CLIMATE CHANGE

Scientific Assessment and Policy Analysis

WAB 500102 032

Pledges and Actions

A scenario analysis of mitigation costs and carbon market impacts for developed and developing countries

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A scenario analysis of mitigation costs and carbon market impacts for developed and developing countries

Report
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October 2009

Netherlands Environmental Assessment Agency

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This study is part of the Netherlands Research Programme on Scientific Assessment and Policy Analysis for Climate Change (WAB), project Balancing the Carbon Market

Wetenschappelijke Assessment en Beleidsanalyse (WAB) Klimaatverandering

Het programma Wetenschappelijke Assessment en Beleidsanalyse Klimaatverandering in opdracht van het ministerie van VROM heeft tot doel:

- Het bijeenbrengen en evalueren van relevante wetenschappelijke informatie ten behoeve van beleidsontwikkeling en besluitvorming op het terrein van klimaatverandering;
- Het analyseren van voornemens en besluiten in het kader van de internationale klimaatonderhandelingen op hun consequenties.

De analyses en assessments beogen een gebalanceerde beoordeling te geven van de stand van de kennis ten behoeve van de onderbouwing van beleidsmatige keuzes. De activiteiten hebben een looptijd van enkele maanden tot maximaal ca. een jaar, afhankelijk van de complexiteit en de urgentie van de beleidsvraag. Per onderwerp wordt een assessment team samengesteld bestaande uit de beste Nederlandse en zonodig buitenlandse experts. Het gaat om incidenteel en additioneel gefinancierde werkzaamheden, te onderscheiden van de reguliere, structureel gefinancierde activiteiten van de deelnemers van het consortium op het gebied van klimaatonderzoek. Er dient steeds te worden uitgegaan van de actuele stand der wetenschap. Doelgroepen zijn de NMP-departementen, met VROM in een coördinerende rol, maar tevens maatschappelijke groeperingen die een belangrijke rol spelen bij de besluitvorming over en uitvoering van het klimaatbeleid. De verantwoordelijkheid voor de uitvoering berust bij een consortium bestaande uit PBL, KNMI, CCB Wageningen-UR, ECN, Vrije Universiteit/CCVUA, UM/ICIS en UU/Copernicus Instituut. Het PBL is hoofdaannemer en fungeert als voorzitter van de Stuurgroep.

Scientific Assessment and Policy Analysis (WAB) for Climate Change

The Netherlands Programme on Scientific Assessment and Policy Analysis for Climate Change (WAB) has the following objectives:

- The collection and evaluation of relevant scientific information for policy development and decision-making in the field of climate change;
- The analysis of resolutions and decisions in the context of international climate negotiations and their implications.

WAB analyses and assesses the most recent available data with the aim of making a balanced evaluation to support policy choices. These analyses and assessments are conducted during periods ranging from several months to a maximum of one year, depending on the complexity and the urgency of the policy issue. Assessment teams consisting of the best Dutch experts in their fields are appointed to address the various topics. These teams work on activities that are financed on an incidental and supplemental basis, in contrast to the regular, structurally financed activities of the climate research consortium. The work is intended to reflect the scientific state-of-the-art in the relevant topic.

The main commissioning bodies are the National Environmental Policy Plan departments, with the Ministry of Housing, Spatial Planning and the Environment assuming a coordinating role. Work is also commissioned by civic organisations that play an important role in the decision-making process concerned with climate policy and its implementation. A consortium consisting of the following organisations is responsible for the implementation: the Netherlands Environmental Assessment Agency (PBL), the Royal Dutch Meteorological Institute, the Climate Change and Biosphere Research Centre (CCB) of Wageningen University and Research Centre (WUR), the Energy research Centre of the Netherlands (ECN), the Netherlands Research Programme on Climate Change Centre at VU University Amsterdam (CCVUA), the International Centre for Integrative Studies of the University of Maastricht (UM/ICIS) and the Copernicus Institute at Utrecht University (UU). The Netherlands Environmental Assessment Agency (PBL), as the main contracting body, chairs the Steering Committee.

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Preface

This report was commissioned by the Netherlands Programme on Scientific Assessment and Policy Analysis for Climate Change (WAB). It was written by the Netherlands Environmental Assessment Agency (PBL) and the Energy Research Centre of the Netherlands (ECN), as a deliverable of the WAB project “Balancing the carbon market”. The members of the steering committee for this project are Gerie Jonk and Marcel Berk (Ministry of Environment), Joelle Rekers (Ministry of Economic affairs), Maurits Blanson Henkemans (Ministry of Economic Affairs), Bas Clabbers (Ministry of Agriculture) and Remco van de Molen (Ministry of Finance).

Finally we would also like to thank our colleagues at the Netherlands Environmental Assessment Agency, in particular Leo Meyer and Paul Lucas.

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Statements of views, facts and opinions as described in this report are the responsibility of the author(s).

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Executive Summary

1. Introduction

This report explores the implications of different possible scenarios on the outcomes of the current climate negotiations. To this end it combines the latest emission reduction proposals, the so-called “pledges”, by Annex I (developed) countries (as tabled by August 2009) with different levels of possible domestic abatement actions by non-Annex I (developing) countries and examines the related mitigation costs and impacts on the carbon-market. The domestic mitigation action carried out by non-Annex I countries could for example be achieved through Nationally Appropriate Mitigation Actions (NAMAs). In addition to the analysis of the current proposals, the report describes a scenario with reductions that would limit global warming to 2 degrees above the pre-industrial level, based on comparable efforts of Annex-I countries.

The analysis focuses in particular on:

- the abatement costs (including emissions trading and the Clean Development Mechanisms (CDM)) for developed and developing countries,
- the price of tradable emission units on the global carbon market in 2020,
- the buyers and sellers of carbon credits,
- the costs and financing of non-Annex I REDD[1] activities by Annex I and other non-Annex I countries

The above issues are analysed for the three broad post-2012 climate policy scenarios:

1. **Low ambition scenario**: based on the lower end of the proposed ranges of emission reduction targets for individual Annex I countries and low-ambition mitigation actions in non-Annex I regions, i.e. use of 25% of the reduction potential in energy-efficiency, renewables, non-CO_2 reduction options and avoided deforestation (REDD). Non-Annex I actions may be (partially) financed by Annex I[2].
2. **Higher ambition scenario**: based on the higher proposed reduction targets for individual Annex I countries and more ambitious mitigation actions in non-Annex I regions, i.e. use of 50% of the reduction potential in energy-efficiency, renewables, non-CO_2 reduction options and REDD.
3. **Comparable effort scenario (aimed at meeting the 2-degree climate target)**: This scenario assumes an ambitious aggregated Annex I reduction target (30% below 1990 levels) and non-Annex I reduction that corresponds to an average of 16% below baseline emissions, excluding REDD and LULUCF[3] CO_2 emissions and 19% below baseline emissions including LULUCF CO_2 emissions and REDD. These reductions are needed to meet long-term greenhouse gas concentrations of 450 ppm CO_2 eq, and to limit the global mean temperature increase to 2°C compared to pre-industrial levels.

   For the differentiation of the aggregated reduction of 30% for Annex I countries, this scenario uses the concept of comparability of efforts, which is based on the notion of equal treatment of countries in similar circumstances. In this scenario, the reductions for the individual Annex I countries are based on the calculated, averaged reduction targets from six different approaches for defining *comparable mitigation efforts* for Annex I countries[4]. For the allocation of the overall non-Annex I reduction, we assumed that the more advanced countries[5] in the group will reduce their emissions by 20% below baseline and those at a

1 Reducing Emissions from Deforestation and Forest Degradation in Developing Countries

2 Note that the question of the source of finance for actions in non-Annex I (apart for REDD financing) is not dealt with in this report. Thus the costs can (in part) be covered by external financial support.

3 Land Use, Land-use Change and Forestry CO_2 emissions

4 Such as equal reduction below a baseline, equal MAC and equal mitigation costs, as described in the *Comparable Effort Study* of den Elzen et al. (2009a). The reductions by different Annex I countries must meet an aggregate reduction of 30% below 1990 levels by 2020.

5 Advanced developing countries: Mexico, rest of Central America, Brazil, rest of South America, South Africa, Kazakhstan region, Turkey, Middle East, Korea region and China; Other developing countries: Northern Africa region, Middle East, India, rest of Southern Asia, Indonesia region and rest of South-East Asia; least developing countries: Western Africa, Eastern Africa and rest of South-Africa region

lower level of development by 10%, while the least developed countries would be exempt from any emission reduction efforts all together.

In exploring the implications for emissions reductions and abatement costs for each scenario we considered two variants, one including and one excluding REDD actions and LULUCF CO_2 emissions. In the scenarios excluding REDD and LULUCF CO_2 the REDD actions are not included in the reductions presented, and in the scenarios including REDD and LULUCF CO_2 the REDD actions are *additional* reductions (for the mitigation actions by non-Annex I countries, and for the reduction proposals for the USA and Australia). Therefore, the costs for REDD action are calculated separately, and do not influence the abatement costs, the carbon price and financial flows of the carbon market. Furthermore, for the scenarios including REDD and LULUCF CO_2 emissions, we assumed that non-Annex I regions will finance 20% of the REDD reductions domestically and the remaining 80% is financed by Annex I regions or other non-Annex I regions.

2. Methodology

The calculations in this paper are mostly based on the FAIR model, used in conjunction with the IMAGE land use model and TIMER energy model, as developed at the Netherlands Environmental Assessment Agency (PBL). The costs calculations are based on Marginal Abatement Costs (MAC) curves for the different emissions sources. For the default calculations the baseline emissions are based on the TIMER and IMAGE model implementation of a baseline without an economic crisis. As an additional uncertainty analyses on the impact of the crisis, we have also developed a baseline including the impact of the economic crisis. The MAC curves of the energy- and industry-related CO_2 emissions from the TIMER energy model are calculated by imposing a carbon tax and recording the induced reduction of CO_2 emissions. The cost estimates for non-CO_2 gases are based on marginal abatement costs of the EMF[6]-21. These curves have been made consistent with the baselines used here and made time-dependent to account for technology change and removal of implementation barriers over time.

One of the inputs of the model analysis are the potential emission reductions by non-Annex I countries. Those were calculated with the help of the Energy research Centre of the Netherlands (ECN) MAC curve and based on the assumptions on potential mitigation action in developing countries (NAMAs). For the low and higher ambition scenario, we assumed that NAMAs would mobilize 25% and 50% of the mitigation potential in energy efficiency, renewables, non-CO_2 greenhouse gases and avoided deforestation, respectively, and we calculated the level of emission reduction (below baseline) to which such mitigation action would lead. The results of these calculations (presented in the "findings" section) were then used as input for the model-based scenario analysis. For the comparable effort scenario, we assumed an average reduction of 16% below baseline emissions for non-Annex I as a group, which is consistent with a 2 degree target.

The main findings of this study are the following:

3. Environmental effectiveness of the scenarios

As of August 2009, the low and high pledges for GHG reductions of Annex I countries (including the US) respectively imply for 2020 a reduction of 10-15%[7] below 1990 levels when excluding REDD and LULUCF CO_2, which is far less than the 25-40% reduction required to meet the 2 degree climate target. If the surplus AAUs of Russia and Ukraine (due to pledges above baseline levels) are forfeited, or not used, the Annex I reduction increases to 14-19% below 1990 levels.

- Russia and Ukraine will have a surplus of AAUs[8] ("new hot air ") by 2020 because their low and high pledges are above baseline emissions. The annual "new" hot air would amount to 1.1 and 1.0 $GtCO_2eq$ for the low and high pledge, respectively. If this hot air is forfeited by Russia and Ukraine, which means it will not be used and traded with other Annex I

[6] EMF: Energy Modelling Forum

[7] The new pledge from Japan (September 2009) of 25% reduction below 1990 levels in 2020 has not been taken into account – it would mean a reduction of 11-16 % below 1990 levels by 2020 instead of 10-15%.

[8] Assigned Amount Units

countries to offset their reductions, the pledges for GHG reductions of the Annex I countries (including the USA) as a group could improve by as much as 14-19% below 1990 levels.

- The low and high pledges for GHG reductions of Annex I countries including REDD and LULUCF CO_2 imply for 2020 a reduction of 8-18% below 1990 levels, which is also less than the 25-40% reduction needed to meet the 2 degree target.
- The absolute reductions including LULUCF CO_2 and REDD but excluding new hot air of the low and higher ambition scenario are about 40% and 60% below the reductions of the comparable effort scenario (Figure S.1). If hot air is excluded these differences are reduced.
- In all scenarios all Annex I countries show a considerable downward trend in per-capita emissions between 1990-2020, especially for the comparable effort scenario.

The high pledges of the EU, USA and Japan[9] are less distant from the comparable effort reductions to meet a 30% aggregated Annex I reduction target, than the pledges of Canada, Russia and Ukraine, which are far below the comparable effort reductions.
Comparing the reduction targets under the low and higher ambition scenario with the reductions of the comparable effort scenario[10] shows the following:

- The high pledges of the EU, USA and Japan are about 5-15 % points lower than the reduction targets assumed in the comparable effort scenario (necessary to achieve the 450 ppm stabilisation target). For example, the high pledge of the EU is 30% below 1990 levels, whereas the comparable effort reduction is 35%.
- The pledges of Canada, Russia and Ukraine are far below the comparable effort reductions: for Canada 25% and for Russia and Ukraine 35%. The pledges of Russia and Ukraine are so low they will create new hot air (or surplus of AAUs) by 2020.

It should be noted that the comparable effort reductions depend greatly on the aggregated Annex I reduction target (here 30% below 1990 levels), the starting point of the emissions in 2010, the comparable efforts approaches considered and model and parameter assumptions.

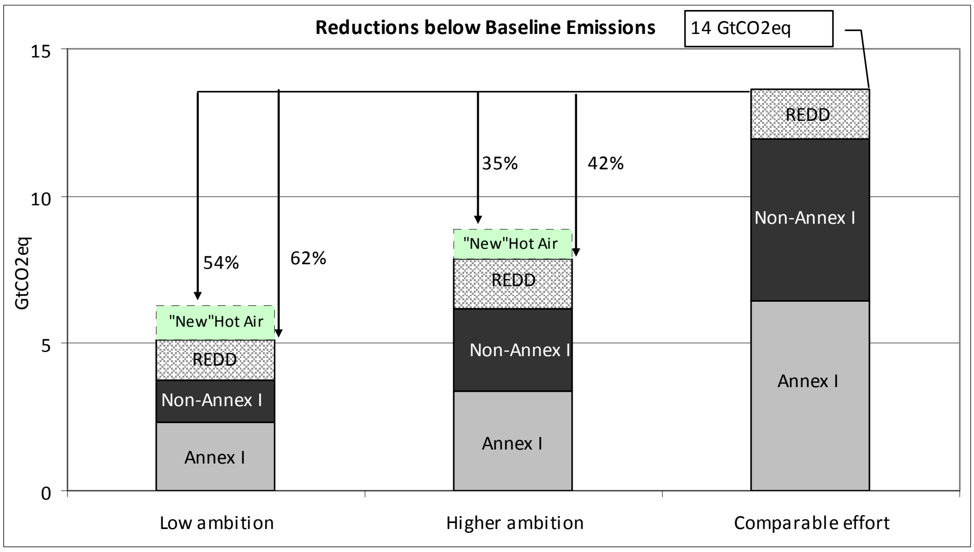

Figure S.1 The total reductions of the three scenarios, i.e. reduction in Annex I and non-Annex I (non-REDD abatement measures), REDD activities in non-Annex I (partly financed by Annex I or other non-Annex I regions) and possible forfeit of 'new' hot air (i.e. surplus of AAUs) by 2020.

Conservatively estimated, NAMA-based mitigation actions (excluding REDD/LULUCF CO_2) could reduce the emissions of eight emerging economies[11] to 5-11% below baseline

[9] This is based on pledge by previous government, i.e. not taking into account the proposed target announced in September 2009.
[10] "Comparable effort" reductions are based on the average outcome of six approaches for comparability of the mitigation efforts by Annex I countries, in accordance with the previous PBL study.
[11] Mexico, Rest of South America, Brazil, China, India, Indonesia, Korea and South Africa.

levels by 2020, and 4-8% for the non-Annex I countries as a group. This is less than the 15-30% reduction below baseline emissions by 2020 that may be needed to realise a global emissions pathway consistent with limiting warming to about 2 °C (i.e. together with 25-40% Annex I reduction below 1990 levels).

We have analysed the reduction potential of possible NAMAs, including effective measures that would realise 25% (low ambition scenario) and 50% (higher ambition scenario) of the potential of energy-efficiency, renewables, non-CO_2 reduction options and avoided deforestation for the eight emerging economies, and made assumptions for the reductions of the other non-Annex I countries.

- At the time of writing (mid-2009), there was much uncertainty about how NAMAs for non-Annex I countries would evolve. However it is likely that they could mobilise an important part of the mitigation potentials, in particularly in the sectors of renewable energy, energy efficiency, non-CO_2 emissions and REDD.
- The eight emerging economies show possible emission reductions (excluding REDD measures and LULUCF CO_2) of 1.2 to 2.4 $GtCO_2eq$ by 2020, which amounts to 5-11% below baseline for the low and higher ambition scenarios. If REDD/LULUCF CO_2 measures are included, the reductions range from 7 to 12% for the low and higher ambition scenarios (i.e. from 2.6 to 4.2 $GtCO_2eq$).
- Based on the above reductions for the eight emerging economies and assumed reductions for other non-Annex I countries[12], the low and higher ambition scenarios achieve reductions which bring the emissions of non-Annex I countries as a group to a level of 4-8% below baseline, when excluding REDD/ LULUCF CO_2 mitigation measures and 7-12% if they are included.

4. Costs implications of the scenarios (excluding the costs of REDD)

The abatement costs for the Annex I countries as a group are about 0.01-0.04% of GDP in 2020 for the low and higher ambition scenarios, and 0.24% for the comparable effort scenario, if use of emissions trading and CDM are allowed. If all Annex I pledges and comparable efforts must be implemented domestically (no emissions trading), the total abatement costs increase by a factor of 4-13. There are large differences in total costs between countries.

