 46 Gt CO_2 eq compatible with the 2°C target. Of the 45.8 Gt CO_2 eq, 14.8 Gt CO_2 eq is emitted by Annex I countries and 30.5 Gt CO_2 eq by Non-Annex I countries (the remainder being aviation and marine transport emissions). This translates into a reduction effort of about 21% below 1990 levels for Annex I countries as a group and 15% below BAU levels for Non-Annex I countries as a group. According to den Elzen and Höhne (2008), a reduction of 25 to 40% below 1990 levels and 15 to 30% below BAU for Annex I and Non-Annex I as a group, respectively, is compatible with meeting the 2°C target. Non-Annex I countries as a group are just within this range. In order for Annex I countries to meet this range, they would need to decrease emissions by at least a further 0.7 Gt CO_2 eq by 2020. This would result in a global emission level of 45.1 Gt CO_2 eq.

There are other options to bridge the gap to meet the 2°C target but have not been further analysed here. These options include:

- Countries could deliver and exceed their high pledges, particularly those Annex I countries with a relatively low reduction target based on comparability indicators, such as Canada, Ukraine and Russia (see Chapter 2). A higher target for Russia and Ukraine could be coupled to a 'non-tradable strategic reserve', based on the difference between the Copenhagen Accord pledge and a more realistic emission projection including efficiency measures. The reserve can be used for compliance only (den Elzen et al., 2009c).

Box 5.1: continued

India national climate plan

The additional measures in the national climate plan of India include:

- *A target of 50% of additional coal plants consisting of efficient supercritical plants;*
- *Installation of 20 GW PV and solar-thermal generation capacity by 2020;*
- *Increased use of renewable energy with 30 GW;*
- *Increased use of nuclear power with 40 GW;*
- *Additional energy efficiency measures;*
- *Aforestation of degraded land.*

The above measures could reduce emissions by 19% relative to BAU (as compared to 3% for their submitted NAMA). However, this target could be very ambitious and full feasibility could be questioned, because of the necessary rapid technological improvement to achieve the target for efficient coal plants and the fact that 20 GW of solar power in 2020 being comparable to the expected installed solar capacity in Europe.

Interpretation of the reductions from the national plans varies among the studies. Renewable and nuclear energy, as well as the efficiency related measures, can lead to significant emission reductions. Many studies do not consider the forestry related measures, which could contribute to an extra reduction of up to 0.2 Gt CO_2 eq. Including all possible measures could lead to reductions of 0.5 to 0.6 Gt CO_2 eq in 2020 below BAU (see Figure 5.4).

We conclude from this analysis that India's national measures have a higher reduction potential than what is covered in its pledge under the Copenhagen Accord. The actual reduction effect of the pledge is highly uncertain due to its formulation as intensity target, but according to most studies, it does not lead to a reduction below BAU. However, all studies agree that the currently planned and implemented national measures do lead to substantial emission reductions.

Total emissions after reductions in India, 2020 **Figure 5.4**

Greenhouse gas emissions, including CO_2 from land use

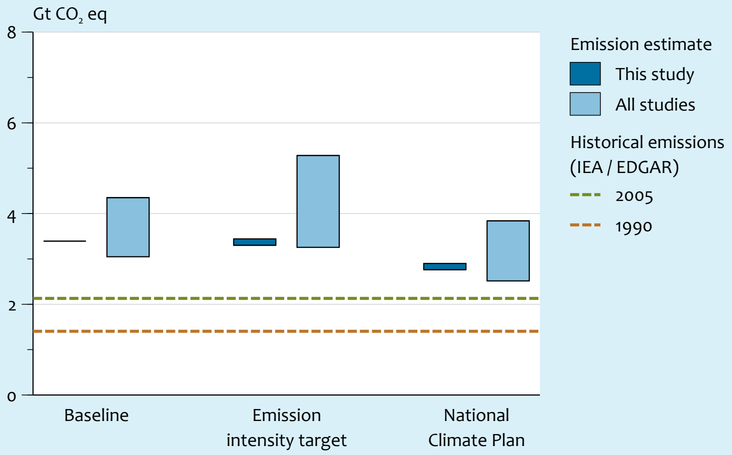


Table 5.4

Comparison of global greenhouse gas emissions in 2020 according to all studies resulting from the low and high pledge scenario and additional measures under the national plans (Gt CO_2 eq)

Global emissions including land use	Low pledge scenario	High pledge scenario	Interpretation national plans
This study	50.1	48.7	47.9
Catalyst project (European Climate Foundation, 2010)	53.5		49
UNEP Climate Pledge Tracker (Stern and Taylor, 2010)	49.2		48.2
*Climate Action Tracker (2010)**	54.8	52.0	48.3
Rogeli et al. (2010)	53.6		47.9
PricewaterhouseCoopers[v] (2010)	50.3	48.3	
Trevor Houser[vv] (2010)	51.5	48.2	

* Including updated estimates for Brazil, China and India, as described in this study.

[v] These estimates do not include the identified potential for double-counting of 1 billion tonnes from offsets http://www.ukmediacentre.pwc.com/Content/Detail.asp?ReleaseID=3571&NewsAreaID=2.

[vv] Peterson Institute for International Economics, http://www.iie.com/publications/pb/pb10-05.

Table 5.5

Range of global greenhouse gas emissions in 2020 according to all studies resulting from the low and high pledge scenario and additional measures under the national plans (Gt CO_2 eq)

Global emissions including land use	Overview all studies
BAU	55.1 – 58.2
Copenhagen accord (low pledge scenario)	49.2 – 54.8
Copenhagen Accord (high pledge scenario)	48.2 – 52.0
Interpretation of national plans, 2020	47.9 – 49.0

* All studies in Table 5.4.

- Countries without targets or intended actions could also reduce their emissions.
- Financial support for mitigation committed through the Copenhagen Accord could result in higher reductions by focusing on cost-effective areas where reductions beyond existing targets may be possible, such as REDD (see option 3). There are also other areas such as non-CO_2 mitigation options.

5.4 Comparison with other model studies

Table 5.4 lists the global greenhouse gas emissions in 2020 resulting from the pledges, according to various studies that have assessed the pledges.[4] Table 5.5 lists the minimum and maximum of the emissions from the different studies for the low and high pledge scenario, as well as the additional measures following the national plans of China and India. For calculating the emission reduction target of China and India, some studies (European Climate Foundation, 2010; Stern and Taylor, 2010) include both the action submitted to the Copenhagen Accord and reductions due to the existing national climate plan of China and India, whereas they are separated in our study and in the Ecofys study (see Table 5.4). Of the other studies (PricewaterhouseCoopers and Trevor Houser), it is unclear whether the reduction target estimates for India and China include the impact of national policies (we have assumed this not to be the case in our calculations).

The range from the various studies reflects different interpretations of the pledges. These include assumptions with regard to BAU emissions, deforestation emissions, new surplus emissions, the role of land use change, the inclusion of the national plans of China and India (as part of the high pledge scenario), the use of offsets included in other country targets, and inclusion of peat land emissions outside Indonesia. Moreover, each estimate has an uncertainty range of at least ± 2 Gt CO_2 eq/yr because of uncertainty in base year and BAU emissions, future energy intensity and other reference points for emission reductions (UNEP, 2010).