- The annual abatement costs for the Annex I countries as a group are about 0.01-0.04% of GDP in 2020 (or about 6-21 billion $US\$_{2005}$) for the low and higher ambition scenarios. This is under the assumption of full emissions trading between Annex I regions, limited trade with advanced developing countries, and use of CDM credits from the other developing countries. For the comparable effort scenario, the annual costs by 2020 increase to 0.24% of GDP (about 120 billion $US\$_{2005}$).
- If no emissions trading is allowed and all Annex I pledges have to be met domestically, total costs increase 13 times (to 0.15-0.38% of GDP for the low and higher ambition scenario, respectively), and more than three times (to 0.88%) for the comparable effort scenario).
- There are large differences in total costs between countries. With emission trading, the total annual abatement costs for reaching the targets remain well below 0.5% of GDP for the low and higher ambition scenario and below 1% of GDP for the comparable effort scenario for all of the countries/regions analysed in this report.
- Russia, Ukraine and Belarus benefit from the revenues of selling part of the banked hot air from the first commitment period, and the selling of new hot air as their proposed reduction targets by 2020 are above their baseline emissions. Here we assumed that Russia, Ukraine and Belarus adopt an optimal banking strategy in order to optimise their financial revenues in the first commitment period and in the period 2013-2023. This implies full banking of hot air from the Kyoto period, and releasing only part of the banked hot air from the second commitment period (2013-2017) and third commitment period (2018-2023).
- Australia appears to have the highest mitigation costs compared to GDP to meet its pledge. This is due to a combination of the level of the pledge and the sectoral emission composition (large share of heavy industry in international trade in the region, which leads to high domestic costs for emissions reductions).

[12] Similar to the ones above depending on the countries' stage of development

- The abatement costs compared to GDP found for the USA and Japan (based on the July 2009 pledge and not the more recent pledge of September 2009) are lower than for the EU for all scenarios.

The abatement costs expressed as a percentage of GDP of mitigation action in non-Annex I regions are lower than the costs of the Annex I countries. With the current pledges of Annex I regions the non-Annex I countries may even have net gains after emissions trading. In this study, we do not make assumptions on who should bear the cost of mitigation action in non-Annex I countries (except for REDD). Non-Annex I actions could also be partly financed by Annex I, in which case there would be no costs for non-Annex I, and only net gains from the carbon market.

- The low and higher ambition scenarios show small gains for the non-Annex I countries as a group (about -0.3 to -0.6 billion $US\$_{2005}$), and for the comparable effort scenario the costs are low: 0.18% of GDP (about 43 billion $US\$_{2005}$).
- There are large differences in abatement costs between the advanced developing countries and least developed countries. The advanced developing countries may have costs as high as 0.3-0.5% of their GDP for the comparable effort scenario, but rather low costs for the low and higher ambition scenario. The least developing countries have net gains from CDM for all three scenarios.
- The demand for CDM and carbon credits from the Annex I countries to complement part of their reductions implies financial flows to the non-Annex I countries that amount to 2.5-11 billion $US\$_{2005}$ per year in 2020 for the low and higher ambition scenarios, and to 42 billion $US\$_{2005}$ for the comparable effort scenario.
- Nearly all non-Annex I countries (Mexico, the rest of South America, Brazil, China, India, Indonesia, Korea and South Africa) increase their emissions per capita in all the scenarios, excluding LULUCF and REDD emissions, from 1990 until 2020. The only exceptions are Brazil for the higher ambition scenario and South Africa for the higher ambition and comparable effort scenarios.

5. Supply and demand on the carbon market and its role in defining costs for developed and developing countries (excluding costs of REDD)

The estimated carbon price in 2020 is 4 and 15 US$/t$CO_2$eq for the low and higher ambition scenarios, respectively, and 58 US$/t$CO_2$eq for the comparable effort scenario, which can be considered as rather low. Due to hot air, the main sellers on the carbon market would be Russia and the Ukraine; the main buyers would be the EU and USA.

The carbon price found for the three scenarios explored is rather low (e.g. compared to current price levels in the EU ETS). This is the cumulative effect of the following causes:

  - The conservative ECN MAC curve leads to relatively low NAMA-based emission reductions of 4-8% for the non-Annex I countries, so the developing countries still have a potentially abundant source of relatively low cost abatement options, which can be used for offsetting reductions in Annex I countries, which lowers the carbon price. There are also some non-Annex I regions like the Middle East for which low or no domestic mitigation action is assumed, which means they can offer all of their mitigation potential to the carbon market.
  - Allowing banking of hot air from the Kyoto period (from Russia and Ukraine) results in the release of 1.1-1.3 GtCO_2 hot air to the market by 2020, which also lowers the price.
  - "New" hot air induced by low post-2012 targets by 2020 for Russia and Ukraine for the low and higher ambition scenario further increases the supply of carbon credits, and lowers the price.

- Most Annex I countries (except Russia, Ukraine and Belarus) will act as buyers on the international carbon market. The EU and the USA are the dominant buyers on the market, with a total demand share of about 80-90% of total trade. The Annex I countries except USA and EU still realise at least 50% of the total reduction domestically, and this fraction increases for the high and comparable effort scenario due to higher carbon prices.
- Russia, Ukraine and Belarus are benefiting from the trading revenues from selling part of the banked hot air from the first commitment period and the selling of new hot air. Russia

has a share of 40-50% of the total supply of carbon credits. Even for the comparable effort scenario in which Russia has a reduction target below the baseline emissions, the share amounts 40%. Ukraine has a share of about 20% of carbon market sales.

- The non-Annex I countries as a group act as sellers with a share of the total supply of 30% for the low and higher ambition scenario and 40% for the comparable effort scenario. China acts as the dominant seller of non-Annex I credits, with shares of 6-12%.
- In the low ambition scenario, most non-Annex I regions are acting as sellers on the carbon market. For the high and comparable effort scenario, some regions (i.e. Mexico, Brazil and South Africa for the higher ambition scenario) are amongst the buyers of credits.
- Trade in carbon credits from hot air between Russia and Ukraine, and other Annex I countries, leads to lower trade of carbon credits from non-Annex I to Annex I countries. Consequently, Annex I countries as a group (including Russia and Ukraine) only need to acquire an amount of emission credits through offsetting mechanisms equal to 3% of their 1990 emissions. Non-Annex I countries reduce their emissions by around 18% compared to baseline emission levels (after trade and CDM).

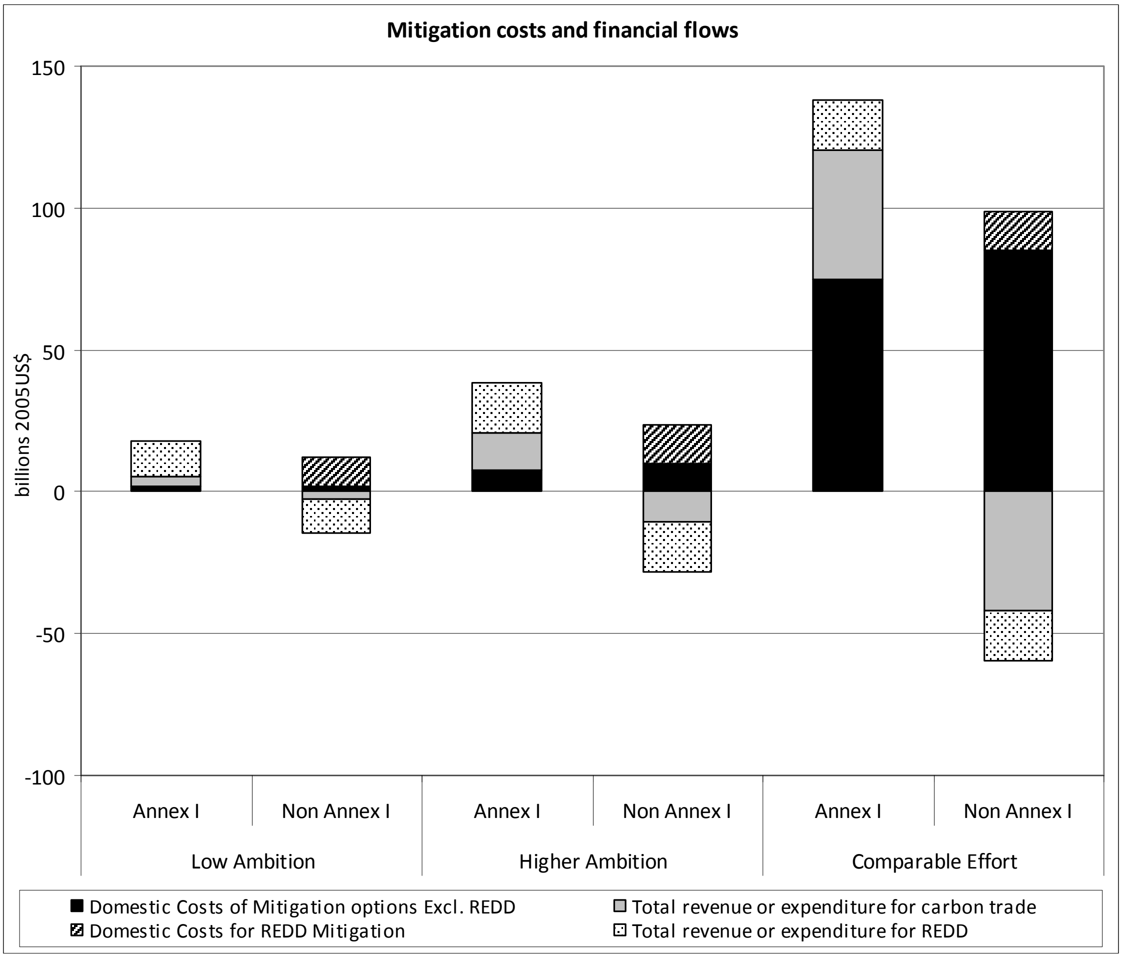

Figure S.2. Mitigation costs and financial flows associated with the various scenarios, Note: domestic costs excluding REDD consists of the domestic costs to meet the own reduction target and the domestic costs for additional reductions to offset reductions in Annex I.

- Large financial flows from Annex I to non-Annex I will go through the carbon market. For the Annex I region the total expenditure for carbon credits exceeds the costs for domestic mitigation measures in the low and higher ambition scenario (see Figure S.2). For the comparable effort scenario the carbon credits expenditure is lower than the domestic costs, representing about 40% of the total costs for Annex I (see Figure S.2).

- For the non-Annex I regions the total revenues of carbon trade exceed the costs of domestic mitigation measures, resulting in gains in the low and higher ambition scenario, whereas in the comparable effort scenario the total revenues cover about half of the domestic costs.

6. The mitigation costs of financing REDD measures outside the carbon market

Given the assumption that Annex I countries would finance 80% of REDD activities in non-Annex I countries at the REDD market price[13], the costs would be around 18 billion US$ for Annex I countries, while non-Annex I countries would earn around 4 billion US$ by 2020 despite of its 20% own contribution. This would lead to halving the emissions from deforestation.

The calculations assume that REDD action is additional and financial flows are independent of the financial flows in the carbon market.

- Given the already low carbon prices for the low and higher ambition scenario, REDD is only a relatively low cost option in the comparable effort scenario.
- More specifically, the average abatement costs[14] of REDD for the low and higher ambition scenario (about 7-8 US$/tonne) are above the average abatement costs of the (used) non-REDD mitigation options (about 1-3 US$/tonne). The average abatement costs for REDD (about 8 US$/tonne) are lower than the average abatement costs of the non-REDD mitigation options for the comparable effort scenario (about 16 US$/tonne).

We have two options for the financing of REDD: (1) against the REDD market price, and (2) against the marginal abatement costs.

- When REDD projects are directly financed against the REDD market price the average abatement costs (total domestic costs plus gains from trading) for non-Annex I regions are negative (-2.5 to 4 billion $US\$_{2005}$ for the three scenarios). For Annex I regions the costs are about 12 to 18 billion $US\$_{2005}$.
- When REDD projects are directly financed against the marginal abatement costs, there are domestic costs from REDD to meet their own 20% target for non-Annex I regions of about 0.5 to 1 billion $US\$_{2005}$, and costs for Annex I are about 9 billion and 13 billion $US\$_{2005.}$

- There is still a significant quantity of REDD action (as part of the 80% external financing) that is currently not supported under the reduction proposals from the Annex I countries (0.5-1.1 $GtCO_2$).

7. Mitigation costs and financial flows related to REDD and carbon trade and its role in defining costs for Developed and Developing Countries

Under all scenarios, large financial flows exist from Annex I to non-Annex I through the carbon market and REDD financing, representing 40-80% of the total mitigation costs for Annex I

- In addition to expenditure for carbon credits, another important cost category for Annex I countries is financing of REDD (together with the domestic costs they account for the total mitigation costs). The expenditure of carbon credits through carbon trade and REDD financing form 80% of the total mitigation cost of Annex I in the low and higher ambition scenario, and 40% in comparable effort scenario (see Figure S.2). The higher shares in the low and higher ambition scenario can be explained by the relatively low reductions of the non-Annex I regions of 4-8% below the baseline emissions, and the availability of low costs mitigation options in these regions.
- The costs of mitigation and REDD for the Annex I region range from 18 billion to 138 billion US$. For the non-Annex I region, the total costs are negative for the low and higher

[13] I.e.: the marginal costs of last abated tonne of carbon from REDD

[14] Average costs are defined as the total abatement costs (i.e.: domestic costs of REDD activities in non-Annex I countries to meet their 20% target, and costs of buying REDD credits or financing 80% of the REDD activities in non-Annex I countries by Annex I countries or other non-Annex I countries) divided by the total abatement of REDD.

ambition scenarios (−3 to −5 billion $US\$_{2005}$), while for the comparable effort scenario the net costs are about 40 billion $US\$_{2005}$.
- There are large financial flows from Annex I to non-Annex I through the expenditure for carbon credits and REDD financing by Annex I of 15 to 60 billion $US\$_{2005}$ for the three scenarios, which exceed the domestic costs in non-Annex I of additional reductions to offset reductions in Annex I countries and REDD reductions of about 10 to 30 billion $US\$_{2005}$. The resulting net gains are in the order of 5 to 30 billion $US\$_{2005}$.

Comparing the financial flows of REDD against those on the carbon market, we conclude the following:
- The net gains of REDD for non-Annex I countries are much higher than the net gains of carbon trading[15] for the low ambition scenario, but in the higher ambition and comparable effort scenario the net gains of REDD are much lower (about 80%) than the net gains of carbon trading.

8. The impacts of the economic crisis

The economic crisis decreases the carbon prices for all scenarios. The Annex I countries have much lower costs during the crisis due not only to the lower price, but also to the lower reduction effort that is required (lower baseline, but same target). The domestic abatement cost in non-Annex I countries is somewhat lower but so are the revenues from carbon trading.
- The economic crisis may results in a decrease in GHG baseline emissions (without climate policy) of about 10% by 2010 and 8% by 2020 compared to the baseline emissions without the crisis. This is based on our assumption that the crisis will result in a reduction in GDP growth in 2009 and 2010 and a convergence to the original growth path after this period. However, if increased growth after the crisis is assumed, the impact in the long term will obviously be much smaller, and the emission differences may become zero after 2020.
- The surplus of AAUs or hot air in the first commitment period increases by an additional 20%, to 3 $GtCO_2eq$, which represents about 8% of the 1990 emissions of the Annex I countries. The new hot air by 2020 is higher under the crisis scenario, up to 1.4 and 1.1 $GtCO_2eq$/year for the low and higher ambition scenario. The comparable effort scenario does not lead to hot air for Ukraine and Russia, because their comparable effort reduction targets are below their baseline emissions.
- The carbon price decreases compared to the price under the default (no-crisis) baseline emissions by 1-2 US$/tonne CO_2 (12-16%) for the low and higher ambition scenarios and 16 US$/tonne CO_2 (30%) for the comparable effort scenario.
- The abatement costs for the Annex I countries as a group decrease by about 30-35% for the low and higher ambition scenario and 65% for the comparable effort scenario.
- Compared to a no-crisis scenario, the carbon trade from the non-Annex I countries to the Annex I countries (from offsetting) decreases by 20-25% for the low and higher ambition scenarios and about 95% for the comparable effort scenario. In combination with the lower prices, this leads to a decrease in the financial flows of around 35-40% for the low and higher ambition scenarios and about 95% for the comparable effort scenario. For the non-Annex I countries, the decrease in trade and financial flows ultimately decreases their gains. However these gains still appear to compensate the domestic costs.
- The global abatement cost is reduced by about 25-30% for the low and higher ambition scenarios and 45% for the comparable effort scenario.

9. Caveats of this study
- The results (i.e. emission reductions and costs indicators) are dependent on the models and the parameter assumptions. For instance the assumptions about baselines, banking, hot air and marginal abatement costs curves (as analysed for Annex I and non-Annex I countries as a group in den Elzen et al., 2009b), and what post-Kyoto land-use accounting rules are

[15] Calculated as the total revenues of selling carbon credits minus the total domestic costs of the additional reduction to offset reductions in Annex I countries.

assumed (in the present study, the same rules as under Kyoto were applied). In addition, the reduction potential contained in the ECN MAC can be considered conservative, which means that the reductions in the NAMA strategies, and the corresponding calculated reductions below baseline for the non-Annex I region may also be considered as being conservative estimates.

Samenvatting

1. Introductie

Dit rapport analyseert de emissies en de gevolgen voor de kosten van de laatste voorstellen ('pledges') met betrekking tot emissiereducties zoals deze zijn ingediend (tot augustus 2009) door Annex I landen of geïndustrialiseerde landen in combinatie met mogelijke mitigatiemaatregelen voor de niet-Annex I landen of ontwikkelingslanden. De niet-Annex I landen kunnen een deel van het potentieel in energie-efficiëntie, hernieuwbare energie, niet-CO_2-reductie opties en vermeden ontbossing realiseren. Dit kan bijvoorbeeld worden bereikt door middel van 'National Appropriate Mitigation Actions' (NAMAs). Het rapport beschrijft ook de analyse waarbij de reductiedoelen worden beschreven die nodig zijn om de mondiale opwarming te beperken tot 2°C ten opzichte van het pre-industriële niveau gebaseerd op de vergelijkbare reductie-inspanningen van Annex I landen

De analyse richt zich voornamelijk op
- De kosten van emissiereducties (inclusief de kosten van reductieverplichtingen in het buitenland middels emissiehandel en het 'Clean Development' Mechanismen (CDM)) voor de Annex I en niet-Annex I landen
- De prijs in 2020 van verhandelbare emissierechten op de mondiale koolstofmarkt
- De kopers en verkopers van emissierechten
- De kosten en financiering van niet-Annex I REDD[16] activiteiten door Annex I landen en andere niet-Annex I landen (die geen REDD activiteiten ondernemen)

De bovenstaande onderwerpen worden geanalyseerd in de volgende drie post-2012 beleidsscenario's:
1. **Laag ambitie scenario**: gebaseerd op de ondergrenzen van de voorgestelde reductie-doelstellingen door de afzonderlijke Annex I landen en lage ambitie mitigatie-acties in niet-Annex I regio's d.w.z. het realiseren van 25% van het reductiepotentieel in energie-efficiëntie, hernieuwbare energie, niet-CO_2-reductie opties en vermeden ontbossing. Niet-Annex I acties worden deels gefinancierd door Annex I landen.[17]
2. **Hoger ambitie scenario**: gebaseerd op de bovengrenzen van de voorgestelde reductiedoelstellingen door de afzonderlijke Annex I landen en ambitieuzere reductie-maatregelen in niet-Annex I regio's, d.w.z. het realiseren van 50% van het reductiepotentieel.
3. **Vergelijkbare inspanning scenario** (gebaseerd op het halen van de temperatuurs-doelstelling van 2 graden): dit scenario gaat uit van een ambitieuze totale Annex I doelstelling (30% onder het niveau van 1990) en een niet-Annex I reductiedoelstelling die overeenkomt met een gemiddelde reductie van 16% onder de baseline emissies exclusief landgebruik, LULUCF[18] CO_2 en REDD en 19% onder de baseline emissies met inbegrip van landgebruik, LULUCF CO_2 en REDD. Deze reducties zijn noodzakelijk om te voldoen aan de doelstelling om lange termijn concentraties van broeikasgassen tot 450 ppm CO_2eq te beperken welke gerelateerd is aan de doelstelling om de wereldwijde gemiddelde temperatuurstijging tot 2°C te beperken ten opzichte van pre-industriële niveaus.

Voor de verdeling van de gezamenlijke reducties voor Annex I en niet-Annex I landen gebruikt dit scenario het concept van de vergelijkbaarheid van inspanningen ('comparable efforts') wat is gebaseerd op het idee van gelijke inspanning van landen die in soortgelijke omstandigheden verkeren. In dit scenario worden de reducties voor de afzonderlijke Annex I landen bepaald op basis van de berekende gemiddeld reductiedoelstellingen van zes benaderingen die momenteel gebruikt worden om de vergelijkbaarheid te beoordelen van

[16] Het voorkomen van emissies veroorzaakt door ontbossing, in de klimaatwereld vaak aangeduid met de Engelse term REDD, i.e. Reducing Emissions from Deforestation and Forest Degradation.
[17] Merk op dat de kwestie van de bron van financiering voor acties in niet-Annex I (behalve voor de financiering van REDD) niet wordt geanalyseerd in dit rapport. Dus de kosten kunnen (gedeeltelijk) worden gedekt door externe financiële steun.
[18] Land Use, Land-Use Change and Forestry

Annex I reductie-inspanningen[19]. De reducties van de verschillende Annex I regio's moet voldoen aan een totale vermindering van broeikasgassen van 30% onder het niveau van 1990 in het jaar 2020. Voor de verdeling van de totale niet-Annex I reducties wordt aangenomen dat de meer ontwikkelde landen[20] in deze groep hun uitstoot verminderen met 20% onder de baseline en de landen met een lager ontwikkelingsniveau[21] met 10% terwijl de minst ontwikkelde landen[22] worden vrijgesteld van alle reductie-inspanningen.
Voor elk scenario hebben wij twee varianten in ogenschouw genomen die elk een ander effect laten zien op de emissiereducties en reductiekosten: inclusief en exclusief REDD en LULUCF-CO_2 emissies. Bovendien veronderstellen we voor de scenario's inclusief REDD en LULUCF-CO_2 dat niet-Annex I landen 20% van de NAMA maatregelen m.b.t. REDD financieren en dat het overige deel van 80% wordt gefinancierd door Annex I regio's of andere niet-Annex I regio's tegen marginale kosten of tegen de REDD marktprijs. Samen vormen deze varianten negen scenario's voor de modelanalyse.

Om het resultaat van emissiereducties en reductiekosten voor elk scenario te bepalen hebben we twee varianten geanalyseerd. De eerste exclusief en de tweede inclusief REDD activiteiten en LULUCF CO_2 emissies. In de scenario's exclusief LULUCF CO_2 en REDD activiteiten zijn de REDD reducties niet opgenomen in de gerapporteerde reducties en in de scenario's inclusief LULUCF CO_2 en REDD activiteiten worden additionele reducties gedaan (voor de reductie-activiteiten van niet-Annex I landen en voor de reducties van toezeggingen van de VS en Australië). Daarom zijn de kosten voor REDD activiteiten afzonderlijk berekend en hebben geen invloed op de reductiekosten, de koolstofprijs en de financiële stromen van de koolstofmarkt. Verder hebben we in scenario's inclusief REDD en LULUCF CO_2-uitstoot de aanname gemaakt dat niet-Annex I regio's 20% van de REDD reducties zelf financieren en dat de resterende 80% wordt gefinancierd door Annex I of andere niet-Annex I regio's.

2. Methodologie

De berekeningen in dit rapport zijn grotendeels gebaseerd op het FAIR model dat wordt gebruikt in samenwerking met het IMAGE landgebruikmodel en het TIMER energiemodel, zoals ontwikkelt door het Planbureau voor de Leefomgeving (PBL). De kostenberekeningen zijn gebaseerd op Marginale reductie kostencurven (MACs) voor verschillende emissiebronnen van broeikasgassen. De basisberekeningen voor de baseline emissies gaan niet uit van een economische crisis. Als een toegevoegde onzekerheidsanalyse naar de impact van de economische crisis hebben we ook een baseline emissie scenario ontwikkeld waarbij wel met de economische crisis rekening wordt. De MAC curven van de energie- en industrie gerelateerde emissies van het TIMER energiemodel worden berekend door een koolstofbelasting aan het model op te leggen en te bepalen welke CO_2 reducties hieruit volgen. De kostenschattingen voor niet-CO_2 gassen zijn gebaseerd op marginale reductiekosten uit de EMF-21 studie voor 2010. Deze curven zijn consistent gemaakt met de baseline die in deze analyse wordt gebruikt en is tijdsafhankelijk gemaakt door rekening te houden met technologische ontwikkelingen en het verwijderen van implementatiebarrières in de tijd.

Een van de inputs van de modelanalyse zijn de potentiële emissiereducties door niet-Annex I landen. Deze zijn bepaald met behulp van de Energieonderzoekcentrum Nederland (ECN) MAC curven welke zijn gebaseerd op mogelijke mitigatie acties op basis van de NAMAs van deze niet-Annex I landen. In het lage en hogere ambitie scenario veronderstellen we voor de NAMAs een 25% en 50% reductie van het totale potentieel aan energie-efficiëntie, hernieuwbare energie, niet-CO_2-reductie opties en vermeden ontbossing. We hebben de reductieniveaus bepaald ten opzichte van de baseline waar deze NAMA activiteiten toe kunnen leiden. De resultaten van deze activiteiten (welke in latere secties worden besproken) worden als input gebruikt voor de scenarioanalyse. In het vergelijkbare inspanningsscenario hebben we

[19] Zoals gelijke reductie beneden de baseline, gelijke MACs en gelijke mitigatiekosten, zoals beschreven in de 'Comparable effort study' van Den Elzen et al. (2009a)
[20] Mexico, rest van Centraal Amerika, Brazilië, rest van Zuid Amerika, Zuid Afrika, Kazakstan regio, Turkije, Midden-Oosten, Korea regio en China
[21] Noordelijk Afrika, India, rest Zuidelijk Azië, Indonesië regio en rest van Zuidoost Azië
[22] West Afrika, Oost Afrika en rest van Zuidelijk Afrika

verondersteld dat de niet-Annex I landen als groep16% ten opzichte van baseline reduceren, wat consistent is met de 2°C doelstelling.

De belangrijkste bevindingen van deze studie zijn de volgende:

3. Milieueffectiviteit van de scenario's

De lage en hoge toezeggingen gepubliceerd tot augustus 2009 impliceren reducties van broeikasgasemissies van 10-15%[23] onder het niveau van 1990 in 2020 van Annex I landen (waaronder de VS), exclusief LULUCF CO_2. Dit is veel minder dan de 25-40% reductie die noodzakelijk is om te voldoen aan de 2 graden klimaat doelstelling. Als de overtollige emissierechten (de zogenaamde 'hot air') van Rusland en Oekraïne (doordat toezeggingen boven de baseline niveaus zijn) niet worden gebruikt of verhandeld, stijgen de reducties van de Annex I landen tot 14-19% onder het niveau van 1990.

- Rusland en Oekraïne zullen ook nieuwe 'hot air' (of overtollige AAU[24]'s) in 2020 genereren omdat de lage en hoge toezeggingen boven de baseline emissies uitkomen. De jaarlijkse nieuwe 'hot air' zal respectievelijk neerkomen op 1,1 en 1,0 $GtCO_2eq$ voor de lage en hoge toezeggingen. Als deze 'hot air' niet gebruikt wordt door Rusland en Oekraïne, wat betekent dat het niet zal worden verhandeld met andere Annex I landen die het gebruiken om binnenlandse emissies te compenseren, zullen de toezeggingen van de Annex I landen (met inbegrip van de Verenigde Staten) als groep verbeteren tot 14-19% onder het niveau van 1990.
- De lage en hoge toezeggingen met betrekking tot emissiereducties voor Annex I landen inclusief LULUCF CO_2 impliceren een reductie van 8-18% t.o.v. 1990 niveaus. Dit is minder dan de 25-40% die noodzakelijk zijn om aan de 2° doelstelling te voldoen.
- De absolute reducties (inclusief LULUCF CO_2 en REDD) in het lage en hogere ambitie scenario zijn ongeveer 70% en 50% lager dan de reducties in het vergelijkbare inspanningsscenario.
- Alle landen van Annex I laten een aanzienlijke neerwaartse trend in emissies per hoofd van de bevolking zien tussen 1990-2020. Dit geldt vooral voor het vergelijkbare inspannings-scenario.

De hoge toezeggingen van de EU, de VS en Japan[25] zijn minder ver verwijderd van de vergelijkbare inspanningen (30% totale Annex I reductiedoelstelling) dan de toezeggingen van Canada, Rusland en Oekraïne die ver beneden deze vergelijkbare inspanning reducties liggen.

Vergelijking van de reductiedoelstellingen onder de lage en hogere ambitie scenario's (scenario 1 en 2) met de reducties van het vergelijkbare inspanningsscenario[26] (scenario 3) laat het volgende zien:

- De hoge toezeggingen van de EU, de VS en Japan zijn ongeveer 5-15% punten lager dan de reducties verondersteld in het vergelijkbare inspanningsscenario (welke nodig zijn om het 450 ppm stabilisatie doel te bereiken). De hoge toezegging van de EU is bijvoorbeeld 30% t.o.v. 1990 terwijl de vergelijkbare inspanningsreductie 35% is.
- De toezeggingen van Canada, Rusland en Oekraïne liggen ver beneden de vergelijkbare inspanningsreducties. Voor Canada is dit 25% te laag en voor Rusland en Oekraïne 35%. Daarnaast zullen op basis van hun toezeggingen Rusland en Oekraïne nieuwe 'hot air' (of overschot van AAU's) genereren in 2020.

Hierbij moet worden opgemerkt dat de vergelijkbare inspanningsbeperkingen sterk afhankelijk zijn van het model en de parameter veronderstellingen.

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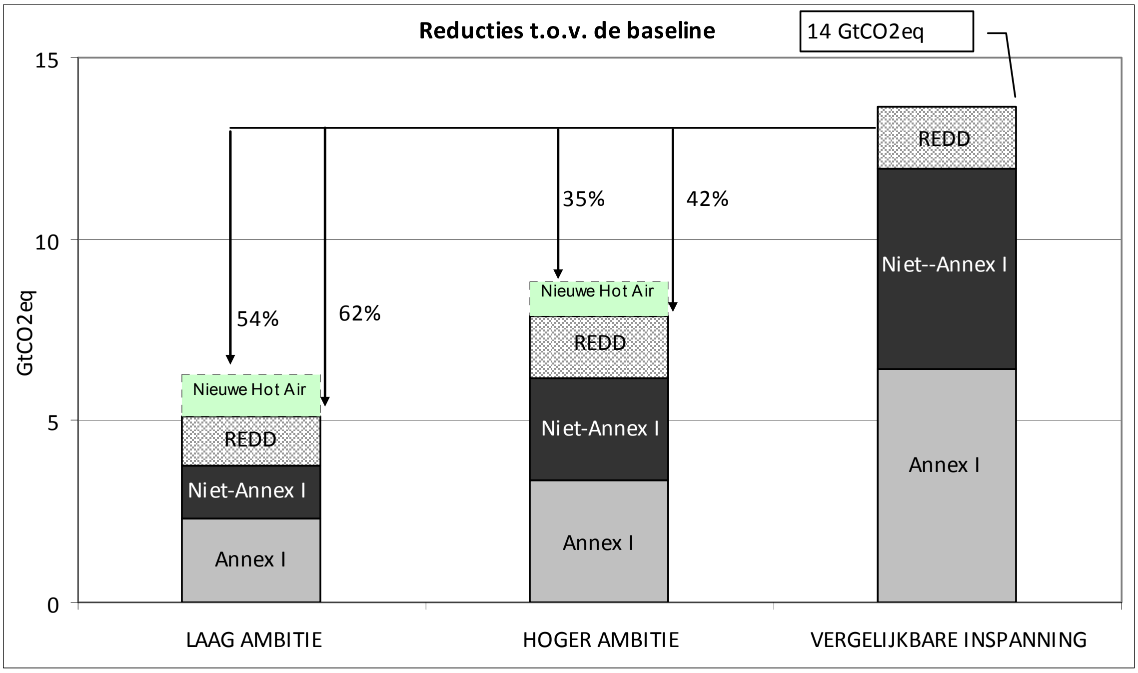
[23] De nieuwe toezegging van Japan is niet meegenomen in de berekeningen, het wel meenemen hiervan resulteert in 11-16% reducties voor de industrielanden t.o.v. het 1990 niveau in 2020 in plaats van 10-15%

[24] Assigned Amount Unit

[25] Gebaseerd op toezegging van vorige overheid, dus de huidige toezegging is niet meegenomen

[26] De vergelijkbare inspanningsreducties zijn gebaseerd op de gemiddelde uitkomst van de zes benaderingen voor vergelijkbare mitigatie-inspanningen door Annex I landen welke gebaseerd zijn op de voorgaande PBL studie



Figuur S.1 De totale reductie van de drie scenario's, namelijk reductie van de Annex I en niet-Annex I regio's (niet-REDD maatregelen), REDD maatregelen in niet-Annex I (gedeeltelijk gefinancierd door Annex I of andere niet-Annex I regio's) en mogelijke opgave van de 'nieuwe' hot air (dat wil zeggen overschot van AAU's) uit de derde periode, 2018-2023).

Een voorzichtige schatting geeft aan dat de mitigatiemaatregelen op basis van de NAMA's van de acht opkomende economieën een verlaging van emissies in 2020 met zich meebrengen van 5-11% t.o.v. de baseline in 2020 onder de baselines en 4-8% t.o.v. baseline in 2020 voor de niet-Annex I landen als groep. Dit is minder dan de 15-30% reductieniveaus t.o.v. de baseline die nodig zijn om het 2 graden klimaat doel te bereiken (samen met de 25-40% reductie t.o.v. 1990 van Annex I landen).
We hebben het reductiepotentieel van de NAMA strategieën geanalyseerd waarbij 25% (lage ambitie scenario) en 50% (hogere ambitie scenario) van het potentieel van energie-efficiëntie, hernieuwbare energiebronnen, niet-CO_2 reductie opties en vermeden ontbossing gerealiseerd wordt.

- In de periode medio-2009 wanneer dit rapport is geschreven was er nog veel onzekerheid over hoe de NAMAs voor de niet-Annex I genoemde landen er uit gaan zien. Het is echter waarschijnlijk dat zij een belangrijk deel van de mitigatie mogelijkheden kunnen vergroten vooral voor de mogelijkheden met betrekking tot hernieuwbare energie, energie-efficiëntie, niet- CO_2-emissies en REDD.
- We hebben het reductiepotentieel van een aantal mitigatiestrategiën die door de NAMA strategieën kunnen worden verwezenlijkt geanalyseerd voor de acht opkomende economieën (Mexico, Rest van Zuid-Amerika, Brazilië, China, India, Indonesië, Korea en Zuid-Afrika). Deze laten emissiereducties zien (exclusief REDD maatregelen en LULUCF-CO_2) van 1,2 tot 2,4 $GtCO_2eq$ in 2020 die neerkomen op 5-11% reducties onder de baseline voor de lage en hogere ambitie scenario's. Als REDD en LULUCF- CO_2 maatregelen mee worden genomen zullen de reducties variëren van 7 tot 12% voor de lage en hogere ambitie scenario's (of 2,6 tot 4,2 $GtCO_2eq$).
- Op basis van de eerder genoemde mogelijke reducties voor de acht opkomende economieën en de veronderstellingen voor reducties onder de baseline voor de andere niet-Annex I landen (afhankelijk van het stadium van ontwikkeling van deze landen) zijn de reducties voor de niet-Annex I landen als groep voor de lage and hogere ambitie scenario's 4-8% onder de baseline emissies exclusief REDD en LULUCF CO_2-uitstoot en 7-12% inclusief (d.w.z. van 1,4 tot 2,8 $GtCO_2eq$ per jaar exclusief REDD en LULUCF- CO_2 en 2,6 tot 4,6 $GtCO_2eq$ per jaar inclusief).

4. Kostenimplicaties van de scenario's (exclusief kosten van REDD financiering)

De reductiekosten van Annex I landen als groep als emissiehandel en CDM zijn toegestaan zijn ongeveer 0,01-0,04% van het BBP voor de lage en hogere ambitie scenario’s en 0,24% voor het vergelijkbare inspanningsscenario. Als alle Annex I toezeggingen en vergelijkbare inspanningen in eigen land moeten worden uitgevoerd (geen emissiehandel) zullen de reductiekosten stijgen met een factor 4-13. De verschillen in totale kosten tussen de verschillende landen zijn groot.