The Catalyst study has assumed in their low pledge scenario less ambitious pledges for the USA and Japan, and this explains the higher emission estimate compared to the other studies. The UNEP Climate Pledge Tracker has the lowest emissions, which are due to their lower emissions for China, lower deforestation emissions outside Brazil and Indonesia and their lower emissions for the other Non-Annex I countries.
For the high pledge scenario, excluding the impact of the national plans of China and India, most studies are on the lower end of the range, except for the Climate Action Tracker with a higher estimate.

Finally, all studies agree for the high pledge scenario, including the impact of national plans for China and India, on a relatively narrow range for global emissions by 2020 of 47.9 and 49 Gt CO_2 eq/yr (Table 5.5). This implies that the studies give comparable estimates of the effect of the pledges on global greenhouse gas emissions.

4 The Climate Action Tracker (Rogelj et al., 2010) and the Climate Interactive Scorecard (http://climateinteractive.org/scoreboard), which are not included in Table 5.4 and Table 5.5, assess targets and intended actions for 2020 and beyond. However, as few countries have made commitments beyond 2020, these analyses inevitably conclude that a likely outcome is the 2°C goal would be missed and that temperature would rise by 3.5°C or more (Stern and Taylor, 2010).

6 Robustness of results

Key findings

- A scenario assuming a lower reduction target for the USA with the indirect effect of lowering the reduction targets of all other countries would lower Annex I and Non-Annex I reduction targets considerably. This would also lead to very low total abatement costs.
- A high reduction target scenario assuming an optimistic interpretation of the national plans of China and India and high end proposals for all Annex I countries leads to higher Non-Annex I reductions and total global abatement costs of USD 110 billion in 2020.
- Different options for banking and using Kyoto and new surplus AAUs also influence Annex I emission reduction targets. The assumptions on the pledges greatly affect Annex I costs, which range from 0.16 to 0.22% of global GDP in 2020, and Annex I reduction levels, which range from 9 to 19% below 1990 levels.

An analysis is presented of the sensitivity of the results on the following key assumptions in the FAIR model: banking surplus AAUs; emissions trading; baseline; reduction pledges; land use and forestry rules; inertia of non-CO_2 abatement; and baseline development. The effects on emissions of some of these uncertainties have been discussed in the previous chapters. In this chapter, the effect on total abatement costs is analysed.

Impact of banking of surplus AAUs
The two extreme assumptions for banking surplus AAUs are: 1) full banking and trading; and 2) no banking and trading of surplus AAUs (Kyoto and new surplus AAUs). The effects of these two extremes on Annex I emission reduction targets and the carbon price are presented in Figure 6.1. In the full banking case, the reduction target decreases to 9% below 1990 levels compared to 18% for the default case. No banking slightly increases the reduction target to 19% below 1990 levels (see den Elzen et al., 2009c). The carbon price is close to zero for the full banking case (due to the very high supply of carbon credits) and USD 24 with no banking of surplus AAUs.

More detailed results of the effect of total abatement costs are presented in Table 6.1. As expected, the full banking scenario leads to lower costs for Annex I countries, excluding Russia and Ukraine. Full banking and trading of surplus AAUs has a negative effect on Russia and Ukraine because of the very low carbon price. The effect of no banking leads to only a minor change for Russia and Ukraine, since they still receive money for JI projects at a higher carbon price.

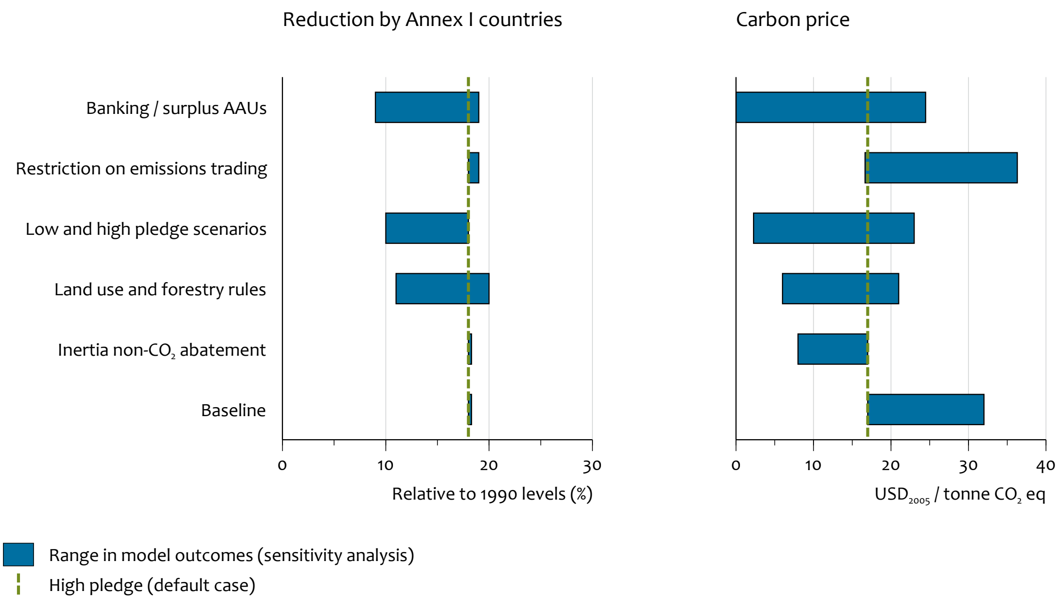
Impact of emissions trading
In the default calculations, we assume that two-thirds of Annex I emission reduction targets and all of Non-Annex I reduction targets needed to be achieved domestically. These results were compared with a scenario without emissions trading (entirely domestic emission reduction).

The effects of assuming a full global emissions trading scheme by 2020 are shown in Figure 6.1 and Table 6.1. Full emissions trading lowers domestic emission reductions by Annex I countries, increases their demand for emissions trading and CDM, and thus doubles the carbon price on the international market. As expected, this increase in flexibility decreases global abatement costs. The costs to the Non-Annex I countries as a group, and to Russia and Ukraine, decrease as well (or the revenues increase) because these regions will sell more carbon permits at a higher price. The higher international carbon price increase the costs of Annex I countries (excluding Russia and Ukraine) compared to our default costs.

Impact of a low and high reduction target scenario
In Chapter 5, the effect on global emission reductions was analysed on an assumption of lower emission reductions in the USA triggering lower reduction targets of all other countries. This scenario is a return to 2005 levels by 2020 for the USA, a 15% reduction target below 2005 levels for Japan, and mitigation actions of all other countries move towards the low abatement end. This scenario lowers reduction targets and abatement costs of Annex I countries considerably and leads to very low total abatement costs. The

Impact of main uncertainties on reduction greenhouse gas emissions and carbon price, 2020

Figure 6.1



Robustness of results for the high pledge scenario, 2020

Table 6.1

	Emission reductions		Carbon price	Total costs (including international financial transfers for financing abatement costs of emerging economies)				
	Annex I	Non-Annex I	Global	Global	Annex I excluding Russia & Ukraine	Russia and Ukraine	Emerging economies	Rest of Non-Annex I
Scenario	Relative to 1990 levels (%)	Relative to BAU levels (%)	USD /t CO_2			*Billion USD (costs as percentage of GDP)*		
Default (high pledge)	18	10	17	100 (0.15)	85 (0.20)	−7 (−0.40)	27 (0.17)	−4 (−0.06)
a. Full banking/trading surplus AAUs	9	10	0	96 (0.14)	67 (0.16)	0.7 (0.04)	27 (0.17)	0.01 (0.00)
b. No banking/trading surplus AAUs	19	10	24	98 (0.15)	92 (0.22)	−7 (−0.40)	20 (0.13)	−7 (−0.10)
Full emissions trading	19	10	36	76 (0.11)	96 (0.23)	−20 (−1.16)	12 (0.08)	−13 (−0.08)
a. Low reduction target (see risk #1 for broadening)	10	7	2	27 (0.04)	11 (0.03)	0 (0.00)	17 (0.11)	0.2 (0.00)
b. High reduction target: national plan China and India	18	14	23	110 (0.16)	91 (0.22)	−15 (−0.86)	41 (0.25)	−6 (−0.09)
a. No emission allowance increases of from land use and forestry rules	20	10	21	107 (0.16)	100 (0.24)	−10 (−0.56)	22 (0.14)	−6 (−0.08)
b. High estimate emission allowance increases of from land use and forestry rules	11	10	6	77 (0.12)	58 (0.13)	−2 (−0.10)	27 (0.17)	−1 (−0.02)
No inertia non-CO_2	18	10	8	80 (0.12)	65 (0.15)	−3 (−0.16)	19 (0.12)	−2 (−0.03)
Baseline without crisis	18	10	32	125 (0.17)	140 (0.33)	−21 (−1.09)	18 (0.11)	−14 (−0.20)

effects on the international carbon price and total abatement costs are presented in Figure 6.1 and Table 6.1.

For the high reduction target scenario, we assume high end proposals for all countries, and inclusion of the national climate plans of China and India[1].

The Non-Annex I reduction target increases from 10 to 14% with the carbon price increasing from 17 to 23 USD per t CO_2. The higher carbon price also results in higher costs for Annex I countries and the emerging economies as a whole, while Russia, Ukraine and the rest of Non-Annex I countries benefit from the higher carbon price.

1 Our reduction estimate for the national plan of China of 9% is somewhat lower than in other studies: Ecofys (Höhne et al., 2009a), more than 20%; Catalyst project (European Climate Foundation, 2010), 12%; Stern (2009), 10%; World Energy Outlook 2009 (IEA, 2009), 12%; Chinese Energy Research Institute (ERI, 2009), 15%).

Impact of land use and forestry rules

In the default calculations, we assume that emission allowance increases from land use and forestry rules amount to 2.5% of 1990 Annex I emissions, which is 450 Mt CO_2 (see Chapter 2, 4 and 5). If these emission allowance increases are excluded, total abatement costs of the Annex I countries as a whole would increase by almost USD 7 billion (Table 6.1). If the total emission allowance increases would be 9% of Annex I 1990 emissions (see Risk 5 for widening the gap in Chapter 5), total costs for Annex I countries would decrease by USD 23 billion and the Annex I reduction level would be reduced from 18 to 11% below 1990 levels.

Impact of inertia of non-CO_2 abatement measures

The improved model used in this study accounts for the inertia of reducing non-CO_2 emissions (see Appendix E) and leads to slightly higher costs. This can be seen when the costs are calculated without non-CO_2 abatement inertia. This decreases the costs by about 20%.

Impact of economic crisis

In the default calculations, we assumed a baseline which includes the impact of the economic crisis. Excluding this impact would not only slightly lower the total emission reduction target for Annex I countries due to less surplus AAUs (see Figure 6.1), but more importantly, would also increase the carbon price by 80%, to USD 32/t CO_2.

7 Main conclusions

As part of the Copenhagen Accord, Annex I Parties (industrialised countries) and Non-Annex I Parties (developing countries) have submitted reduction proposals (pledges) and mitigation actions to the UNFCCC secretariat. This study has analysed the implications of all reduction pledges submitted by Annex I Parties and the mitigation actions of the seven major Non-Annex I Parties on total emissions and abatement costs. The key findings are:

- The pledges of Annex I countries and the seven major Non-Annex I countries would lead to a global emission level in 2020 of 48.7 to 50.1 Gt CO_2 eq if new surplus AAUs are forfeited (not used). Various studies suggest an emission level of 44 to 46 Gt CO_2 eq in 2020 is in accordance with a 2°C target with a 50% probability. There is a gap of about 2.7 to 6.1 Gt CO_2 eq.
- The high pledges of Annex I countries are estimated to lead to a total reduction target that is 18% below 1990 levels. This is well below the range of 25 to 40% below 1990 levels indicated by IPCC as potentially consistent with the 2°C target. According to various comparability indicators, the pledges especially of Russia, Ukraine and Canada seem to be less ambitious.
- The high end of the Copenhagen Accord submissions of the seven largest emitting Non-Annex I countries are estimated to reduce emissions by approximately 11 to 14% below BAU in 2020. If all other Non-Annex I countries do not reduce emissions, the Non-Annex I countries would be about 7 to 10% below BAU. Most studies indicate that meeting the 2°C target would correspond to a 15 to 30% reduction below BAU in Non-Annex I countries. The submissions especially of China and India seem relatively less ambitious than their currently implemented and planned national policies.
- The average abatement costs of Annex I countries, excluding Ukraine and Russia, are about 0.2% of GDP in 2020 for the high reduction pledges. This assumes that at least two-thirds of the target is achieved through domestic emission reductions and abatement costs of emerging economies are partly financed internationally. The abatement costs for the seven major Non-Annex I economies are of a similar order of magnitude. This assumes again that 50% of the abatement costs of Brazil, Indonesia, Mexico and South Africa are financed by Annex I countries.
- There are large differences in total costs between countries. Ukraine and Russia may still make significant profits from selling *new* surplus AAUs and the costs as share of GDP are very low for China and India. For the high pledges of Korea, Indonesia, Brazil and Mexico, costs are expected to be relatively high, even with substantial financial support.
- A set of options could lead to an additional 2.9 Gt CO_2 eq emission reduction that is likely to narrow the 2020 emissions gap to the 2°C target. The options relate to additional deforestation measures, not allowing credits from land use and forestry rules, mitigating bunker fuel emissions, and enhancing mitigation action for China and India according to their national climate policies (not part of their submission to the Copenhagen Accord).
- There are also a number risks that the high end pledges could be watered down. These include: countries may decide to lower their pledges; lenient land use and forestry rules may decrease the ambition level by 1.2 Gt CO_2 eq; double counting of offsets may decrease the ambition level by 1.3 Gt CO_2 eq; lower reductions from NAMAs because of inadequate international financial support may decrease the ambition level by 0.8 Gt CO_2 eq; use of new AAUs could decrease the ambition level by 0.7 Gt CO_2 eq, and use of Kyoto surplus AAUs may decrease the ambition level by 1.5 Gt CO_2 eq. Uncertainty in baseline estimates may decrease the ambition level by 1.5 Gt CO_2 eq. The total impact of these risks could be that almost no emission reductions are achieved.