- De jaarlijkse reductiekosten voor de lage en hoge toezeggingen van de Annex I landen als groep zijn ongeveer 0.01-0.04% van het BBP in 2020 (gelijk aan 6-21 miljard US$$_{2005}$) als emissiehandel tussen Annex I regio's is toegestaan; er is beperkte emissiehandel met de meest ontwikkelde niet-Annex I landen en CDM met andere niet-Annex I landen. Voor het vergelijkbare inspanningsscenario stijgen de jaarlijkse kosten naar 0,24% van het BBP (gelijk aan 120 miljard US$$_{2005}$).
- Als geen emissiehandel is toegestaan waardoor alle toezeggingen in eigen land moeten worden uitgevoerd dan zullen de totale kosten toenemen met een factor 13 (0.15-0.38% van het BBP voor de het lage en hogere ambitie scenario) en met meer dan drie voor het vergelijkbare inspanningsscenario. Gegeven de veronderstelling dat emissiehandel niet mogelijk is beschikken enkele regio's niet over voldoende potentieel om hun doelstellingen te halen (hoge toezegging: de EU en eventueel Oceanië; vergelijkbare doelstelling: Canada, de EU en Oceanië).
- Er zijn grote verschillen in de totale kosten tussen landen. Als emissiehandel wordt toegestaan zullen de totale jaarlijkse reductiekosten voor het bereiken van de doelstellingen om aan de toezeggingen te voldoen in alle landen/regio ’s die in dit verslag worden geanalyseerd veel lager zijn dan 0,5% van het BBP. In het vergelijkbare inspanningsscenario zal dit minder zijn dan 1% van het BBP.
- Rusland, Oekraïne en Wit-Rusland profiteren van de baten uit emissiehandel en zullen profiteren van de verkoop van ‘hot air’ ontstaan in de Kyoto periode en blijven profiteren van de nieuwe ‘hot air’ uit de volgende periodes. De nieuwe ‘hot air’ ontstaat omdat de voorgestelde doelstellingen in 2020 tot een hogere uitstoot dan baseline zullen leiden. Hier wordt uitgegaan van een optimale strategie voor Rusland en Oekraïne met betrekking tot ‘banking’ van ‘hot air’ zodat hun financiële inkomsten worden geoptimaliseerd in zowel de eerste verbintenisperiode als in de periode 2013-2023. Dit betekent volledige ‘banking’ van ‘hot air’ uit de Kyoto periode en het vrijgeven van deze ‘hot air’ in de tweede periode (2013-2017) en de derde periode (2018-2023).
- Uit de analyses blijkt dat Australië de hoogste mitigatiekosten ten opzichte van het BBP heeft om aan haar toezeggingen te voldoen. Dit is te wijten aan een combinatie van de ambitie van de toezegging en de sectorale samenstelling m.b.t. emissies (groot aandeel van de zware industrie in de internationale emissiehandel van deze regio) welke leidt tot hoge kosten voor binnenlandse emissiereducties.
- De reductiekosten van de EU ten opzichte van het BBP zijn hoger dan voor de VS en Japan (voor alle scenario's).

De reductiekosten uitgedrukt als percentage van het BBP van niet-Annex I regio's zijn lager in vergelijking met de kosten van de Annex I landen. Met de huidige toezeggingen van Annex I regio's kan zelfs een netto winst worden gerealiseerd door de niet-Annex I landen. In deze studie doen we geen aannames over welke landen de mitigatiekosten in niet-Annex I landen zouden moeten financieren, met uitzondering van REDD. Niet-Annex I reducties kunnen ook worden gefinancierd door Annex I landen in wat zal betekenen dat niet-Annex I landen geen kosten hebben en alleen winsten laten zien uit de koolstofmarkt.

- Het hoge en lagere ambitie scenario laten kleine winsten zien voor de niet-Annex I regio's als groep (ongeveer -0.3 tot -0.6 miljard US$$_{2005}$) en lage kosten voor het vergelijkbare inspanningsscenario: 0,18% van het BBP (gelijk aan 43 miljard US$$_{2005}$).
- De verschillen in reductiekosten tussen meest ontwikkelde en minst ontwikkelde ontwikkelingslanden is groot. In het vergelijkbare inspanningsscenario zijn de kosten voor de meest ontwikkelde ontwikkelingslanden zijn in de orde van 0.3-0.5% van het BBP. Voor

het lage en hogere ambitie scenario zijn ze vrij laag. De minst ontwikkelde landen hebben winsten in alle drie de scenario's.

- De vraag naar CDM en emissierechten uit de Annex I landen ter compensatie van een deel van hun reducties genereren financiële stromen naar de niet-Annex I regio's. Deze vraag impliceert een bedrag van 2,5-11 miljard US$$_{2005}$ per jaar voor de lage en hogere ambitie scenario's en 43 miljard US$$_{2005}$ dollar voor het vergelijkbare inspanningscenario.
- Voor bijna alle niet-Annex I landen (Mexico, Rest van Zuid-Amerika, Brazilië, China, India, Indonesië, Korea en Zuid-Afrika) en in alle scenario's nemen de emissies (exclusief LULUCF- CO_2 en REDD) per hoofd van de bevolking toe van 1990 tot 2020. De enige uitzonderingen zijn Brazilië in het hogere ambitie scenario en Zuid-Afrika in het hoge- en vergelijkbare inspanningscenario.

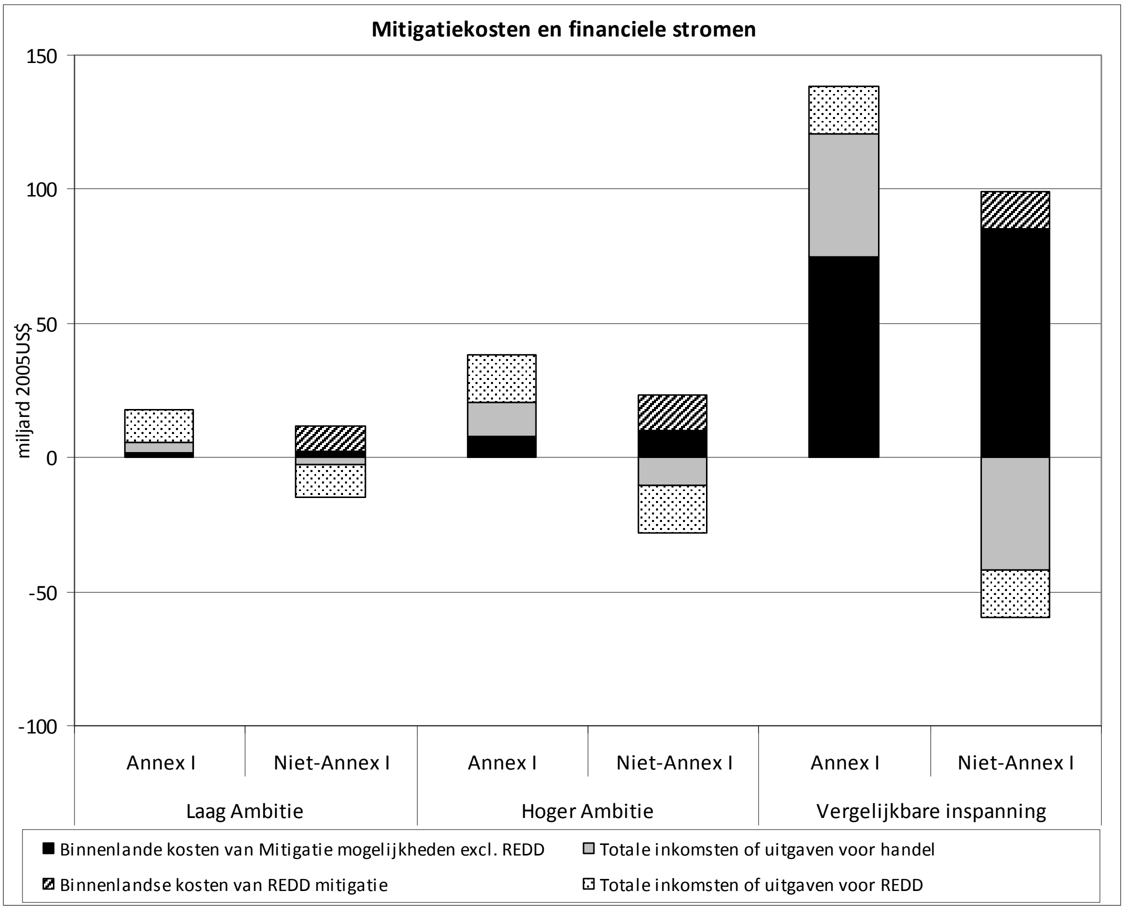
5. Het in evenwicht brengen van vraag en aanbod op de koolstofmarkt en haar rol bij het bepalen van de kosten voor ontwikkelde landen en ontwikkelingslanden

Rusland en Oekraïne fungeren als de dominante verkopers van emissierechten op de koolstofmarkt door verkoop van de 'hot air'. De hoeveelheid 'hot air' op de koolstofmarkt heeft nadelige gevolgen voor de niet-Annex I landen. De andere Annex I landen, in het bijzonder de VS en de EU, fungeren vooral als kopers op de koolstofmarkt.

- De geschatte koolstofprijzen zijn 4 en 15 US$/ton CO_2eq voor het lage en hogere ambitie scenario en 58 US$/ton CO_2eq voor het vergelijkbare inspanningsscenario, wat als vrij laag kan worden beschouwd. Dit is het cumulatieve effect van de volgende oorzaken:
    - De conservatieve ECN MAC-curve leidt tot relatief lage NAMA emissiereducties van 4-8% voor de niet-Annex I landen. Er zijn ook enkele niet-Annex I regio's zonder (in de studie gebruikte) NAMA zoals het Midden-Oosten waarvoor lage of geen binnenlandse reductiedoelstellingen zijn aangenomen waardoor een groot deel van hun reductiepotentieel via de koolstofmarkt verhandeld kan worden.
    - Het toestaan van 'banking' van 'hot air' uit de Kyoto periode (door Rusland en Oekraïne) resulteert in het vrijkomen van 1.1-1.3 $GtCO_2$ 'hot air' op de markt in 2020 waardoor de prijs lager wordt.
    - Nieuwe 'hot air' die wordt veroorzaakt door lage post-2012 doelstellingen in 2020 voor Rusland en Oekraïne voor de lage en hogere ambitie scenario zorgen voor een verdere stijging van het aanbod van emissierechten.
- De meeste Annex I landen (met uitzondering van Rusland, Oekraïne en Wit-Rusland) zullen optreden als kopers op de internationale koolstofmarkt. De EU en de VS zijn de dominante kopers op de markt met een totaal aandeel in de vraag van ongeveer 80-90%. Deze Annex I landen realiseren nog steeds minstens 50% van de totale reducties in eigen land en deze fractie neemt toe voor het hoge ambitie scenario en vergelijkbare inspanningscenario.
- Rusland, Oekraïne en Wit-Rusland profiteren van de baten uit handelsactiviteiten door verkoop van een deel van de opgespaarde 'hot air' uit de eerste verbintenisperiode en de verkoop van nieuwe 'hot air'. Rusland heeft een aandeel van 40-50% van het totale aanbod van emissierechten. Zelfs voor het vergelijkbare inspanningsscenario waarin Rusland een reductiedoelstelling t.o.v. 1990 heeft die ongeveer uitkomt op de baseline bedraagt het aandeel 40%. Oekraïne heeft een aandeel van ongeveer 20%.
- De niet-Annex I landen als groep zijn verkopers met een aandeel van het totale aanbod van 30% voor het lage en hogere ambitie scenario en 40% voor het vergelijkbare inspanningsscenario. China treedt op als de dominante verkoper van emissierechten met een aandeel van 6-12% en een nog hogere waarde in het vergelijkbare inspannings-scenario.
- Voor het lage ambitie scenario zien we inderdaad dat de meeste niet-Annex I regio's fungeren als de verkopers op de koolstofmarkt. Voor het hogere ambitie en vergelijkbare inspanningsscenario zijn sommige regio's (namelijk Mexico, Brazilië en Zuid-Afrika voor het hogere ambitie scenario) kopers van emissierechten.
- De emissiehandel in 'hot air' tussen Rusland, Oekraïne en andere Annex I landen leidt tot vermindering van emissiehandel met niet-Annex I landen. Het niveau van binnenlandse reducties (na emissiehandel en CDM) voor Annex I landen wordt hierdoor beïnvloed. In deze studie zijn de Annex I reducties verlaagd van 30% tot ongeveer 27% onder het 1990 niveau voor het vergelijkbare inspanningsscenario terwijl in eerder werk ongeveer 23% was.

Annex I landen (inclusief Rusland en Oekraïne) vragen nu slechts een bedrag aan emissierechten uit compensatie mechanismen gelijk aan 3% van hun uitstoot in 1990 terwijl dit in eerder werk 7% was. Niet-Annex I landen reduceren (na emissiehandel en CDM) hun uitstoot met ongeveer 18% ten opzichte van de baseline (eerder werk: 20%).

- Grote financiële stromen van Annex I naar niet-Annex I gaan via de koolstofmarkt. In het lage en hogere ambitie scenario zijn voor de Annex I regio's de totale uitgaven aan emissiehandel hoger dan de kosten voor binnenlandse reducties (zie figuur S.2). Voor het vergelijkbare inspanningsscenario zijn de totale uitgaven lager dan de binnenlandse kosten die ongeveer 40% van de totale kosten voor Annex I regio's zijn.
- Voor de niet-Annex I regio's zijn de totale inkomsten van emissiehandel hoger dan de binnenlandse kosten wat resulteert in winsten in het lage en hogere ambitie scenario terwijl voor het vergelijkbare inspanningsscenario de totale inkomsten ongeveer de helft van de binnenlandse kosten zijn.



Figuur S.2. Mitigatiekosten en de financiële stromen in de verschillende scenario's

6. De reductiekosten van de REDD financiering buiten de koolstofmarkt

Annex I landen financieren 80% van de REDD activiteiten in niet-Annex I landen. Als dit tegen de REDD marktprijs wordt gedaan zijn de kosten ongeveer 18 miljard US$ voor de Annex I landen terwijl de niet-Annex I landen ondanks de 20% eigen bijdrage rond de 4 miljard US$ verdienen in 2020. Dit leidt tot een halvering van de emissies van ontbossing.

In de berekeningen wordt verondersteld dat REDD activiteiten additioneel zijn en de financiële stromen onafhankelijk zijn van de financiële stromen in de koolstofmarkt.

- REDD reductie is een optie die relatief lage kosten met zich meebrengt in het vergelijkbare inspanningsscenario. Door de lage koolstofprijs in het lage en hogere ambitiescenario is dit in deze scenario's niet het geval.

- De gemiddelde reductiekosten van REDD voor het lage en hogere ambitie scenario (ongeveer 7-8 US $/ton) zijn hoger dan de gemiddelde reductiekosten van de (gebruikte) niet-REDD reductiemogelijkheden (ongeveer 1-3 US$/ ton). Deze gemiddelde reductie-kosten van REDD (ongeveer 8 US$/ ton) zijn ook lager dan de gemiddelde reductiekosten van de niet-REDD reductiemogelijkheden voor het vergelijkbare inspanningsscenario (ongeveer 16 US$/ ton).

We hebben twee opties voor de financiering van de REDD: (1) tegen de REDD marktprijs en (2) tegen de marginale reductiekosten.

- De REDD marktprijs is hoger dan de gemiddelde marginale reductiekosten voor niet-Annex I regio's. Bij de REDD projecten die rechtstreeks worden gefinancierd tegen de REDD marktprijs zijn de totale kosten (totale binnenlandse kosten plus de winsten uit de handel) voor niet-Annex I regio's negatief (-2,5 tot 4 miljard US 2005 dollar voor de drie scenario's). Voor Annex I regio's zijn de kosten ongeveer 12 tot 18 miljard $US\$_{2005}$.
- Als de REDD projecten rechtstreeks worden gefinancierd tegen de marginale reductie-kosten dan zijn de binnenlandse kosten van REDD voor niet-Annex I landen om hun doelstelling van 20% te halen ongeveer 0,5 tot 1 miljard $US\$_{2005}$ en de kosten voor Annex I landen ongeveer 9 miljard en 13 miljard $US\$_{2005}$.

- Een aanzienlijke hoeveelheid REDD activiteiten (als onderdeel van de 80% externe financiering) wordt momenteel niet ondersteund door de reductietoezeggingen van Annex I landen (0.5-1.1 GtCO2).

7. Mitigatiekosten en financiële stromen gerelateerd aan REDD en emissiehandel en hun rol in het bepalen van kosten voor ontwikkelde en ontwikkelingslanden

In alle scenario's worden de kosten voor Annex I landen grotendeels bepaald door de aankoop van emissierechten op de koolstofmarkt of door REDD financiering (80% van de totale kosten voor het lage ambitie scenario en 40% voor vergelijkbare inspanning).

- Het financieren van REDD is naast de aankoop van emissierechten een belangrijke kostenpost voor Annex I landen. Deze twee posten bepalen samen met de binnenlandse kosten de totale mitigatiekosten. In het lage en hogere ambitie scenario bepalen de uitgaven op de koolstofmarkt en de financiering van REDD 80% van de totale mitigatiekosten van de Annex I landen en 40% in het vergelijkbare inspanningsscenario. De hogere percentages in het lage en hogere ambitie scenario worden veroorzaakt door de relatief lage niet-Annex I reducties gelijk aan 4-8% t.o.v. de baseline en de aanwezigheid van goedkope mitigatie mogelijkheden in deze regio's.
- De kosten voor de in Annex I regio's variëren van 18 miljard tot 138 miljard US$. Voor niet-Annex I regio's in de lage en hogere ambitie scenario's zijn de totale kosten negatief (-3 tot -5 miljard $US\$_{2005}$) terwijl voor het vergelijkbare inspanningsscenario de kosten 40 miljard $US\$_{2005}$ zijn.
- Grote financiële stromen gaan via de koolstofmarkt en via REDD reducties van Annex I regio's naar niet-Annex I regio's (15 tot 60 miljard $US\$_{2005}$) voor de drie scenario's. Deze stromen overtreffen de extra binnenlandse kosten van de extra reducties die door Annex I landen ter compensatie gebruikt worden en zijn gelijk aan 10 tot 30 miljard $US\$_{2005}$. Dit resulteert in netto baten van de emissiehandel van 5 tot 30 miljard $US\$_{2005}$.
- We hebben de financiële stromen van REDD vergeleken met die van de koolstofmarkt en concluderen dat in het lage ambitiescenario de netto winsten uit REDD voor niet-Annex I landen veel hoger zijn dan de netto winsten uit de koolstofmarkt. Voor het hogere ambitiescenario en het vergelijkbare inspanningsscenario zijn de netto winsten uit REDD veel lager (ongeveer 80%) dan de netto winsten uit de koolstofmarkt.

8. De effecten van de economische crisis

Door de economische crisis dalen de koolstofprijzen in alle scenario's. De Annex I landen hebben veel lagere kosten tijdens de crisis en deze zijn niet alleen het gevolg van de lagere prijs maar ook van de lagere reductie-inspanning die nodig is (lagere baseline, maar hetzelfde doel). Voor de niet-Annex I regio's zijn de binnenlandse kosten enigszins

lager maar daarbij zijn de inkomsten uit de emissiehandel van emissierechten ook lager wat uiteindelijk tot een verlaging van hun winsten leidt.