Appendix A Reduction pledges of Annex I countries as part of the Copenhagen Accord

The low and high pledge commitments by individual Annex I countries, for the year 2020. Source: UNFCCC (http://unfccc.int/home/items/5264.php) **Table A.1**

Party	Pledges for 2020		Reference year	Inclusion of land use CO_2	Inclusion of mechanisms
	Low	High			
Australia [a]	–5%	–15% to –25%	**2000**	Yes	Yes
Belarus	–5%	–10%	1990	TBD	Yes
Canada [b]	–17%	–17%	**2005**	TBD	TBD
Croatia	–5%	–5%	1990		
European Community (EU-27) [c]	–20%	–30%	1990	No for 20% Yes for –30%	Yes
Iceland	–30%	–30%	1990	Yes	TBD
Japan [d]	–25%	–25%	1990	Yes	Yes
New Zealand [e]	–10%	–20%	1990	Yes	Yes
Norway [f]	–30%	–40%	1990	Yes	TBD
Russia [g]	–15%	–25%	1990	TBD	TBD
Switzerland [h]	–20%	–30%	1990	Yes	Yes
Ukraine [i]	–20%	–20%	1990	TBD	Yes
United States [j]	–17%	–17%	2005	Yes	Yes

Pledges differ in scope and conditionality. The following conditions apply (http://unfccc.int/home/items/5264.php):
[a] Australia will unconditionally reduce their emissions by 5% below 2000 levels, and by up to 15% by 2020 if there is a global agreement which falls short of securing atmospheric stabilization at 450 ppm CO2 eq. Australia will reduce by 25% below 200 levels if the world agrees to an ambitious global deal capable of stabilizing greenhouse gas concentrations at 450 ppm CO2 eq and under which major developing economies commit to substantially restrain emissions and advanced economies take on commitments comparable to Australia's.
[b] to be aligned with the final economy-wide emissions target of the United States in enacted legislation.
[c] As part of a global and comprehensive agreement for the period beyond 2012, the EU reiterates its conditional pledge to move to a 30% reduction by 2020 compared to 1990 levels, provided that other developed countries commit themselves to comparable emission reductions and that developing countries contribute adequately according to their responsibilities and respective capabilities.
[d] 25% reduction target, which is premised on the establishment of a fair and effective international framework in which all major economies participate and on agreement by those economies on ambitious targets.
[e] New Zealand is prepared to take on a responsibility target for greenhouse gas emissions reductions of between 10% and 20% below 1990 levels by 2020, if there is a comprehensive global agreement. This means the global agreement sets the world on a pathway to limit temperature rise to not more than 2°C; developed countries make comparable efforts to those of New Zealand; advanced and major emitting developing countries take action fully commensurate with their respective capabilities; there is an effective set of rules for land use, land use change and forestry; and there is full recourse to a broad and efficient international carbon market.
[f] As part of a global and comprehensive agreement for the period beyond 2012 where major emitting Parties agree on emissions reductions in line with the 2 degrees Celsius target, Norway will move to a level of 40% reduction target for 2020. The land use sector is included according to the existing rules under the Kyoto Protocol. If the rules change, Norway's national target will change accordingly.
[g] the range of the greenhouse gas emission reductions will depend on the following conditions: Appropriate accounting of the potential of Russia's forestry in frame of contribution in meeting the obligations of the anthropogenic emissions reduction; Undertaking by all major emitters the legally binding obligations to reduce anthropogenic greenhouse gas emissions.
[h] As part of a global and comprehensive agreement for the period beyond 2012, Switzerland reiterates its conditional pledge to move to a 30% reduction by 2020 compared to the 1990 levels, provided that other developed countries commit themselves

to comparable emission reductions and that developing countries contribute adequately according to their responsibilities and respective capabilities.
[i] Ukraine associates with Copenhagen Accord under the following conditions: To have the agreed position of the developed countries on quantified emissions reduction targets of the Annex I countries; To keep the status of Ukraine as a country with economy in transition and relevant preferences arising from such status; To keep the existing flexible mechanisms of the Kyoto Protocol; To keep 1990 as the single base year for calculating Parties commitments; To use provisions of Article 3.13 of the Kyoto Protocol for calculation of the quantified emissions reduction of the Annex I countries of the Kyoto Protocol for the relevant commitment period.
[j] the range of 17%, in conformity with anticipated U.S. energy and climate legislation, recognizing that the final target will be reported to the Secretariat in light of enacted legislation. The pathway set forth in pending legislation would entail a 30% reduction in 2025 and a 42% reduction in 2030, in line with the goal to reduce emissions 83% by 2050

Appendix B Detailed analysis of mitigation action plans of China, India and Brazil

China

Various studies were analysed in order to estimate the emission reductions under the targets submitted to the Copenhagen Accord. The studies provide different levels of detail:

- Almost all studies provide BAU emissions including our study; World Energy Outlook 2009 (IEA, 2009); Catalyst project (European Climate Foundation, 2010); the Chinese Energy Research Institute (ERI, 2009); Ecofys (Moltmann et al., 2009) and Stern (2009)).
- Several studies provide all information needed to estimate emissions after implementation of a certain measure (such as reduction of emission intensity by 40% to 45% by 2020). These include our study; World Energy Outlook 2009 (IEA, 2009); Catalyst project (European Climate Foundation, 2010); the Chinese Energy Research Institute (ERI, 2009).
- Some studies only provide energy CO_2 emissions (World Energy Outlook 2009 (IEA, 2009), ERI (2009) and were completed by non-energy emission values from USEPA (2006) and reduction potential from other studies to be comparable.
- Only a few studies provide estimates of all measures currently implemented in China. Stern (2009) and Moltmann et al. (2009) provide emissions after implementation of all measures in the national climate change strategy. Höhne et al. (2009a) only provide reductions for some measures but no complete BAU scenario. Results from Höhne et al. (2009a) and Moltmann et al. (2009) have been used to complete other studies where a single quantifiable measure was not covered by the results from other sources (see Table B.1).

Official emission scenarios from China are not available and thus there is considerable room for interpretation. Several major issues arise in the comparison of studies:

- Biomass (mostly fire wood) can be either included or excluded in the non-fossil fuel target. Current statistical practice in China is to exclude biomass, but WEO for instance includes biomass as a renewable source. In estimating this target using the WEO data, we did not include the past share of renewables towards meeting the target.
- The Chinese Bureau of Statistics accounts for non-fossil energy use in primary energy with the average conversion efficiency of coal-fired power plants in China[1]. The National

1 See Table 6-1 in the 2008 statistical yearbook at http://www.stats.gov.cn/tjsj/ndsj/2008/indexeh.htm

Emission mitigation potential of single measures in the category "Other" of Table B.2 for China in 2020 Table B.1

China		Ecofys (Höhne et al., 2009)		Ecofys (Moltmann et al., 2009)
Area/sector	Policy as described in national plan	Low estimate	High estimate	
Energy	Develop coalbed methane (CBM) industry; increase gas production by 10 billion m³ in 2010 and by 40 billion m³ in 2020	60	106	
	Waste-use	0	17	
Industry	By 2010, N_2O emissions from industrial processes will remain at 2005 levels			156
Agriculture	Promote adoption of low-emission and high-yield rice varieties, rice cultivation technique of semi-drought, and scientific irrigation technology; Strengthen R&D on ruminant animal breeds and large-scale breeding and management techniques; reinforce the management of animal wastes, wastewater and solid waste, and promote biogas use to control the growth rate of methane			45

BAU emissions, mitigation potential of pledge and national plans, emissions after pledge and national plan (in Mt CO_2 eq) according to all sources considered for China in 2020 **Table B.2**

	This study	WEO/OECD (2009)	Catalyst	Ecofys (Höhne et al., 2009)	Ecofys (Moltmann et al., 2009)	TERI	Stern
BAU	13 761	12 469	13 889		13 077	12 807	12 444
Emission intensity reduction target	–449 - +490	0 - 799				–809 - +107	
Increased hare of non-fossil energy	143 - 633	0 - 386	1 050		1 452	733 - 840	
Increased forest coverage	150	111 - 150	150	13 789	111	111 - 150	
Total pledge	783	497 - 949				951 - 990	
Reduced energy consumption per unit GDP	0 - 569	0 - 125	530			776 - 957	
Other (see Table B.1)	261 - 325	261 - 325		290 - 1 460	2 089	261 - 325	
Total pledge and national plan	1 044 - 1 677	883 - 1 273	1 730	315 - 1 576	3 652	1 988 - 2 272	1 244
Emissions after pledge	12 978	11 520 - 11 972				11 817 - 11 856	
Emissions after pledge and national plan	12 084 - 12 716	11 195 - 11 586	12 159		9 425	10 535 - 10 819	11 200

Climate Change Program states that primary energy supply contained 7.5% non-fossil energy in 2005. This figure can only be reproduced from historic data by assuming 33% conversion efficiency to account for non-fossil sources in primary energy. This differs from the IEA approach, which uses a 33% efficiency factor for nuclear energy in primary energy and direct equivalent electricity output for hydro, wind and other renewable sources.