- De economische crisis leidt tot een afname van de baseline emissies (zonder klimaatbeleid) van ongeveer 10% in 2010 en 8% in 2020 ten opzichte van de baseline zonder de crisis. Dit is gebaseerd op onze veronderstelling dat de crisis zal leiden tot een vermindering van de groei van het BBP in 2009 en 2010 en een convergentie naar het oorspronkelijke groeipad (dus niet oorspronkelijke baselines) na deze periode. Als echter een hogere groei na de crisis wordt aangenomen zal het effect op de lange termijn natuurlijk veel kleiner zijn (en zal de crisis alleen effect hebben op de periode van 2009 tot mogelijk 2020) en de verschillen in emissies zullen tot nul convergeren na 2020.
- Het overschot van AAU's of 'hot air' in de eerste verbintenisperiode stijgt met een extra 20% tot en met 3 GtCO_2eq welke in totaal ongeveer 8% van de Annex I emissies in 1990 vertegenwoordigt. De nieuwe 'hot air' in 2020 is hoger onder het crisis scenario en neemt toe tot 1,4 en 1,1 GtCO_2eq per jaar in de lage en hogere ambitie scenario's. Het vergelijkbare inspanningsscenario leidt niet tot nieuwe 'hot air' voor Oekraïne en Rusland omdat hun vergelijkbare inspanningsreductiedoelstellingen onder hun baseline emissies komen.
- De koolstofprijs daalt met een extra 12-16% voor het lage en hogere ambitie scenario en met 30% voor het vergelijkbare inspanningsscenario.
- De reductiekosten van de Annex I als groep dalen met ongeveer 30-35% voor het lage en hogere ambitie scenario's en met 65% voor het vergelijkbare inspanningsscenario.
- In vergelijking met het scenario zonder crisis daalt de emissiehandelsstroom in tonnen CO_2eq van niet-Annex I regio's naar de Annex I regio's (ter compensatie) met 20-25% voor het lage en hogere ambitie scenario's en 97% voor het vergelijkbare inspanningsscenario. In combinatie met de lagere prijzen leidt dit tot een daling van de financiële stromen van ongeveer 35-40% voor het lage en hogere ambitie scenario's en 97% voor het vergelijkbare inspanningsscenario. Voor de niet-Annex I vermindert de daling van de emissiehandels- en financiële stromen uiteindelijk hun winsten. Deze winsten compenseren echter nog steeds de binnenlandse kosten.
- De wereldwijde reductiekosten worden verminderd met ongeveer 25-30% in het lage en hogere ambitie scenario en met 45% voor het vergelijkbare inspanningsscenario.

9. Voorbehouden voor deze studie:

- De resultaten (d.w.z. emissiereducties en kosten indicatoren) zijn sterk afhankelijk van het model en de parameter instellingen. Bijvoorbeeld de veronderstellingen over de baselines, 'hot air' en 'banking' en reductiekostencurven (zoals geanalyseerd voor Annex I en niet-Annex I als groep in den Elzen et al. 2009b) en de interpretatie van de post-Kyoto landgebruik boekhoudkundige regels (in de huidige studie hanteren we dezelfde regels als die het Kyoto protocol worden toegepast). Daarbij kunnen de reductiepotentiëlen die verwerkt zijn in de ECN MAC curven gezien worden als conservatief en mogen dus de reducties van de NAMA strategieën en de corresponderende reducties ten opzichte van de baseline ook als conservatieve schattingen worden beschouwd.

List of acronyms and abbreviations

AAUs	Assigned Amount Units
ACESA	American Clean Energy and Security Act (Waxman-Markey)
AD	Avoided Deforestation
ADC	Advanced Developing Countries
ARD	Afforestation, Reforestation and Degradation
AR4	IPCC Fourth Assessment Report
AWG-KP	Ad Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol
AWG-LCA	Ad Hoc Working Group on Long-term Cooperative Action under the Convention
CDM	Clean Development Mechanism
CO_2	Carbon Dioxide
COP	Conference of the Parties
DC	Developing Countries
ECN	Energy Research Centre of the Netherlands
EDGAR	Emission Database for Global Atmospheric Research
EE	Energy Efficiency
EMF	Energy Modelling Forum
EU	European Union
FAIR	Framework to Assess International Regimes for the differentiation of commitments
FM	Forest Management
FSU	Former Soviet Union
G4M	Global Forestry Model (former DIMA) of IIASA
GCOMAP	Generalized Comprehensive Mitigation Assessment Process Model
GDP	Gross Domestic Product
GHG	Greenhouse gas
$GtCO_2eq$	Giga tons of Carbon Dioxide Equivalent
GTM	Global Timber Model
GW	Giga Watt
IAMC	Integrated Assessment Modelling Consortium
IEA	International Energy Agency
IET	International Emissions Trading
IIASA	International Institute for Applied Systems Analysis
IMAGE	Integrated Model to Assess the Global Environment
IPCC	Intergovernmental Panel on Climate Change
JI	Joint Implementation
JRC	Joint Research Centre
LDC	Least Developed Country
LULUCF	Land-Use, Land-Use Change and Forestry
NAMA	Nationally Appropriate Mitigation Action
MAC	Marginal Abatement Costs
MER	Market Exchange Rate
$MtCO_2eq$	Mega tons of carbon dioxide (CO_2) equivalent
MW	Megawatt
OECD	Organisation for Economic Cooperation and Development
POLES	Prospective Outlook on Long-term Energy Systems
ppm	parts per million
QELRO	Quantified Emission Limitation and Reduction Objective
RCP	Reference Concentration Pathways
RE	Renewable Energy
REDD	Reducing Emissions from Deforestation and Degradation
SD-PAMs	Sustainable Development Policies and Measures
SRES	Special Report on Emissions Scenarios
TIMER	Targets Image Energy Regional model

UNFCCC	United Nations Framework Convention on Climate Change
WM bill	Waxman-Markey bill
WRI	World Resource Institute

1 Introduction

The EU, the G8 group[27] of nations and a large number of individual countries have acknowledged the importance that global temperature increase does not exceed 2°C relative to pre-industrial levels. Many of these countries including the EU have made the global temperature increase limit of 2°C their objective of their climate policy (see EC, 2006). Greenhouse gas (GHG) concentrations in the atmosphere must be stabilised below 450 ppm CO_2equivalent (CO_2eq) to have a probability of more than 50% of meeting this target (based on the uncertainty in climate sensitivity) (Fisher et al., 2007; Meinshausen et al., 2009). In addition, the IPCC indicated that in order to achieve low stabilisation targets, Annex I countries [28]as a group will have to reduce their emissions to within a range of 25% to 40% below 1990 levels by 2020 (Gupta et al., 2007) (IPCC Box 13.7) if emissions in non-Annex I countries[29] deviate substantially from their baseline. The IPCC authors of Box 13.7 elaborated further on the issue of substantial deviation from the baseline by analysing the underlying studies and the literature obtained after the completion of the IPCC report (den Elzen and Höhne, 2008). They concluded that in addition to the emission reduction of 25-40% in Annex I countries, emissions in non-Annex I countries need to be reduced by 15% to 30% below the baseline − i.e. below the most current business-as-usual greenhouse gas emission projections − in order to meet 450 ppm CO_2eq.

At the time of writing (August 2009), climate negotiations were well underway in advance of the Copenhagen Conference of Parties and the positions of the parties (countries) were evolving in terms of their proposed reduction targets for greenhouse gas (GHG) emissions, as summarised in an informal note published by the UNFCCC secretariat (www.unfccc.int), see Table 2.1. Many uncertainties still exist about these reduction proposals and the possible outcome of Copenhagen in terms of GHG emission reductions of the Annex I and non-Annex I countries.

By using three alternative scenarios, this report sketches out various potential developments in international climate policy. The first two scenarios refer to the Annex I countries and their proposals concerning emission reduction commitments; the so-called “pledges” including low and high reduction options (see Table 2.1). For the non-Annex I countries, we have assumed different levels of possible domestic mitigation action, which could be implemented through Nationally Appropriate Mitigation Actions (NAMAs). The level of ambition of the NAMAs depends on the Annex I reduction ambition. First, for political reasons and second, because the implementation of the these NAMAs – which can consist of both unilateral and supported action, will partly depend on the level of support by Annex I in terms of finance, technology and capacity building. NAMAs may also be developed under the carbon market, but this option is not covered in this report.

The third scenario is based on reductions for the Annex I and non-Annex I countries required in line wit the long-term concentration target of 450 ppm CO_2eq. For the Annex I countries we have assumed aggregate reduction of 30% below 1990 levels by 2020, as described in den Elzen et al. (2009a). The reductions for the individual Annex I countries are based on the calculated, averaged reduction targets from six approaches currently in use to assess the *comparability* of Annex I country GHG mitigation efforts[30]. The non-Annex I countries are assumed to meet an aggregate reduction of 16% below baseline, as described in Bole et al. (2009). This 16% reduction below baseline for non-Annex I countries as a group is based on the

[27] The G8 also supported the formulated reduction targets by 2050 in their latest declaration (July 2009), i.e. at least a 50% reduction of global emissions and 80% for emissions of the developed countries. By accepting the 2°C target they also acknowledged that global emissions must peak as soon as possible.
[28] Developed countries
[29] Developing countries
[30] Such as equal reduction below a baseline, equal MAC and equal mitigation costs, as described in the *Comparable Effort Study* of den Elzen et al. (2009a). The reductions by different Annex I countries must meet an aggregate reduction of 30% below 1990 levels by 2020.

more advanced countries (ADCs)[31] in the group reducing their emissions 20% below baseline and those on a lower developmental level (OtherDCs) reducing emissions by 10%, while the least developed countries (LDCs) would be exempt from any emission reduction efforts (den Elzen et al., 2009a). This “comparable effort” scenario has a reasonable chance (more than 50%) of meeting the long-term 2°C temperature threshold, whereas the emission reductions under the low and higher ambition scenarios are insufficient to limit warming to 2 °C.[32]

The three post-2012 climate policy scenarios are characterised as follows:

1. **Low ambition scenario**: based on the lower end of the proposed ranges of emission reduction targets for individual Annex I countries and low-ambition mitigation actions in non-Annex I regions, i.e. 25% of the reduction potential in energy-efficiency, renewables, non-CO_2 reduction options and avoided deforestation (REDD). Non-Annex I actions may be (partially) financed by Annex I[33].
2. **Higher ambition scenario**: based on the higher proposed reduction targets for individual Annex I countries and more ambitious mitigation actions in non-Annex I regions, i.e. 50% of the reduction potential in energy-efficiency, renewables, non-CO_2 reduction options and REDD.
3. **Comparable effort scenario**: reduction targets for Annex I region based on comparable effort approaches, assuming that the aggregated Annex I reduction target is equal to 30% below 1990 levels. Non-Annex I countries reductions meet an aggregate reduction of about 16% below baseline excluding LULUCF[34] CO_2, and around 20% below baseline emissions including LULUCF CO_2, due to an additional REDD[35] equivalent to the higher ambition scenario, with higher reductions compared to baseline for advanced developing countries with high deforestation emissions (i.e. 42% for Brazil, 26% for the rest of South America and 25% for Mexico), and 20% below baseline emissions for Indonesia.

In addition, two variants are considered for each scenario: including or excluding REDD and LULUCF CO_2 emissions. Furthermore, for the scenarios including REDD and LULUCF CO_2 emissions, we assume that non-Annex I regions will finance 20% of the NAMA measures of REDD domestically and the remaining 80% will be financed by Annex I regions or other non-Annex I regions at the marginal costs or at the REDD market price. Taken together these variants (including the cases marginal costs and market price) yielded nine scenarios for the model analysis, which we will discuss in more detail in Chapter 3.

The main objective of this report is to analyse the emissions and cost implications for the Annex I and non-Annex I countries of the low ambition scenario, the higher ambition scenario and the comparable effort scenario. It also analyses the impact on the supply and demand side of the carbon market, and the resulting carbon price and total abatement costs at the level of regions (including the major regions of the USA, EU, Japan, Russia, Brazil, India and China), as well as the REDD financing outside of the carbon market.

The report is divided into four main parts and 9 chapters as follows:

- The first part (Chapters 2, 3 and 4) includes the background information of the pledges for Annex I countries and possible NAMAs for non-Annex I countries, detailed descriptions of the scenarios and a description of the modelling framework and its main model assumptions

[31] ADCs: Mexico, rest of Central America, Brazil, rest of South America, South Africa, Kazakhstan region, Turkey, Middle East, Korea region and China; OtherDCs: Northern Africa region, Middle East, India, rest of Southern Asia, Indonesia region and rest of South-East Asia; LDCs: Western Africa, Eastern Africa and rest of South-Africa region

[32] Rogelj et al. (2009) have analysed reductions under the pledges for the Annex I countries and some advanced non-Annex I countries up to the date of submission (June 2009) and how they collectively compare to the goal of limiting warming to 2 °C above pre-industrial levels. They concluded that these national targets offer virtually no chance of limiting warming to 2 °C.

[33] The question of the source of finance for non-Annex I actions (apart for REDD financing) is ignored in this report.

[34] Land Use, Land-use Change and Forestry

[35] Reduction of Emissions from Deforestation and Degradation

- The second part (Chapters 5 and 6) analyses the emissions reductions for the scenarios excluding and including REDD/LULUCF CO_2 emissions, the abatement costs excluding the costs of financing REDD and the abatement costs associated with REDD for the Annex I regions (Chapter 5) and non-Annex I regions (Chapter 6). The underlying baseline (without climate policy) does not account for the impact of the economic crisis.
- The third part (Chapter 7) discusses the financing options for REDD, the financing costs and the abatement costs associated with REDD for both Annex I and non-Annex I regions
- The fourth part (Chapter 8) includes an analysis the GHG emission reductions and costs for the three scenarios, but with a baseline that accounts for the impact of the economic crisis. Chapter 9 describes the limitations of the study, and Chapter 10 contains the conclusions of the study.

2 Background of the scenarios

2.1 Annex I pledges[36]

Various Annex I countries have announced their pledges for national reduction targets. Table 2.1 briefly describes the proposed pledges of the major Annex I countries. For those countries that proposed a reduction target independent of an international agreement, we used such a target for the low ambition scenario; in other words the low pledge corresponds to the unilateral proposal from different countries. For the higher ambition scenario we used either the proposed target in case of a multilateral agreement or the more ambitious target proposed by individual countries.

Table 2.1. Information relating to possible quantified emission limitation and reduction objectives (QELROs) of the low-pledge and high-pledge commitments of individual Annex I countries for the year 2020 (based on an informal memorandum of the UNFCCC secretariat published in August 2009, see www.unfccc.int)

Party (in alphabetical order)	***Information relating to possible QELROs by 2020***			***Inclusion of LULUCF CO_2***	***Inclusion of mechanisms***	***Status***
	Low	high	reference year			
Australia	−5%	−25%, which includes −20% cap and trade and −5% government purchases of international credits (REDD)	**2000** (−25% relative to 1990; without LULUCF CO_2 the target would be about −5% to −10% compared to 1990 levels)[a]	Yes	Yes	Officially announced; Rudd 4 May 2009
Belarus	−5%	−10%	1990	TBD	Yes	Under consideration
Canada	−20%	−20%	**2006** (+ 23% compared to 1990 with LULUCF CO_2, −3% without LULUCF CO_2)	TBD	TBD	Officially announced
European Community (EU-27)	−20%	−30%	1990	No for −20% Yes for −30%	Yes[b]	Adopted by legislation.
Iceland	−15%	−15%	1990	Yes	TBD	
Japan	−15%	−15%[c]	**2005**	No	No	Officially announced
Liechtenstein	−20%	−30%	1990	No	Yes	Officially announced
Monaco	−20%	−20%	1990	TBD	TBD	Officially announced
New Zealand	−10%	−20%	1990	Yes	Yes	Officially announced
Norway	−30%	−30%	1990	Yes[d]	TBD	Officially announced
Russia	−10%	−15%	1990	TBD	TBD	Officially announced
Switzerland	−20%	−30%	1990	Yes	Yes	Consultation in progress
Ukraine	−20%	−20%	1990	TBD	Yes	Under consideration

[36] Part of the text in this section is from the supplementary material of Rogelj et al. (2009), presenting an overview of the pledges of Annex I and non-Annex I countries as of June 2009, and from the informal memorandum of the UNFCCC secretariat published in August 2009, see www.unfccc.int.

USA	0%	−17% to −23% Which includes: −3% cap and trade and add. national policies −14% purchases of REDD Max −6% other additional purchases of international credits	1990	Yes	Yes	Waxman & Markey bill as of May 19 (WRI)

Abbreviations: LULUCF = land use, land-use change and forestry, TBD = to be determined, QELROs = Quantified Emission Limitation and Reduction Objectives.

[a] The national UNFCCC reported GHG emissions including LULUCF CO_2 of 524 $MtCO_2$ in 2000, so a 25% reduction would lead to 393 $MtCO_2$, which is about 4% below 1990 levels excluding LULUCF CO_2 (416 $MtCO_2$), and also about 24% below 1990 levels including LULUCF CO_2 (516 $MtCO_2$)

[b] The European Community envisages a restricted use of the mechanisms for the range of possible QELROs.

[c] The new Japanese government is considering a conditional 25% target, which is not included in this study,

[d] The LULUCF sector is included according to the existing rules under the Kyoto Protocol. If the rules change, Norway's national goal will change accordingly.

In March 2007, the **European Union (EU)** decided to adopt a unilateral target of reducing its GHG emissions by 20% compared to 1990 levels by the year 2020, and declared its willingness to reduce emissions by 30%. This would constitute the EU's contribution to a global and comprehensive agreement for the period beyond 2012, provided that other Annex I countries commit themselves to comparable emission reductions and that economically more advanced developing countries also contribute proportionally according to their responsibilities and respective capabilities. By adopting a 20% unilateral target and proposing a 30% target as part of a broader post-2012 agreement, thus indicating the level of commitments it is willing to adopt, the EU has moved ahead of the Ad Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol (AWG-KP) process and has put pressure on other Annex I countries to follow suit. However, the EU has also agreed to allow its Member States to deviate from the adopted 30% reduction target. Consequently, the EU in its Council Conclusion[37] the EU "*STRESSES that the overall target for developed countries must be distributed in a manner that is fair and ensures the comparability of efforts*". Criteria such as capability to pay, reduction potential, early action and population trends should guide the distribution of the overall target, according to the conclusions. Note that the options presented by the EU Commission to distribute the 30% reduction target by 2020 for Annex I countries do not take the LULUCF CO_2 sector into account.

On 18 November 2008, President Elect Barack Obama (**USA**) declared during a speech for the Bi-Partisan Governors Climate Summit that he intended to establish an economy-wide cap-and-trade system with stringent annual targets that would set the USA on a course to reduce emissions to their 1990 levels by 2020, and to 80% below the same reference by 2050. On May 2009 the American Clean Energy and Security Act (ACESA) (entitled H.R. 2554) was released, sponsored by Chairmen Waxman and Markey[38]. The World Resource Institute (WRI) (Larson and Heilmayr, 2009) has analysed the reductions that could be achieved by the ACESA. Their main findings are:

- The pollution caps proposed in the ACESA would reduce total GHG emissions 15% below 2005 levels by 2020 and 73% below 2005 levels by 2050.
- When all complementary requirements of the ACESA are considered in addition to the caps, (i.e. additional national policies and purchases of REDD[39]), GHG emissions would be reduced 28% below 2005 levels by 2020 and 75% below 2005 levels by 2050 (although it is not certain that these additional reductions will all be achieved).

[37] http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/envir/106429.pdf

[38] Waxman, H., E. Markey (2009). Discussion draft of climate and energy legislation from House Energy and Commerce Committee Chairman Henry Waxman (D ‐ CA) and Energy and Environment Subcommittee Chairman Edward Markey (D ‐ MA). http://energycommerce.house.gov/Press_111/20090331/acesa_discussiondraft.pdf

[39] Note that companies may also use also REDD credits to meet the emission caps only (i.e. 15% below 2005 levels by 2020).