The original text does not indicate how China's Copenhagen pledge should be evaluated. We believe, and Chinese experts have confirmed our view, that the Chinese method of accounting should be applied. This is relevant because the emission reduction of this measure is defined by the gap between the share of non-fossil energy in the baseline scenario and the 15% target. The impact of the non-fossil pledge is much larger when the IEA accounting method is used than when the Chinese accounting method is used.

- WEO and ERI provide BAU scenarios for China but no explicit analysis of the impact of China's proposal for the Copenhagen Accord. To get a first order estimate for these studies, we made some calculations on the pledges under the Copenhagen agreement and the following actions submitted by China:

1. –40% and –45% intensity target;
2. non-fossil target, assuming an equal decrease for all fossil sources;
3. 20% intensity reduction target in terms of energy per GDP from 2005 to 2010. The intensity reduction can be implemented in different ways which influence emissions differently. The low case assumes that energy is reduced equally over all energy sources, while the high case assumes that only fossil sources are reduced. We extended the effect of the target to 2020 by assuming that the BAU energy efficiency measures are implemented a few years earlier to meet the target by 2010.

We have assumed that all three targets are achieved with the same technical measures. The final impact of these three targets is determined by the one with the highest mitigation potential.

There could be substantial overlap of targets and measures as the reduction plans do not give detailed information about the measures included. There is a possible overlap between the 40% to 45% intensity reduction target (1 above) and the 15% non-fossil energy target (2 above). According to our methodology, we considered the intensity target first and then added additional emission reduction potential from the non-fossil target, where likely. As the non-fossil target normally leads to a higher reduction potential, the additional benefit from this target is simply the difference between the two. This simplified method implies that all reductions under the intensity reduction target are covered by the non-fossil target, which means we assume a 100% overlap of these two targets.

If the overlap is less, the intensity target would include measures not covered by the non-fossil target. Adding the effect of both targets would then lead to a higher emission reduction potential. As the magnitude is not very clear, we have assumed in this report no additional benefit from the intensity target in combination with the non-fossil target. Also, there is an important overlap of the earlier energy intensity reduction target of 20% from 2005 to 2010 (3) with the emission intensity reduction target between –40% and –45% from 2005 to 2020 (1). The studies that considered the first and then extended it to 2020 find no additional reductions from the second.

The results in China under all studies considered are given in Table B.2 and Figure B.1. Most studies give two cases, one for a 40% and the other for a 45% emission reduction in per GDP. Thus, the main differentiator is the assumption on the intensity target. However, variations on other assumptions can add smaller differences to the emission reduction potential of these two cases.

Generally, this study provides the highest emission estimates. Stern (2009) and the WEO (2009) provide comparatively low BAU scenarios, most likely because they include reduction measures first. The lowest estimates in 2020 (highest reduction potential) are provided by Ecofys Moltmann et al. (2009).

Total emissions after reductions in China by 2020, according to various studies **Figure B.1**

Greenhouse gas emissions, including CO_2 from land use

India

Different sources provide different levels of detail:

- Nearly all studies provide BAU emissions (our study; World Energy Outlook 2009 (IEA, 2009); Catalyst project (European Climate Foundation, 2010); TERI (Climate Modelling Forum, 2009); Ecofys (Moltmann et al., 2009) and Stern (2009).
- Several studies provide all information needed to estimate emissions after implementation of a certain measure (such as reduction of emission intensity by 20% to 25% by 2020). These include our study; World Energy Outlook 2009 (IEA, 2009); Catalyst project (European Climate Foundation, 2010) and Moltmann et al. (2009),
- Some studies only provide CO_2 emissions and were completed from other sources. World Energy Outlook 2009 (IEA, 2009) provides only energy CO_2. The Energy and Resource Institute (TERI), in the Climate Modelling Forum (2009) includes CO_2 from energy and industry. In order to be comparable, non-energy or non-CO_2 emission values from USEPA (2006) were added to the above CO_2 only projections.
- Stern (2009) and Moltmann et al. (2009) give estimates on BAU data and emissions after implementation of all measures from the national climate change strategy.
- TERI, again in Climate Modelling Forum (2009), provides different assumptions on India's BAU. We applied the minimum and the maximum of the scenarios and added assumptions on emission reductions due to the pledged intensity target.
- Results from Höhne et al. (2009a) and Moltmann et al. (2009) have been used to complete other studies where a single quantifiable measure was not covered by the results from other sources.

BAU emissions, mitigation potential of pledge and national plans, emissions after pledge and national plan (in Mt CO_2 eq) according to all sources considered for India in 2020 **Table B.3**

	National data	This study	WEO/OECD (2009)	Catalyst	Ecofys (Höhne et al., 2009)	Ecofys (Moltmann et al., 2009)	TERI	Stern
BAU		3 394	3 048	3 333		4 352	3084 - 4 084	3 871
Emission intensity reduction target (total pledge)		−47 - +92	−365 - −207	0		0	−2 197 - +368	
Mission on Enhanced Energy Efficiency	1 000	0			32 - 215	70		
Supercritical coal plants		40		100				
Solar mission plans	42	40		63	0 - 25			
Increased capacity from renewables by 2012, including hydropower					0 - 350	262		
Increased capacity from renewables by 2020, excluding hydropower		60		0 - 100	0	0		
Nuclear plants		175		0 - 240	0 - 61			
Increased area of forest plantations		55 - 191		55 - 191	55 - 191	58		
Reduced transmission and distribution losses and other measures		124		124		124		
Total pledge and national plan		494 - 630		342 - 818	87 - 846	514		271
Emissions after pledge		3 302 - 3 441	3 048	0		4 352	3 084 - 3 715	
Emissions after pledge and national plan		2 764 - 2 900		2 516 - 2 991		3 838		3 600

The lack of official scenarios providing emission intensity per GDP and official assumptions on future emission and GDP growth introduce the largest uncertainty about the impact of India's targets. Furthermore, some of the additional measures provided in India's national climate strategy could overlap with the intensity target or with each other. This can be interpreted in various ways.

Our key assumptions are as follows:

- WEO and TERI provide BAU scenarios for India but no explicit analysis of the impact of the intensity target proposed by India in the Copenhagen Accord. To obtain a rough estimate, simple calculations were made based on the 2005 emissions and the GDP growth assumed by both sources.
- India stated in its current five-year plan that 30GW capacity would be added from renewables by 2012, including from large hydropower plants. The Indian Government also expects to add another 30GW of renewables, excluding large hydropower plants, by 2020. There are also additional assumptions on increasing use of single renewable technologies. In our study, we have assumed that the sum of the single sources add up to the overall objective.