- When additional potential emission reductions − i.e. complementary requirements such as REDD and additional reductions such as 1.25 offset requirement for international offsets[40] − are considered, the ACESA could achieve maximum reductions of up to 33% below 2005 levels by 2020 and up to 81% below 2005 levels by 2050. The actual amount of reductions will depend on the quantity of international offsets used for compliance.
- The ACESA's proposed pollution caps result in reductions of total GHG emissions of 15% below 2005 levels by 2020. This is less than the 17% reduction from 2005 levels that the Waxman Markey Discussion Draft as released would have achieved.

Figure 2.1 shows the reductions on a graph and Table 2.2 shows them in a table. A full description of the methods and assumptions used for this analysis can be found on page 4 of the WRI report. The low pledge reflects the objective mentioned by President Obama (return to 1990 levels), the high end is taken from the economy-wide reduction target as contained in the ACESA (H.R. 2554) bill of −17% to −23% below 1990 levels, which is compiled as follows: −3% cap-and-trade and additional national policies, −14% purchases of REDD, and a maximum of −6% other additional purchases international credits (see Table 2.2). Note that ACESA is not a formal pledge of the USA. So far, the USA has not made a formal pledge. Because much depends on the further development of that bill[41], the implied reductions compared to 1990 could be higher or lower than indicated.

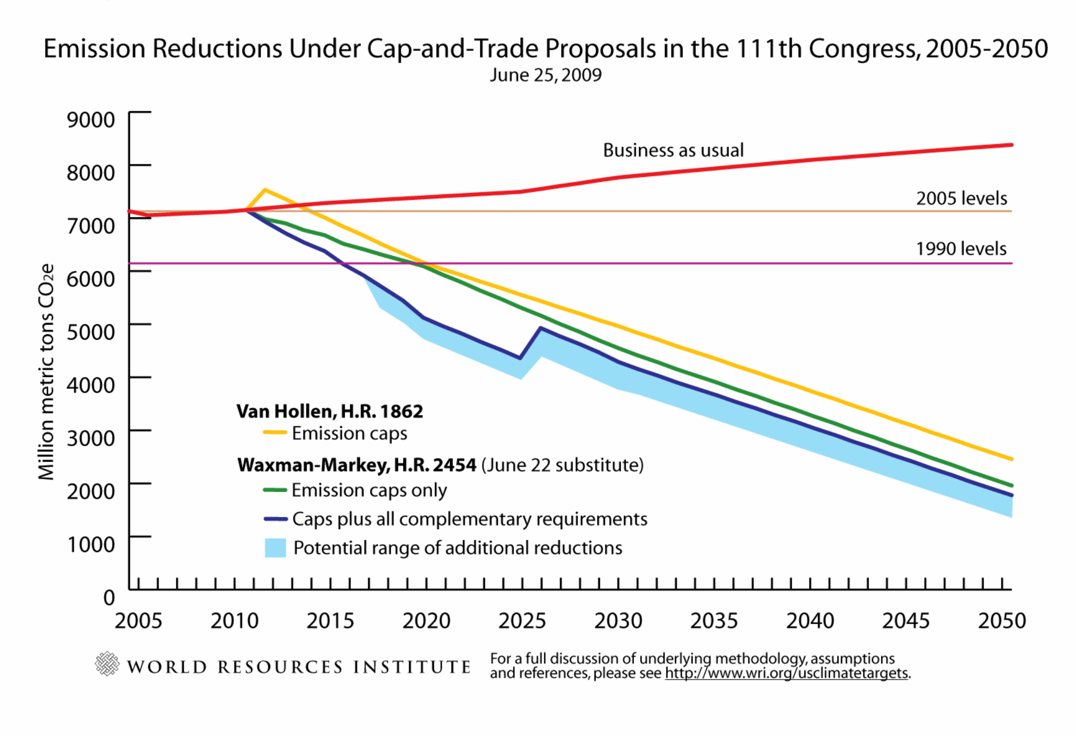


Figure 2.1. Emission Reductions of the USA under Cap-and-Trade Proposals in the 111th Congress, 2005-2050. Source: WRI, Larson and Heilmayr (2009)

[40] If the motivation for discounting is to account for the uncertainty regarding the environmental integrity of offsets, then the discounted reductions cannot be added to the pledge

[41] The next steps for the ACESA will be that the Senate will develop its own bill, likely in the autumn. A 60% majority is needed to pass legislation in Senate. Once this bill passes the Senate, Senate and House bills will be reconciled through "conference" negotiations. Finally, president Obama signs or vetoes the bill.

Table 2.2. Comparison of estimates of total GHG emissions and emission reductions achieved by H.R. 2454 and the Waxman-Markey Discussion Draft (Million tonnes of CO_2eq). Source: WRI, Larson and Heilmayr (2009)

Absolute Emissions										
	H.R.2454					Waxman Markey Discussion Draft				
	2012	2020	2030	2040	2050	2012	2020	2030	2040	2050
Business as usual emissions	7,185	7,390	7,765	8,102	8,379	7,185	7,390	7,765	8,102	8,379
Emissions caps only	6,980	6,095	4,547	3,262	1,961	6,990	5,917	4,565	3,262	1,961
Caps plus all complementary requirements	6,934	5,125	4,287	3,040	1,779	6,938	4,951	4,305	3,040	1,779
Potential range of additional reductions	6,934	4,750	3,809	2,621	1,384	6,438	4,451	3,702	2,496	1,259
Percent change from 2005 emissions										
	H.R.2454					Waxman Markey Discussion Draft				
	2012	2020	2030	2040	2050	2012	2020	2030	2040	2050
Business as usual emissions	1	4	9	14	18	1	4	9	14	18
Emissions caps only	-2	-15	-36	-54	-73	-2	-17	-36	-54	-73
Caps plus all complementary requirements	-3	-28	-40	-57	-75	-3	-31	-40	-57	-75
Potential range of additional reductions	-3	-33	-47	-63	-81	-10	-38	-48	-65	-82
Percent change from 1990 emissions										
	H.R.2454					Waxman Markey Discussion Draft				
	2012	2020	2030	2040	2050	2012	2020	2030	2040	2050
Business as usual emissions	17	20	26	32	36	17	20	26	32	36
Emissions caps only	14	-1	-26	-47	-68	14	-4	-26	-47	-68
Caps plus all complementary requirements	13	-17	-30	-51	-71	13	-19	-30	-51	-71
Potential range of additional reductions	13	-23	-38	-57	-77	5	-28	-40	-59	-80

By 2009, the other Annex I countries Australia, Belarus, Canada, the European Community (and its Member States), Iceland, Japan, New Zealand, Norway, Russia, Switzerland, Ukraine followed by clarifying their own commitments to reducing GHG emissions in a Joint Submission[42] under amendments to the Kyoto Protocol (UNFCCC, 2009a) and under a new agreement or protocol to be decided in Copenhagen in December (UNFCCC, 2009b). These commitments are summarised in Table 1, which shows the values or ranges of these pledges, the base year to which they refer, and information on their status. We briefly describe the commitments of the most important emitting countries below.

The **Australian** Government has made a policy commitment to unconditionally reduce Australia's emissions by 5% below 2000 levels by 2020 (unilateral reduction target). Should the parties reach a global agreement that includes commitments by all major economies, including key developing countries, to restrain emissions and by all Annex I countries to take on comparable emissions reduction targets, Australia will commit itself to reduce emissions by up to 15% below 2000 levels by 2020. Australia will commit, therefore, to a medium-term (2020) target to reduce its GHG emissions by between 5% and 15% below 2000 levels. Australia's national ambition for 2020 represents a 12 to 22% reduction on Australia's target for 2008-2012 (FCCC/KP/AWG/2009/ MISC.1/Add.2, page 3). In May 2009, Australia[43] announced that it would increase its target to 25% if there is a "comprehensive global action capable of stabilising CO_2eq concentrations at 450ppm CO_2eq or lower. This requires a clear pathway to achieving an early global peak in total emissions, with major non-Annex I economies slowing the growth and then reducing their emissions, advanced economies taking on reductions and commitments

[42] See submission of Australia on behalf of Australia, Belarus, Canada, European Community and its Member States, Iceland, Japan, New Zealand, Norway, Russian Federation, Switzerland and Ukraine (2009). Information relating to possible quantified emissions limitation and reduction objectives as submitted by Parties, Submission to the AWG LCA and AWG KP, 5 May 2009, http://unfccc.int/resource/docs/2009/awg8/eng/misc08.pdf

[43] Joint Media Release with the Treasurer Wayne Swan and the Minister for Climate Change and Water, Penny Wong, 'A New Target for Reducing Australia's Carbon Pollution' 04 May 2009, http://www.pm.gov.au/media/Release/2009/media_release_0966.cfm.

comparable to Australia, and access to the full range of international abatement opportunities through a broad and functioning international market in carbon credits[44]."

In the medium term, the government of **Canada** is committed to a 20% reduction of Canada's total GHG emissions by 2020 relative to 2006 levels. This equals a reduction in annual emissions of approximately 145 $MtCO_2eq$ by 2020. This commitment has been developed as a domestic goal on Canada's long-term emission reduction pathway. It does not assume or provide for significant use of the Kyoto mechanisms, in particular emission trading under Article 17. In the long term (by 2050), the government is committed to reducing Canada's GHG emissions by 60-70% below 2006 levels (FCCC/KP/AWG/2007/MISC.4/Add.1, page 5 and further elaboration by Canada).

On 10 June 2009, **Japan** announced its target of reducing its GHG emissions to 15% below 2005 levels. This is equivalent to a reduction of 9.1% from 1990 emission levels by 2020. Its Kyoto target for the first commitment period 2008-2012 is a 6% reduction relative to 1990 levels. A more ambitious suggestion by the Democratic Party stipulates a 25% reduction relative to 1990. This corresponds to a 30% reduction below 2005. This conditional target is still under consideration by the Japanese government, and therefore not included in this study.

By 2020, **New Zealand** aims to cut its carbon emissions between 10 and 20% below 1990 levels; the government officially announced this tentative target during the international climate negotiations in Bonn in August, with the final target depending on the shape of the broader global climate pact that is under negotiation. In late July 2009, the New Zealand government tentatively announced that it would be likely to achieve a reduction of 15% in 2020, and intended to announce a more official policy target for 2020 during the next stage of international negotiations in Bonn in August[45]. The target would be achieved through domestic emission reductions, the storage of carbon in forests and the purchase of emission reductions from other countries. New Zealand would use the emissions trading scheme (created by 2008) as the main tool to fight climate change, and it was the government's aim to have the scheme finalised by the time of the Copenhagen meeting. New Zealand's long-term target is likely to be a 50% reduction from 1990 levels by 2050. New Zealand's total emissions increased 24% from 1990 to 2008 and amount to the 11th highest emissions per capita globally.

In the joint submissions to the AWG-KP, **Russia** indicated its ambition to stabilise emissions at 10 to 15% below 1990 levels in 2020. The high pledge is consistent with the 15% below 1990 levels indicated by President Medvedev on 19 June 2009, see: Annex I of European Commission report on comparability (http://www.endseurope.com/docs/90729a.pdf).

Ukraine has stated its ambition to reduce emissions with a 2020 and 2050 target below 1990 levels: "Ukraine is ready to commit to the GHGs emissions reduction by 20% by 2020 and by 50% by 2050".[46]

2.2 Potential non-Annex I emission reductions through NAMAs[47]

The scenarios analysed in this report include the realization of a part of the mitigation potential across a range of options in non-Annex I countries, leading to a certain level of emission

[44] The Government has said that up to 5 percentage points of this target could be met by purchasing international credits, such as avoided deforestation credits, by using revenue from their emissions trading system from 2015 onwards.
[45] See: http://uk.reuters.com/article/idUKTRE5790LV20090810, and more general information on New Zealand's 2020 Emissions Target, see: http://www.mfe.govt.nz/publications/climate/nz-2020-emissions-target/html/index.html.
[46] Ukraine (2009). Contribution of Annex I Parties, individually or jointly, to the scale of emission reductions to be achieved by Annex I Parties in aggregate, Submissions by Parties, FCCC/KP/AWG/2009/MISC1/ http://unfccc.int/resource/docs/2009/awg7/eng/misc01.pdf
[47] Part of the text below is from the supplementary material of Rogelj et al. (2009), presenting an overview of the pledges of Annex I and non-Annex I countries as of June 2009.

reductions. These reductions for non-Annex I countries could be mobilized through NAMAs (Nationally Appropriate Mitigation Actions). Parties have proposed[48] that these actions should lead to an appropriate or significant deviation from baseline, and reflect capabilities and national circumstances. They can be differentiated based on different groups of non-Annex I countries. NAMAs could be Sustainable Development Policies and Measures (SD-PAMs), low-carbon strategies including specific energy efficiency policies, e.g. based on existing climate action plans. They could be energy efficiency standards or technology deployment plans. Some Parties have also suggested sectoral trading or programmatic CDM. The revised AWG-LCA negotiation text[49] states that NAMAs can be any actions defined by non-Annex I country Parties, and can include SD-PAMs, technology or efficiency programmes, sectoral targets, REDD and other mitigation activities including agriculture. However, to date no official proposals containing concrete suggestions for which technologies or policy measures could interpreted as NAMAs have been put forward. WRI (2009) contains 'indicative' NAMAs based on national strategies, which are mentioned below.

A classification into three categories of NAMAs has been made by various Parties and researchers (See Figure 2.2):

1. Autonomous action by non-Annex I countries without outside support, i.e. unilateral NAMAs
2. Action undertaken with support from Annex I country Parties, i.e. conditional NAMAs
3. Action that could be partially or fully credited for sale on the global carbon market.

The goal of unilateral and conditional NAMAs is to produce non-Annex I country emissions reductions that are not offsets, but where non-Annex I countries make additional contributions to climate protection.

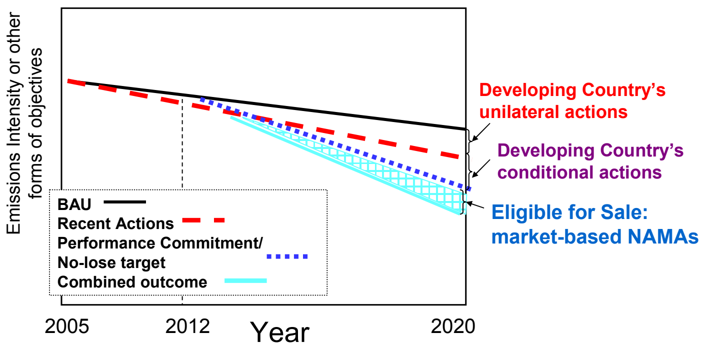


Figure 2.2. Non-Annex I country contribution to GHG mitigation: three categories of NAMAs (Center for Clean Air Policy, 2009)[50]

Next, we present an overview of some of the measures which could be developed as NAMAs. It includes policies that are currently under consideration or have already been adopted by non-Annex I countries, as these could be called 'nationally appropriate'.

Policies under consideration

Many policies that could reduce emissions[51] are being developed or considered. Recent examples include[52]:

- In Brazil:
  - A 3% biodiesel blend is currently mandated and an increase to 4% has been proposed.

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[48] UNFCCC (2009a) *Ideas and proposals on paragraph 1 of the Bali Action Plan. Revised note by the Chair*. FCCC/AWGLCA/2008/16/Rev.1, 15 January 2009.

[49] UNFCCC (2009b). *Revised negotiation text*. FCCC/AWGLCA/2009/INF.1, 22 June 2009.

[50] "NAMAs and the NAMA Registry: Key issues to be resolved for an international agreement at Copenhagen", report presented at the CCAP dialogue workshop in July 2009 (Amsterdam).

[51] If these policies were included in the baseline, then they would not reduce emissions. Here we assumed that most of these policies are going beyond baseline.

[52] Source: New Energy Finance 2009, unless otherwise mentioned. This list is by no means exhaustive and only for illustration purposes.

- Energy efficiency measures aiming at reducing emissions by 30 $MtCO_2$/yr compared to baseline by 2030.
- The National Plan on Climate Change[53] outlines the following key goals in the land-use change and forestry sector: a) A reduction of 40% in the average illegal deforestation rate by the 2006 - 2009 period relative to the average rate of the ten-year reference period used by the Amazon Fund (1996 - 2005). An additional two periods of four years would achieve 30% reductions relative to each of the previous periods from 2009 to 2017. b) Eliminate the net loss of forest coverage in Brazil by 2015 by doubling the area of plantation forests from 5.5 million ha to 11 million ha by 2020

- In India:
  - A mandatory 10% ethanol blend is being considered by the Indian government.
  - The Indian state of Maharashtra has set a target of 500 MW from biomass and cogeneration by 2012 (current production: 52 MW).
  - A nation-wide CFL (compact fluorescent lamp) promotion scheme has been announced, where CFLs will be distributed to households for $0.30 each (supported by CDM credits).
  - Promotion of Concentrated Solar Power (WRI, 2009).
  - Forest expansion plan to cover 1/3 of country area (WRI, 2009).
- In China:
  - Subsidies are available for hybrid and electric cars (7.3 and 8.8 k$/vehicle respectively) as well as for fuel cell cars and clean buses.
  - Six wind power bases of 10 GW each are planned, with a target of 3% renewable electricity from non-hydro sources in 2020.
  - Reduce energy consumption per unit GDP by approximately 20% below 2005 level by 2010.
  - Increase the share of renewable energy to 10% in the primary energy supply relative to 2005 levels.
- In Indonesia:
  - A study is underway to determine whether a biodiesel subsidy of 0.09 US$/litre is viable.
  - Project tenders for 1.5 GW of geothermal project tenders will be offered to developers.
- South Korea is setting up a US$ 73 million clean energy fund, with half to be allocated to wind. Other technologies are solar, tidal, bio ethanol and fuel cells.
- Argentina is planning to tender the development of geothermal projects of 30 MW.
- The Philippines expect to invest 220 M$ in clean energy.
- Abu Dhabi will announce a strategy and commitment to a target of 7% of electricity from renewable sources (creating a 6-8 billion US$ market over the next ten years).
- South Africa's energy strategy includes incentives for renewables and energy efficiency, including feed-in tariffs (WRI, 2009).
- Many countries are setting up Bus Rapid Transit system and toll roads in large cities.
- Reduction of landfill methane emissions, e.g. in Mexico and China (WRI, 2009).

These measures mostly relate to renewable energy. In the context of NAMAs, energy efficiency could be equally important, but few concrete policy initiatives have been announced. In a report on contributions from emerging economies, Höhne et al (2008) showed that a large share of the no-regret potential is in the industrial sector (e.g. for China, India and South Korea, 21%, 15% and 20% reduction, respectively, relative to the baseline), but also in buildings and power generation.

Measures other than renewable energy and energy efficient that could be considered 'nationally appropriate' could include the following:

- Reduction of gas flaring associated with oil and gas production.
- Decomposition of industrial gases (HFC-23, N_2O, perhaps PFC and SF_6) or other non-CO_2 gases like methane from landfills. Some countries have included these gases in their climate strategies (Rogelj et al., 2009) and these measures generally have low abatement cost (Bakker et al., 2009)

[53] Brazil (2008). National Plan on Climate Change Executive Summary 2008, Inter-ministerial Committee on Climate Change Decree No. 6263 of November 21, 2007, Brasilia, December 2008. http://www.mma.gov.br/estruturas/imprensa/_arquivos/96_11122008040728.pdf

- Avoided deforestation, as indicated by Brazil's National Plan on Climate Change.

Climate mitigation plans proposed by non-Annex I countries
In addition to policies and measures, some non-Annex I countries have proposed their own climate mitigation plans related to national or sectoral GHG emission reductions. We will not use these in the scenarios, although the following examples (Rogelj et al., 2009) show that several non-Annex I countries consider emission reductions as being nationally appropriate, and NAMAs may be part of their strategies to achieve these reductions.

- **Indonesia** aims to lower its energy sector emissions below baseline starting in 2012 so that in 2025 the CO_2 emissions are 17% below baseline.
- **Mexico** wants its GHG emissions to peak by 2012, then decline to 50% below 2000 levels by 2050.
- **South Korea** anticipates that its emissions will peak by 2020, and aims to reduce them by 50% before 2050. In August 2009, three options for their voluntary 2020 target were announced, ranging from +8 to −4% compared to 2005 levels, which is equivalent to 21 to 30% below baseline (Point Carbon, 3 August 2009).
- **South Africa** has set an emissions limit at 10% above 2003 in 2020 and aims at maintaining it at this level until 2030, and then reducing emissions by 30-40% below 2003 by 2050.
- **Costa Rica** aims to achieve a peak in GHG emissions in 2012 and 'carbon neutrality' in 2021.
- **The Philippines** has announced a voluntary target of −5% in 2012 compared to 1990.

The use of the term NAMAs in this study

The mitigation plans from individual countries described above are not included in the scenarios presented in this report, for various reasons. Some countries have for instance announced mitigation efforts with a time-frame longer then this study, while other countries are part of regions in our model and cannot be represented individually. For some countries, however, their proposed mitigation effort is similar to the comparable effort reduction assumed in this study (for example South Africa).

Instead, and without being policy-prescriptive, we assume that NAMAs would mobilize a certain part of the mitigation potential in non-Annex I countries and calculate the reductions such mitigation action could lead to. We also do not make any assumptions on whether these NAMAs would be unilateral actions, financed (or co-financed) by Annex I countries or from the carbon market. The costs of NAMA-based mitigation actions presented later, thus only refer to the costs incurred ***in*** the non-Annex I countries but not necessarily ***by*** the non-Annex I countries.

3 The definition of the scenarios

As mentioned in the introduction, we have developed three main scenarios:

- **Low ambition scenario**: based on the lower proposed reduction targets for individual Annex I countries and a low ambition level of implementing mitigation actions based on NAMAs in non-Annex I countries.
- **Higher ambition scenario**: based on the higher proposed reduction targets for individual Annex I countries and higher ambition level of implementing mitigation actions based on NAMAs in non-Annex I countries.
- **Comparable effort scenario**: reduction targets for Annex I region based on comparable effort approaches, assuming that the aggregated Annex I reduction target is equal to 30% below 1990 levels. Non-Annex I countries reductions meet an aggregate reduction of about 15% below baseline.

The level of ambition of the mitigation actions in non-Annex I countries depends on the Annex I reduction ambition. First, for political reasons and second, because the implementation of the these NAMAs – which can consist of both unilateral and supported action, will partly depend on the level of support by Annex I in terms of finance, technology and capacity building

For each scenario we have considered two variants with implications for emissions reductions and abatement costs: *first*, including or excluding REDD and LULUCF CO_2 emissions. *Second*, for the scenarios including REDD and LULUCF CO_2 emissions, we assume that non-Annex I regions will finance 20% of the NAMA measures of REDD domestically and the remaining 80% will be financed by Annex I regions or other non-Annex I regions at the marginal costs or at the REDD market price. Taken together these sub-variants (including the cases marginal costs and market price) for the three scenarios yielded nine scenarios for the model analysis.

The first sub-variant (including or excluding REDD/LULUCF CO_2 emissions) was introduced assuming that the USA and Australia pledges would include additional reductions from REDD, as shown in Chapter 2. This is an additional reduction that is obtained by financing REDD in other developing or non-Annex I countries. In addition, the scenarios including REDD/LULUCF CO_2 emissions contain REDD NAMAs that take place within non-Annex I countries. These REDD NAMAs can also be partly financed by Annex I countries, but the resulting reductions are not added to the reduction targets of the Annex I countries that provide the financing. Note that there is a direct link between the LULUCF CO_2 emissions and "NAMA REDD reductions" for non-Annex I regions, because REDD decreases the LULUCF CO_2 emissions in these countries. In the case of Annex I regions, the LULUCF CO_2 emissions are independent of the REDD reductions because the later ones take place outside the Annex I countries, i.e. non-Annex I countries with deforestation or positive LULUCF CO_2 emissions.

The second sub-variant for financing REDD for the scenarios including REDD/LULUCF CO_2 emissions was introduced in order to take into account the different possibilities for calculating the costs for the REDD reductions (including the financing of REDD projects) in Annex I and in non-Annex I (i.e. coming from pledged reductions from USA and Australia and/or from NAMAs). We will describe this methodology in more detail in Chapter 7.

In this chapter we will describe the storyline of six scenarios corresponding to the ones that result from combinations of the pledges for the Annex I countries and ambitions mitigation actions in non-Annex I countries and the inclusion or exclusion of REDD/ LULUCF CO_2. The scenarios are referred to as follows:

- 1a. Low excluding REDD/LULUCF CO_2
- 1b. Low including REDD/LULUCF CO_2:
    - 1b-market price
    - 1b-marginal abatement cost
- 2a. High excluding REDD/LULUCF CO_2
- 2b. High including REDD/LULUCF CO_2
    - 2b-market price

  - 2b-marginal abatement cost
- 3a. Comparable effort excluding REDD/LULUCF CO_2
- 3b. Comparable effort including REDD/LULUCF CO_2:
  - 3b-market price
  - 3b-marginal abatement cost

3.1 Overview of reduction targets

Table 3.1 shows the assumed Annex I pledges for the scenarios excluding and including REDD/LULUCF CO_2 according to the description in Chapter 2. This has been done for the regions as included in our model, which implies Australia and New Zealand aggregated into one region, and the EU region including Norway, Switzerland and Central Europe and also Ukraine region including Belarus. Table 3.2 shows the NAMA-based reduction below the baseline based on NAMA plans as calculated with the ECN MAC curves in previous work (Bakker et al., 2007; Bole et al., 2009) (see below), as applied to eight emerging economies. For the remaining non-Annex I countries or regions included in our model (Chapter 4) we made reduction assumptions as shown in Table 3.3, which are compatible with the reduction of the non-Annex I countries in Table 3.2. This chapter describes the assumptions and some of the calculations on which these tables are based.

Table 3.1. The reductions targets in % of the scenarios excluding and including REDD/LULUCF CO_2 of individual Annex I countries and regions relative to the reference year emissions, as assumed in the model calculations

Annex I	***1a. Low ambition (excl. REDD /LULUCF CO_2)***	***1b. Low ambition (incl. REDD /LULUCF CO_2)***	***2a. Higher ambition (excl. REDD /LULUCF CO_2)***	***2b. Higher ambition (incl. REDD /LULUCF CO_2)***	***3a. Comparable effort (excl. REDD /LULUCF CO_2)***	***3b. Comparable effort (Incl. REDD /LULUCF CO_2)***	***Reference year***
Canada	−20		−20		−28 (reference year: 1990)		2005
EU27 (including Norway, Switzerland and Central Europe)	−20		−30		−35		1990
Japan	−15		−15		−19		2005
Oceania region (including Australia and New Zealand)	4[+]	−7[+]	−12*	−21**	−5 (reference year: 1990)		2000
Russia	−10		−15		−50		1990
Ukraine region (including Belarus)	−20		−20		−61		1990
USA	0	0	−3	−17***	−15		1990

[+] 4% increase excl. LULUCF and 7% decrease incl. LULUCF below 2000 levels corresponds to the same end point of emissions as the pledge from the Australia region including New Zealand shown in Table 2.1 (i.e. 5% reduction excl, LULUCF and incl. Deforestation below to 2000 levels for Australia and 10% reduction excl. LULUCF compared to 1990 levels for New Zealand)

* 12% reduction excl. LULUCF and 21% reduction incl. LULUCF below 2000 levels corresponds to the same end point of emissions as the pledge for the Australia region including New Zealand shown in Table 2.1 (i.e. 20% cap and trade below 2000 excl. LULUCF and incl. Deforestation for Australia and 20% reduction excl. LULUCF compared to 1990 levels for New Zealand).

** There is an additional reduction of 5% relative to 2000 that corresponds to financed REDD from the Carbon Market in this scenario

*** An additional 14% relative to 1990 is financed REDD from the Carbon Market in this scenario

Table 3.2. Potential NAMAs-resulting reductions (in %) below the baseline emissions in the eight emerging economies or major emitting non-Annex I countries and regions, as assumed in the model calculations. Numbers in parentheses represent reductions using G4M baseline and MACs.

non-Annex I	***1a. Low ambition (excl. REDD)***	***1b. Low ambition (incl. REDD)+***	***2a. Higher ambition (excl. REDD)***	***2b. Higher ambition (incl. REDD)+***	***3a. Comparable effort (excl. REDD)***	***3b. Comparable effort (Incl. REDD)***	***Reference***
	All GHGs excl. LULUCF CO_2	All GHGs incl. LULUCF CO_2	All GHGs excl. LULUCF CO_2	All GHGs incl. LULUCF CO_2	All GHGs excl. LULUCF CO_2	All GHGs incl. LULUCF CO_2	
Mexico	5.4	6.3 (9)	11	12.5 (18)	20	25	Baseline
Argentina*	3.1	4.0 (8++)	6.2	8 (16++)	20	26	Baseline
Brazil	8	14.5 (38)	16.1	29 (42)	20	42	Baseline
China region**	5.5	5.5 (5)	11	11 (11)	20	20	Baseline
India	5.4	5.4 (5)	10.7	10.7 (11)	10	12	Baseline
Korea region***	2.3	4.3 (2)	4.6	8.6 (4)	20	20	Baseline
Indonesia region****	2.1	1.6 (8)	4.2	3.2 (17)	10	21	Baseline
South Africa	8.5	8.5 (9)	17	17 (17)	20	19	Baseline
Total	5	6 (9)	11	12 (15)	18	22	Baseline

* We used the data for Argentina as representative for the entire South America Region (excluding Brazil)
** Includes Mongolia & Taiwan
*** The range in the announced voluntary target (see Section 2.2) would in fact indicate a significantly larger reduction. The difference in the figures can be primarily attributed to the limited coverage of South Korea's mitigation potential in the ECN MAC
****Includes Papua New Guinea, Timor
\+ Numbers in parenthesis indicate the reduction potential of all GHGs, but for LULUCF CO2 applying a 50% and 25% reduction to the maximum reduction potential for Avoided deforestation (REDD) based on the IIASA land use G4M (formerly DIMA), as described in Kindermann et al. (2008). See also Appendix A.
++ Correspond to the rest of South America and not only Argentina

Table 3.3. The reductions assumptions below baseline emissions for the remaining non-Annex I countries or regions, not included in the analysis of NAMAs.

Others Regions	***1a. Low ambition (excl. REDD)***	***1b. Low ambition (incl. REDD)***	***2a. Higher ambition (excl. REDD)***	***2b. Higher ambition (incl. REDD)***	***3a. Comparable effort (excl. REDD)***	***3b. Comparable effort (Incl. REDD)***	***Reference***
	All GHGs excl. LULUCF CO_2	All GHGs incl. LULUCF CO_2	All GHGs excl. LULUCF CO_2	All GHGs incl. LULUCF CO_2	All GHGs excl. LULUCF CO_2	All GHGs incl. LULUCF CO_2	
Rest of Central America	5	5	11	10	20	20	Baseline
North Africa	0	0	0	0	10	10	Baseline
Western, Eastern and rest of Southern Africa regions	0	0	0	0	0	0	Baseline
Turkey	10	10	15	15	20	20	Baseline
Kazakhstan Region	5	5	10	10	20	20	Baseline
Middle East Region	0	0	0	0	10	10	Baseline
Rest of South Asia Region	0	0	0	0	10	10	Baseline
Rest of South East Asia region	0	0	0	0	10	10	Baseline

3.2 Low ambition scenario

Annex I Parties

For the low ambition scenario we assumed the current policy proposals, as officially announced or under consideration by the various Annex I Parties (see Table 2.1), in particular the lower targets (sometimes these values refer to their target under a unilateral agreement), as described in Table 3.1. We used the same targets for the scenarios including and excluding REDD/LULUCF CO_2 given that there are no specification from most of the low pledges of Annex I countries concerning the land-use emissions and REDD reductions.

Non-Annex I Parties

To avoid prescribing policy, the low and higher ambition scenarios do not specify emission targets or measures of the types listed in Section 2.2. Instead we assumed that a set of appropriate NAMAs could successfully mobilise a certain proportion of a country's mitigation potential. The NAMAs can be unilateral or supported actions, but cannot be used to generate offsets for Annex I as part of the carbon market. They are 'additional' to Annex I targets. Consequently, they contribute to a 'deviation from baseline emissions' for non-Annex I in 2020.

For the low ambition scenario, we assumed that NAMAs include effective measures that realise the following:

- 25% of the energy-efficiency potential, as these measure are cost-effective, but not easy to implement
- 25% of the renewable energy potential, as these options provide significant co-benefits, and many countries are implementing policies, some of them ambitious, to promote them.

- 25% of the non-CO_2 reduction options; this mainly covers agriculture, waste and industrial process emissions.
- 25% of the avoided deforestation potential.

The emission reductions that would result from such NAMAs were calculated as follows: all the mitigation options in the ECN MAC curve for the eight emerging economies: China, South Korea, Brazil, Argentina, Mexico, South Africa, India and Indonesia in 2020 (Bakker et al., 2007; 2009) belonging to any of the above mentioned four categories – energy efficiency (EE), renewable energy (RE), non-CO_2 GHGs (includes other industrial gases, agricultural emissions and waste emissions) and avoided deforestation (AD) – were grouped and added together to calculate the total potential of these categories.[54] Next, 25% of the potential was calculated. The resulting emission reductions (in absolute terms) are reported in the table below.

Table 3.4. Potential NAMA-based reductions for the low ambition scenarios (in $MtCO_2eq$). The numbers in parenthesis correspond to AD reductions using the deforestation emissions and MAC from the G4M model (See Appendix A).

	Energy efficiency	Renewable energy	Avoided deforestation (AD)	non- CO_2	Total excluding AD	Total including AD
Mexico	11	3	6 (59)	27	41	48 (107)
Argentina	3	5	4 (146***)	5	12	16 (159***)
Brazil	14	59	204 (1066+)	33	106	310 (1180)
China	248	151	0 (1)	318	717	717 (797)
India	56	74	0 (3)	83	212	212 (192)
Indonesia*	4	3	18 (111)	14	20	38 (135)
South-Korea	19	0	0 (3)	2	20	20 (23)
South-Africa**	20	13	0 (0)	21	53	53 (51)
Total	373	307	232 (1389)	502	1182	1413 (2644)

* Assuming Indonesia has 33% of South and South East Asia's non-CO_2 reduction potential
** Assuming South Africa contributes to 16% of Africa's CH_4 potential and 100% of Africa's fluorocarbon potential.
*** Corresponds to the Rest of South America and not only Argentina
+ Brazil's Avoided deforestation National policy has a 70% reduction set by 2020 which replaces the 25% NAMA in this case.

Note that "0" can mean not only that there is no significant potential for a certain sector in a given country, but also that a particular country-sector option is not well covered in the ECN MAC curve database. Therefore we should emphasise the conservative nature of these estimates in terms of abatement potential and hence the potential for NAMAs.

While keeping in mind the data availability restrictions, we can see that the highest potential lies with abatement options for non-CO_2 gases (502 $MtCO_2eq$), followed by energy efficiency measures (373 $MtCO_2eq$) and renewable energy (207 $MtCO_2eq$). Avoided deforestation is also a significant option, but only for Brazil and to a lesser degree Indonesia.

It is important to mention here that for the AD potential we implemented the reductions found with the same methodology described above, but using the MAC from the G4M model from IIASA. For Argentina we used the potential for 'rest of south America' as a region and not only Argentina. The results are reported in Table 3.4 under the column AD and in parentheses. The potentials are significantly higher than those found using ECN's MAC.

[54] The potentials analysed here are all technical potentials, but it should be noted that virtually all options are below 100 $/tCO2eq and many are no-regret options.

Breaking down the potential per country, we can see that the highest GHG abatement would occur in China (717 $MtCO_2eq$), followed by Brazil (310 $MtCO_2eq$ with ECN MAC for AD/494 $MtCO_2eq$ using G4M MAC for AD) and India (212 $GtCO_2eq$ with ECN MAC for AD/192 $GtCO_2eq$ using G4M MAC for AD).

If all the emerging economies listed above formulated their NAMAs to use 25% of their potential in the four sectors included in this analysis, their combined efforts could lead to a total emission reduction of around 1200 $MtCO_2eq$, excluding the potential for avoided deforestation. If this potential is included, this figure rises to 1400 $MtCO_2eq$ (2000 $MtCO_2eq$ using the baseline (IMAGE) and avoided deforestation potential from G4M).

These reductions can be compared to baseline to calculate the deviations they would achieve (i.e. Table 3.2). For the group of emerging economies in the analysis, the NAMAs as specified in the low ambition scenario would achieve the following:

- A 5% reduction below baseline if avoided deforestation *is not* included as a NAMA.
- A 6% reduction below baseline if avoided deforestation *is* included as a NAMA using ECN's MAC for AD and 9% using G4M's MAC for AD.