Detailed results for India under all studies considered are presented in Table B.3. Most studies give two cases, one for the 20% and the other for the 25% reduction in emissions per GDP. This means the main differentiator is the assumption on the intensity target. However, variations on other assumptions can also add smaller differences in emission reduction potential of these two cases.

Generally, Moltmann et al. (2009) provides the highest emission estimates. WEO (2009) provides a comparatively low BAU scenario. Catalyst (2009) combined single measures from Höhne et al. (2009) and Moltmann et al. (2009) which resulted in the lowest emissions in 2020.

Total emissions after reductions in India by 2020, according to various studies — **Figure B.2**

Greenhouse gas emissions, including CO_2 from land use

Brazil

Various sources providing different levels of detail were considered:

- Almost all studies provide BAU emissions. These include our study; World Energy Outlook 2009 (IEA, 2009); Catalyst project (European Climate Foundation, 2010); Ecofys (Moltmann et al., 2009); and Stern (2009).
- Most studies can be used to estimate emissions after implementation of a certain measure from the national BAU (our study; Catalyst project (European Climate Foundation, 2010) and Moltmann et al. (2009).
- Moltmann et al. (2009) provide estimates on BAU data and emissions after implementation of all measures from the national climate change strategy. Höhne et al. (2009a) only provide reductions for some individual measures but no complete BAU scenario. Results from Höhne et al. (2009a) and Moltmann et al. (2009) were used to complete other studies if a single quantifiable measure was not covered by the results from other studies.
- Some studies do not include land use emissions such as this study and World Energy Outlook 2009 (IEA, 2009), Here, we added Brazil's own estimates.

Brazil provides very concrete estimates on proposed reduction targets. Nevertheless, the range among studies is comparatively broad. Some aspects should be considered:

- For Brazil, the assumptions on emissions from land use are essential because they make up for about one-third to half of the countries emissions. Brazil itself assumes very high emissions from this sector of more than 1 Gt CO_2.
- Land use provides the highest but also the most uncertain reduction potential in Brazil.
- It is unclear how far non-CO_2 emissions are already covered in Brazil's official estimates.

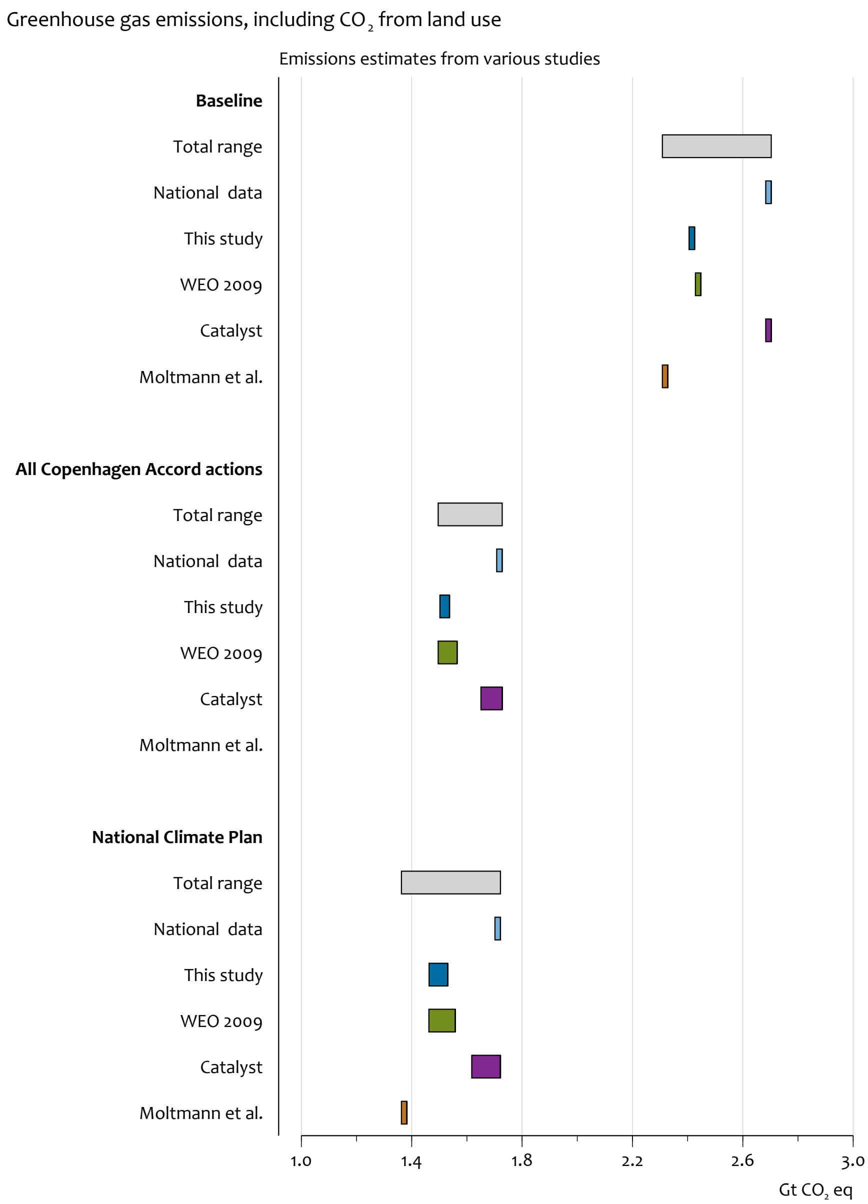
BAU emissions, mitigation potential of pledge and national plans, emissions after pledge and national plan (in Mt CO_2 eq) according to all sources considered for Brazil in 2020 **Tabel B.4**

Policy or pledge	National data	This study	WEO/OECD (2009)	Catalyst	Ecofys (Höhne et al., 2009)	Ecofys (Moltmann et al., 2009)
BAU	2 703	2 425	2 448	2 703		2 308
Reduced GHG of 36-39% below BAU	975 - 1 052		884 - 952	975 - 1 052		
Of which:						
Reduced deforestation Amazon and Cerrado	669	669		669	358 - 477	850
Improved agriculture techniques	141- 176	141 - 176		141 - 176		
Increased use of biofuels	48 - 60	7		48 - 60	46 - 67	13
New hydropower capacity	79 - 99	50		79 - 99		
New renewables capacity	26 - 33	7		26 - 33		
Increased energy efficiency	12 - 15	14		42 339		
Total pledge	975 - 1 052	888 - 923	884 - 952	975 - 1 052		
Electricity from cogeneration running		1				
New thermoelectric plants	-39	-29				
Increased waste recycling		6 - 34	6 - 34			83
Total pledge and national plan		889 - 929	890 - 986	975 - 1 052	420 - 982	946
Emissions after pledge		1 502 - 1 537	1 496 - 1 564	1 651 - 1 728		
Emissions after pledge and national plan	1 722	1 497 - 1 536	1 462 - 1 558	1 651 - 1 728		1 363

Detailed results for Brazil under all sources considered are presented in Table B.4 and Figure B.3. Most studies include two cases, one for the 36% and the other for the 39% reduction in total emissions below BAU. The 36% case includes all less ambitious assumptions, while the 39% case includes the more ambitious assumptions. However, this terminology does not mean that all studies explicitly consider these targets because most were calculated before Brazil officially stated its reduction proposal.

Generally, Brazil's national figures provide the highest emission estimates. Moltmann et al. (2009) provide a comparatively low BAU scenario and the lowest emissions in 2020.

Total emissions after reductions in Brazil by 2020, according to various studies **Figure B.3**



Appendix C Baseline emissions including the impact of the economic crisis

Baseline emissions, including the impact of the economic crisis, were calculated using the TIMER energy model (van Vuuren et al., 2007) for the energy- and industry-related CO_2 emissions, and the IMAGE 2.4 Integrated Assessment model (Bouwman et al., 2006) for the land use related greenhouse gas emissions. The scenario used here was based on the IEA World Energy Outlook (IEA, 2007), and updated to take account of the economic crisis of 2008/2009 (den Elzen et al., 2009b). The adjustments for economic growth for 2008, 2009 and 2010 were based on the IMF publications of June 2009. On average, this led to a negative adjustment for the 2009 GDP growth rate for each world region of 3 to 5%, a somewhat smaller impact for 2010, and a return to the original growth path after this period. The economic crisis resulted in a decrease in baseline greenhouse gas emissions without climate policy of about 10% by 2010, and 8% by 2020, compared to the baseline emissions without the crisis.

A key change compared to the baseline published earlier (den Elzen et al., 2009b) is the model function for cement process emissions. These emissions are now based on an intensity-of-use curve for cement demand, and historic emissions have been updated up to 2007. These adjustments lead to an upward revision of cement process emissions of 55% and 80% in 2020, respectively for the world and China, compared to the earlier baseline. Table C.1 shows the population, GDP per capita and emissions data for the new baseline.

Population, GDP per capita and anthropogenic greenhouse gas emissions for the Annex I countries, for 1990, 2000 and 2020, for the baseline including the economic crisis — **Table C.1**

	Population (in million inhabitants)			GDP (in PPP) (USD 1000 per capita)			Greenhouse gas emissions, excluding land use CO_2 and bunkers (Gt CO_2 eq)		
	1990	2000	2020	1990	2000	2020	1990	2000	2020
Annex I regions	1 167	1 211	1 254	21.0	25.1	35.1	18.9	17.7	18.7
Canada	28	31	35	26.6	31.7	41.4	0.6	0.7	0.8
USA	254	279	337	31.2	38.6	49.3	6.1	7.0	7.6
EU27	508	519	521	28.1	33.1	43.0	4.4	4.3	4.4
Ukraine region	66	65	57	2.3	1.2	4.3	1.1	0.5	0.5
Russian Federation	164	165	149	5.3	3.5	10.5	3.5	2.2	2.2
Japan	124	127	125	30.7	34.4	42.3	1.2	1.3	1.3
Oceania	22	25	30	26.6	33.4	44.0	0.5	0.6	0.8
Non-Annex I regions	4 135	4 918	6 356	1.2	1.7	3.6	13.3	16.7	32.0
China region	1 184	1 325	1 486	0.6	1.4	6.2	3.9	5.0	13.8
India	857	1 016	1 311	0.4	0.6	1.4	1.4	1.9	3.4
World	5 302	6 128	7 611	5.6	6.3	8.8	32.2	34.5	50.6

Appendix D Model descriptions

FAIR 2.3

The integrated modelling framework FAIR (den Elzen et al., 2008; den Elzen and van Vuuren, 2007) was used for the quantitative analysis of emission reduction targets and abatement costs at the level of 26 regions. Abatement costs (in 2005 US dollars) were calculated on the assumption of full use of flexible Kyoto mechanisms such as international emissions trading and CDM. The cost-effective distribution of reductions was calculated for different regions, gases and emission sources.

The model used baseline emissions of greenhouse gas emissions from the IMAGE land use model and TIMER energy model. The aggregated emission credits demand and supply curves were derived from marginal abatement costs curves (MAC) for the different regions, gases and sources (den Elzen et al., 2008). The MAC curves for energy- and industry-related CO_2 emissions were determined with the TIMER energy model (van Vuuren et al., 2007) by imposing a carbon tax and recording the induced reduction in CO_2 emissions. This has been further improved compared to earlier work by including four instead of two tax profiles. This captures a broader range of possible tax paths, representing both early action and highly delayed action paths. The MAC curves for carbon plantations were derived using the IMAGE model (Strengers et al., 2008).

We also included land use CO_2 emissions and marginal costs information from Reducing Emissions from Deforestation and Degradation (REDD), Afforestation, Reforestation and Degradation (ARD) and Forest Management (FM) activities, from three global forestry and land use models. MAC curves from the EMF-21 project (Weyant et al., 2006) were used for non-CO_2 greenhouse gas emissions. These curves were made consistent with the baseline used here and made time-dependent to account for technology change and removal of implementation barriers (Lucas et al., 2007).

The demand and supply curves for emission credits are derived from the regional MAC curves and are used to determine the carbon price in the international trading market, its buyers and sellers, and the resulting domestic and external abatements for each region. The abatement costs for each scenario were calculated based on the MAC curves and the projected reductions. They represent the direct additional costs due to climate policy but do not capture the macroeconomic implications of these costs.

For countries that participated in CDM only, a limited amount of the abatement potential was assumed to be operationally available on the market. This is because of the project basis of the CDM and implementation barriers, such as properly functioning institutions and project size. Consistent with studies of Criqui (2002), Den Elzen and De Moor (2002b) and Jotzo and Michaelowa (2002), this CDM accessibility was set at 20% for 2020, which is twice as high as under the Kyoto commitment period. This meant that only 20% of the total supply would be available for offsetting reductions not achieved by Annex I countries.

The issue of participation in emissions trading is also known to be a crucial element in future climate policy. For the cost calculations, it is assumed that Annex I regions begin or continue with emission reductions in 2012, and all fully participate in emissions trading.

For the Non-Annex I countries, three groups of countries were considered: advanced developing countries; other developing countries; and least developed countries (see Table D.1). The advanced developing countries join the carbon market in 2030 and participate in emissions trading. The other developing countries only participate in CDM and join the carbon market after 2040.

For the late entrants to the carbon market, a transition period is assumed before full exposure to the global carbon price. In fully participating regions (such as the Annex I countries, including the United States), carbon prices are equal. Non-participating or CDM regions have a zero carbon price. For regions in transition from no to full participation, the carbon price grows from zero to the level of the participating regions during the transition period. A linearly growing proportion of the region's mitigation potential is exposed to the global carbon price, and the regional price is that at which the exposed mitigation potential is fully implemented until the global carbon price is reached (Van Vliet et al., 2009) (see Table D.1).

Other main assumptions for the costs calculations are:

- The transaction costs associated with the use of the Kyoto mechanisms are assumed to consist of a constant USD 0.55 per tonne CO_2 eq emissions plus 2% of the total costs.

Assumptions on participation in international emissions trading (IET) and CDM and the fraction of the total reduction potential available for IET or CDM (accessibility factor) **Table D.1**

Advanced developing countries (ADCs)	Mexico, rest of Central America, Brazil, rest of South America, South Africa, Kazakhstan region, Turkey, the Middle East, Korean region and China:	IET (45%)
	Reduce below baseline emissions and can participate in IET	
Other developing countries	Northern Africa, the Middle East, India, rest of South Asia, Indonesian region, Rest Southeast Asia:	IET (30%)
	Reduce below baseline emissions and can participate in CDM	
Least developed countries	Western Africa, Eastern Africa and rest of South African region:	CDM (10%)
	Follow baseline emissions and can participate in CDM	

Effect of model improvements on the international carbon price **Table D.2**

	Original baseline with crisis	Improved baseline with crisis and harmonisation	Improved with halocarbons emissions and MAC	Including inertia of non-CO_2 reduction	Including emissions trading restrictions
Carbon price (in USD/t CO_2)	17	18	19	27	11

- Most Parties propose targets that do not include international bunker fuels, except for the EU[1]. Therefore, the emissions and costs calculations exclude international bunker fuels emission projections and costs of reducing these emissions.

Carbon credits from *forest management* are included, based on a low estimate taken from the estimates in various studies which ranged from 1 to 9% of 1990 Annex I emissions.

Major improvements:
In addition to improvements in the baseline (see Appendix C), the FAIR model version used in this report incorporates the following improvements:

1. Improved baseline with crisis and harmonisation
Projected emission trends are now less sensitive to the harmonisation procedure of modelled data from TIMER with the historic data from UNFCCC/EDGAR/WEO 2008 because of improved correlation between the two datasets. This is mainly due to:

1. Improvement in energy emissions from the TIMER energy model (see TIMER 2.3 Section below);
2. Re-allocation of CO_2 emissions from car manufacturing industry to the energy sector in the historic dataset, in accordance to the TIMER definition;
3. Re-allocation of emissions from inland navigation from the bunkers to the domestic sector in the historic dataset, in accordance to the TIMER definition;
4. Addition of international aviation emissions in the domestic sector in the historic dataset, in accordance with the TIMER definition.

These improvements, together with the improved baseline (see Appendix C), have a relatively small effect on the international carbon price (Table D.1).

1 For the EU, the -20% unilateral target includes emissions from aviation, making the target more stringent. For instance, when emissions from aviation are included, EU emissions reduce by only 6.8% in 2005 compared to 1990. When these emissions are excluded, however, EU emissions decline by 7.9% in 2005 compared to 1990.

2. Update of the halocarbon emissions baseline
Halocarbon emissions were updated from a B2 external scenario to the latest TIMER halocarbons module projections. The MAC curves are now also linked to the TIMER model and are calculated with the same methodology previously described for CO_2 emissions from energy and industry. This update slightly increases the carbon price in 2020 (Table D.1).

3. Including inertia of non-CO_2 emission reductions
In previous versions of the FAIR model, the maximum amount of non-CO_2 reduction did not depend on the reduction level of the last year, but only on the maximum level technically possible (Lucas et al., 2007). Inertia in reducing non-CO_2 was not accounted for. In the current version, a restriction on the pace of reduction based on expert judgement was included for each non-CO_2 emission reduction measure. As expected, including inertia increases the permit price in 2020, because of lower potential for some relatively cheap non-CO_2 abatement options (Table D.1).

4. Restrictions on permit imports: voluntary target for domestic reduction
The Copenhagen Accord contains no quantitative caps on emissions trading (no concrete ceilings on import and export). However, this supplementarity issue has been of importance for Annex I countries in the discussions on meeting their reduction targets. Japan, for instance, seems to aim for 15% domestic reduction of the total 25% reduction target. The EU is imposing concrete ceilings on CDM imports for their Emissions Trading System in order to encourage domestic actions.

The option is included in the model to assess, for example, the impact on the emissions trading market should the EU and Japan voluntarily decide to achieve two-thirds of their own commitments domestically. In the cost model of FAIR, this voluntary target for domestic reduction is represented through a minimum domestic reduction percentage. The demand curves for each of the supplying regions are adapted as discussed in den Elzen and Both (2002) to account for the internal emissions reduction. This restriction on emissions trading increases abatement costs, even though it leads to a lower international permit price because of decreased demand.

TIMER 2.3

The TIMER energy system simulation model describes the long-term dynamics of the production and consumption of about 10 primary energy carriers for 5 end-use sectors in 26 world regions. The model's behaviour is mainly determined by substitution processes of various technologies based on long-term prices and fuel preferences. These two factors drive multinomial logit models that describe investments in new energy production and consumption capacity[2] . The demand for new capacity is limited by the assumption that capital is only replaced at the end of the technical lifetime.

The long-term prices that drive the model are determined by resource depletion and technology development. Resource depletion is important for both fossil fuels and renewables (for which depletion and costs depend on annual production rates). Technology development is determined by learning curves or through exogenous assumptions. Emissions from the energy system are calculated by multiplying energy consumption and production flows with emission factors. A carbon tax can be used to induce a dynamic response such as increased use of low or zero-carbon technologies, energy efficiency improvement and end-of-pipe emission reduction technologies.

2 A multinomial logit model assigns market shares to fuel or technologies based on their relative costs. Low costs options get a large market share, and high costs options a low (or even zero) market share.

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Colophon

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The project was financed by the Dutch Ministry of VROM and the European Commission (DG Climate Action). This report has benefited from the comments and contributions from Marcel Berk, Henriette Bersee, Maas Goote, Gerie Jonk and Hugo von Meijenfeldt (Dutch Ministry of Housing, Physical Planning and Environment), Maurits Blanson Henkemans (Dutch Ministry of Economic Affairs), Bas Clabbers (Dutch Ministry of Agriculture, Nature and Food Quality), Tom van Ierland and Rosella Virdis (European Commission, DG Climate Action), Malte Meinshausen (Potsdam Institute for Climate Impact Research, Germany), Bert Metz (European Climate Foundation), Asger Garnak and Jacob Krog Søbygaard (Ministry of Climate and Energy, Denmark), Alon Carmel (Department for Environment, Food and Rural Affairs, United Kingdom), Svante Bodin and Eva Jernbacker (Ministry of Environment, Sweden), Giacomo Grassi (JRC, Italy), Markus Amann, Hannes Böttcher, Jonah Busch, Michael Obersteiner and Fabian Wagner (IIASA, Austria), Rob Dellink (OECD, France), and Paul Lucas, Leo Meyer, Sido Mylius, Jos Olivier and Martijn Verdonk (PBL).

Evaluation of the Copenhagen Accord: Chances and risks for the 2°C climate goal.
In December 2009, an important United Nations climate change conference (COP15) took place in Copenhagen, Denmark. This conference resulted in the Copenhagen Accord. As part of the Accord, industrialised countries have submitted greenhouse gas emission reduction targets for 2020 and developing countries have submitted actions for reducing emissions. This report presents an overview of: i) the global emission implications of all these submissions; ii) the abatement cost implications; iii) the implications for meeting the 2°C climate goal, specified in the Copenhagen Accord, iv) the main risks that could increase the existing emissions gap towards 2°C, and v) the available options to close the emissions gap towards 2°C.

The country submissions for emission reduction could result in a decrease of the global emission level in 2020 from 56 Gt CO_2 eq to about 49 to 50 Gt CO_2 eq, against limited costs. For meeting the 2°C climate goal, it is estimated that a global emission level of 44 to 46 Gt CO_2 eq is necessary in 2020. Therefore, although the submissions are expected to lead to substantial emission reductions, higher reductions are necessary in order to maintain a reasonable chance of reaching the 2°C climate goal. Several options are identified that could decrease emissions by a further 4 Gt CO_2 eq, which would close the emissions gap completely. However, there are also various reasons why the emission reductions resulting from the country submissions could turn out to be much lower.

Netherlands Environmental Assessment Agency, May 2010