The reductions below baseline at the country level were presented in the scenario overview (Table 3.2) at the beginning of this chapter. In reality, these figures could be significantly larger, since they would include the potential in some countries or sectors currently not well covered by the ECN MAC. In this light it can be noted that the GHG reduction potential (including LULUCF) in McKinsey (2009) is approximately 13 $GtCO_2eq$ in 2020 compared to 8 $GtCO_2eq$ in the ECN MAC. Notwithstanding these data restrictions, this analysis shows that a low ambition scenario – which for emerging economies means formulating NAMAs that mobilise 25% of mitigation potential in energy efficiency, renewables, non-CO_2 gases and avoided deforestation – does not lead to deviations from the baseline of the level that may be required to set global GHG emissions on a path towards low stabilisation levels, i.e. 15-30% (den Elzen and Höhne, 2008).[55]

Other non-Annex I Parties − In the low ambition scenario, for the non-Annex I regions/countries not covered by the ECN MACs we assumed a reduction below baseline consistent with the most compatible region in the world that has a defined reduction. For example, the rest of Central America is assigned a lower reduction than Mexico (i.e. Rest of Central America 5% and Mexico 5.5% excluding LULUCF CO_2 and 5% and 5% including LULUCF CO_2) given their similar but still lower socio-economic development (see Table 3.2 and Table 3.3). In a similar way, the Kazakhstan Region receives a 5% reduction below baseline based on India and China's reduction. In the case of Turkey we assigned a more ambitious target (i.e. 10% below baseline) given the fact that they may enter the EU in the future and their economic development is expected to increase as well.

3.3 Higher ambition scenario

Annex I Parties

For the higher ambition scenarios we used the current policy proposals, as officially announced or under consideration by the different Annex I Parties, specifically the more ambitious reductions mentioned in Table 2.1, and sometimes those mentioned conditional to a multilateral agreement. For the assumed reductions, the calculations for the targets in the higher ambition scenarios only change for the cases of Australia and the USA, which are the countries that have pledged additional REDD reduction and/or those including LULUCF CO_2 emissions. These targets correspond to the targets presented in Table 3.1. For Australia the target excluding REDD/LULUCF CO_2 becomes an 11% reduction relative to 2000 levels (assuming the same end point as with a target of 20% below 2000 incl. LULUCF); for the USA we only took into

[55] The reductions necessary to achieve such deviations from the baseline are explicitly addressed in the comparable effort scenario.

account the initial 3% reduction relative to 1990 levels based on domestic action, hence excluding REDD.

Non-Annex I Parties

Eight emerging economies – For the higher ambition scenario, we assumed that NAMAs include measures to achieve 50% of the mitigation potential available in energy efficiency, renewables, non-CO_2 emitting sectors and avoided deforestation (i.e. similar to the sets of measures in the low ambition scenario, but with a higher share of the potential). Table 3.5 presents the emission reductions that could be achieved in this case.

Table 3.5. Potential NAMA-based reductions for higher ambition scenarios including and excluding REDD/LULUCF CO_2 (in $MtCO_2eq$). The numbers in parenthesis correspond to AD reductions using the deforestation emissions and MAC from the G4M model (See Appendix A).

	Energy efficiency	Renewable energy	Avoided deforestation (AD)	non- CO_2	Total excluding AD	Total including AD
Mexico	22	6	13 (117)	55	82	95 (215)
Argentina	5	9	7 (291***)	9	24	31 (317***)
Brazil	27	119	408 (1066)+	66	212	620 (1293)+
China	495	302	0 (3)	637	1434	1434 (1594)
India	112	147	0 (6)	165	424	424 (384)
Indonesia*	9	5	36 (222)	27	41	77 (269)
South-Korea	37	0	0 (7)	3	40	40 (46)
South-Africa**	39	26	0 (0)	42	107	107 (103)
Total	747	615	463 (1713)	1 003	2365	2828 (4221)

* Assuming Indonesia has 33% of South and South East Asia's non-CO_2 reduction potential
** Assuming South-Africa contributes to 16% of Africa's CH_4 potential and 100% of Africa's fluorocarbon potential.
*** Corresponds to the Rest of South America and not only Argentina
+ Brazil's Avoided deforestation National policy has a 70% reduction set by 2020.

If all eight of the emerging economies included formulated their NAMAs to use 50% of their potential in the four sectors included in this analysis, they could achieve a reduction of over 2300 $MtCO_2eq$ excluding avoided deforestation, or 2800 $MtCO_2eq$ including it (Note: using G4M AD potential, this figure would be above 4200 $MtCO_2eq$). In terms of reductions below baseline this means:

- An 11% reduction below baseline if avoided deforestation *is not* included as a NAMA.
- A 12% reduction below baseline if avoided deforestation *is* included as a NAMA using ECN's MAC for AD and 15% using G4M's MAC for AD.

The reductions below baseline per country were presented in the scenario overview (Table 3.2) at the beginning of this chapter. As discussed in Section 3.2, we should emphasise that in reality these figures could be higher, for some countries considerably higher. Under the higher ambition scenario, the necessary deviation from baseline for emerging economies as a group (15%) would still not be reached, even in the case when avoided deforestation is included. However, this does not apply to individual countries if the differentiated reduction targets based on economic development are taken into account. For India, for example, NAMAs under the higher ambition scenario could lead to an emission reduction of more than 10% below baseline, which would be in line with its contribution to 'comparable' non-Annex I emission reduction (den Elzen et al, 2009a).

Other non-Annex I Parties − For the higher ambition scenario we made the same assumptions for the other non-Annex I regions/countries as for the low ambition scenario. As a result, the rest of Central America was assigned a reduction equal to that of Mexico (i.e. Rest of Central America 11% and Mexico 11% excluding LULUCF CO_2 and 10% and 10% including LULUCF CO_2), given their similar socio-economic development (see Table 3.2 and Table 3.3). In a similar way, the Kazakhstan Region was assigned a 10% reduction below baseline based on India's and China's target. In the case of Turkey, we assigned a slightly more ambitious target (15% below baseline).

3.4 Comparable effort scenario

Annex I Parties

The study by den Elzen et al (2009a) analysed what 'comparable' reduction efforts for different countries are needed to meet an overall target of 30% below 1990 levels for Annex I countries as a group. This Annex I reduction level is within the 25−40% reduction range for meeting the 450 ppm CO_2eq stabilization target[56] (lowest category) of the IPCC AR4 in Box 13.7 (Gupta et al., 2007), provided that emissions in non-Annex I countries deviate substantially from baseline (15-30%) (den Elzen and Höhne, 2008). Den Elzen et al (2009a) explored six approaches for defining comparable efforts, ranging from very simple (equal reductions from baseline and convergence in per capita emissions over time – 2050) to complex (like the Triptych approach that combines a convergence in sector-based efficiencies/technologies and in per capita emissions) as well as approaches based on model-dependent cost calculations (like equal costs).

The results in Table 3.6 show that for a scenario where Annex I countries reduce their emissions by 30% as a group, targets for the EU can result in reductions greater than 30% in a number of cases. Conversely, this also implies that a 30% target for the EU results in a reduction of less than 30% by the Annex I countries as a group under comparable assumptions. The study appears to indicate rather robustly that for most approaches the emission reductions for the EU compared to 1990 levels may be higher than those for the USA and Japan and above the Annex I average. However, this is primarily explained by the fact that the baselines in the model for the USA and Japan are significantly higher than the EU baseline. Because the baseline of the EU was harmonised with historical data until 2005, our baseline also includes the past actions needed for meeting the Kyoto target, which in this way are not associated with any abatement costs.

Note: The USA baseline used in the study of den Elzen et al. (2008) was based on the World Energy Outlook 2006 and significantly overestimates the actual growth in GHG emissions. Later USA projections have adjusted baseline projections substantially, by almost 1Gt in 2020, as also in this study, which uses the World Energy Outlook 2008, lowering the US baseline to a growth of +26% compared to 1990 levels (whereas in den Elzen et al., 2008 this was +35%).
This change in the baseline also affects the reduction targets for Annex I countries of Table 2.5. The first preliminary results show that the EU reduction decreases from -35% to -32%, Canada from -28% to -22%, but no changes for the US reductions and higher reductions for Ukraine and Russia.

This comparable effort scenario is based on reductions for the Annex I countries using comparable effort approaches, i.e. the average reduction presented in Table 3.6, which results from weighting the six approaches equally. The main objective of including this scenario is to compare the national reduction targets under the low and higher ambition scenarios with the "comparable effort" reductions in the comparable effort scenario.

[56] The studies aiming at stabilisation at 450 ppm CO_2eq assume a temporary overshoot of about 50 ppm (den Elzen and Meinshausen, 2006).

Table 3.6. Overview of the reductions (% below 1990 levels) for the comparable effort scenarios by den Elzen et al (2009a). The averages of all six scenarios are also given in first column, which are used for the reduction targets of the Annex I regions of this comparable effort scenario.

Regions	**Average reduction**	**Equal reduction baseline**	**Equal MAC**	**Equal costs (excl. IET & CDM)**	**Equal costs (incl. IET & CDM)**	**Convergin g per capita emissions**	**Triptych**
Canada	–28	–19	–33	–30	–26	–33	–28
USA	–15	–12	–14	–13	–10	–14	–16
EU	–35	–36	–34	–39	–42	–32	–32
Russian Federation	–50	–50	–51	–45	–44	–49	–52
Japan	–19	–20	–13	–20	–25	–28	–15
Oceania	–5	1	7	6	9	–25	–3
Ukraine region	–61	–65	–62	–58	–58	–56	–58
Annex I	–30	–30	–30	–30	–30	–30	–30

*: For 2010 we assumed that all Annex I countries (except the USA) will reach the minimum of their Kyoto target or their reference emissions by 2010.

* Assuming that the USA starts at its national target of +25% above 1990 levels by 2020. If we assume that the USA starts at its Kyoto target, the numbers will 15% lower.

Non-Annex I Parties

For all non-Annex I countries to achieve an approximate 15% reduction below baseline emissions (needed to meet 450 ppm CO_2eq), reductions for the selected emerging economies as a group must be greater than 15%. To allocate the emission reductions between all non-Annex I countries, we assumed differentiated reductions according to the common-but-differentiated responsibilities and capabilities principle of the UNFCCC (1992), in agreement with den Elzen et al. (2008a), as shown in Table 3.7.

Table 3.7. Assumed reduction from baseline or business-as-usual scenario emission levels in 2020 for the non-Annex I countries (in %).

Non-Annex I regions	**Configuration**	**Reduction**
Advanced developing countries	Mexico, rest of Central America, Brazil, rest of South America, South Africa, Kazakhstan region, Turkey, Middle East, Korea region and China	–20
Other developing countries	Northern Africa region, Middle East, India, rest of Southern Asia, Indonesia region, rest of South-East Asia	–10
Least developed countries	Western Africa, Eastern Africa and rest of South-Africa region	0

The absolute emission reductions for the selected countries are given in Table 3.8, and are similar to the reductions in Bole et al. (2009). Bole et al. presented the detailed reduction measures underlying these reductions. For Brazil, Mexico and Indonesia, reductions from avoided deforestation are included in the baseline (the figures shown in brackets correspond to G4M data), as these countries have large deforestation emissions.

The previous considerations mean that for non-Annex I regions, we considered that the reductions for the LULUCF CO_2 emissions correspond to 50% of the mitigation potential of avoided deforestation taken into account for the high NAMA estimates. In Chapter 7 we will discuss the financing of the REDD reduction and the associated costs.

The combined emission reduction requirements by emerging economies included in our analysis would be around 3900 $MtCO_2$eq in 2020 for the case where deforestation emissions are not accounted for and 4100 $MtCO_2$eq for the case where they are (over 4400 $MtCO_2$eq in the case of G4M AD potential).

This scale of reductions could be achieved for example through NAMAs including national programmes of demand-side management together with sectoral agreements on mitigation actions in the energy, industrial and fossil fuels sectors, as these could deliver the largest and most cost-effective emission reductions for the selected emerging economies. As there are significant options at negative cost, the majority of the potential remains available to the carbon market (Bole et al., 2009).

Table 3.8. Emission requirements in 2020 for selected non-Annex I countries, including and excluding emissions from deforestation and LULUCF CO_2 emissions

Country	**Reduction target Excl. REDD /LULUCF CO2 Emissions (below baseline)**		**Reduction target Incl. REDD/ LULUCF CO2 Emissions (below baseline)**	
	[%]	**$MtCO_2eq$**	**[%]++**	**$MtCO_2eq$+**
Rest of South America	20	282	26	573
Brazil	20	285	42	1351
Mexico	20	180	25	297
Korea region	20	240	20	247
China region*	20	3023	20	3026
South Africa	20	119	19	120
India	10	348	12	354
Indonesia region**	10	112	21	334
Total reduction	18	4590	22	6302

* Includes Mongolia & Taiwan
** Includes Papua New Guinea, Timor
*** Numbers in parenthesis correspond to the G4M Avoided Deforestation Potential
\+ The reductions including REDD/LULUCF CO2 emissions presented in this column are calculated by adding the reductions excluding REDD/LULUCF CO2 emissions to the AD NAMA-based reductions for the higher ambition scenario presented in table 3.5 (i.e. G4M AD data).
++ Including sinks

4 The modelling tool and data used

4.1 Analytical framework

We used the integrated modelling framework FAIR (den Elzen et al., 2008b; den Elzen and van Vuuren, 2007) for the quantitative analysis of emission reductions and abatement costs at the level of 26 regions. We calculated the abatement costs (in US$) by assuming full use of the flexible Kyoto mechanisms such as international emissions trading (IET) and CDM, and calculated the cost-effective distribution of reductions for different regions, gases and sources. The model used baseline emissions of GHG 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., 2008b). More specifically, 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 of CO_2 emissions. This has been further improved compared to earlier work by now including four tax profiles instead of two. Consequently, we have captured the full range of possible tax paths that represent early action and highly delayed action. The MAC curves for carbon plantations were derived using the IMAGE model (Strengers et al., 2008). We have also included LULUCF CO_2 emissions and marginal costs information for REDD, ARD and FM activities from three global forestry and land-use models.[57] MAC curves from the EMF-21 project (Weyant et al., 2006) were used for non-CO_2 GHG emissions. These curves have been 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 emission credits demand-and-supply curves were used to determine the carbon price on 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 marginal abatement costs and the actual reductions. They represent the direct additional costs due to climate policy, but do not capture the macro-economic implications of these costs.[58] We assumed that emissions could be traded freely between all the regions that had accepted emission reduction targets. The transaction costs associated with the use of the Kyoto mechanisms were assumed to remain at a constant US$ 0.55 per tonne CO_2eq emissions plus 2% of the total costs (Michaelowa and Jotzo, 2005; Michaelowa et al., 2003).

For countries that only participate in CDM, a limited amount of the abatement potential was assumed to be operationally available on the market, because of the project basis of the CDM and implementation barriers such as properly functioning institutions and project size. Consistent with earlier studies (Criqui, 2002; den Elzen and de Moor, 2002b; Jotzo and Michaelowa, 2002), this so-called CDM accessibility was set at 20% in 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 in Annex I countries.

The issue of *participation in emissions trading* is also known to be a crucial element of future climate policy. Limited participation can both reduce the available potential available to the market and lower the regional price level. In this study the MAC curves were scaled with a

[57] The three models are the G4M model (formerly DIMA) (Kindermann et al., 2008; Kindermann et al., 2006; Rokityanskiy et al., 2007), the Generalized Comprehensive Mitigation Assessment Process Model (GCOMAP) (Sathaye et al., 2005; 2006) and the Global Timber Model (GTM) (Sohngen and Mendelsohn, 2003; Sohngen et al., 2001). A brief description of each model is given in Kindermann et al. (2008).

[58] The FAIR model includes 1) the costs of reducing greenhouse gas emissions (both directly and indirectly); 2) the potential damage of climate change (and our ability to adapt to climate change) and adaptation costs (Hof et al., 2009). The later two are not presented in this study. The FAIR model also includes a simple macro-economic model for calculating the consumption losses of these overall climate costs, which are also not presented here (Hof et al., 2008).

region-specific factor to represent the limited potential available to the carbon market and the price effects. Effectively, we considered three groups of countries, i.e. high-income, middle-income and low-income countries (Table 4.1).

Table 4.1. Assumptions on participation in International emissions trading (IET) and CDM and the calculated fraction of the global carbon price.

Non-Annex I regions	**Configuration**	**Reduction**
High-income countries	Mexico, Middle-East, Korea region	IET (90%)
Middle-income countries	Rest Central America, Brazil, Rest South America, Kazakhstan region, Turkey, Northern Africa region, South Africa, China and Rest South-East Asia	IET (60%)
Low-income countries	Western Africa, Eastern Africa and Rest of South-Africa India and Rest South Asia and Indonesia region	CDM (20%)

We made the following assumptions. The hot air or surplus of AAUs in the first commitment period (i.e. about 2200 $MtCO_2eq$ annual and 11 $GtCO_2$ for the whole commitment period) of Russia and Ukraine are banked for the future commitment periods in order to maximise their financial revenues from trading of emission credits in the first commitment period. In addition, for the future commitment period (2013-2023), Russia and Ukraine adopt a policy of optimal banking with possible forfeiting of “new” hot air or surplus of AAUs over the second and third commitment period (2013-2023) in order to maximise their financial revenues. Because targets for the second commitment period and beyond are still unknown and uncertain, optimal banking is interpreted as maximising revenues in the first commitment period, and maximising revenues in the future commitment period up to 2020, and not for the overall period 2008-2023. For the low and higher ambition scenario an optimal strategy for the period up to 2020 implies releasing the banked hot air of the first period in 2015 and 2020 in equal amounts. For the second commitment period (2013-2018), the “new” hot air is forfeited. We did not account for the expectations of the market participants in the carbon market results in 2020 (i.e., no intertemporal optimisation was considered in this analysis).[59]

All models (IMAGE, FAIR and TIMER) operate on the scale of 26 regions (see Figure 4.1), with the inclusion of a larger number of individual countries[60]. This expansion of the model allows cost calculations to be performed for individual countries, using consistent and accurate data of baseline emission scenarios and marginal abatement costs at the level of major countries, such as Turkey, the Russian Federation, South Africa and China (excluding Korea).

Other main assumptions for the costs calculations were the following:

- The transaction costs associated with the use of the Kyoto mechanisms are assumed to consist of a constant US$ 0.55 per tonne CO_2eq emissions plus 2% of the total costs
- Most Parties propose targets that do not include international bunker fuels, except for the EU[61]. Therefore the emission and costs calculations exclude international bunker fuels emission projections and costs of reducing these emissions.
- We did not assume mitigation options for reducing emissions from deforestation (REDD) for the scenarios excluding LULUCF CO_2; we did assume these options for the scenarios including LULUCF CO_2.

[59] Under a stable climate policy with long-term commitments, such long-term optimisation may occur. Theoretically, in such cases the carbon price should increase at a rate near the discount rate. In addition, the increase could include a premium reflecting, among other things, the regulatory risks.

[60] More specifically, the eight Annex I regions are: Canada, the USA, Western Europe, Central Europe, the Ukraine region, the Russian Federation, Japan and Oceania (Australia and New-Zealand); The eighteen Non-Annex I regions are: Mexico, remainder of Central America, Brazil, remainder of South America, northern Africa, western Africa, Eastern Africa, South Africa, Kazakhstan, Middle East, Turkey, India, Korea region, China region, Mekong region, Indonesia region, remainder of Southern Asia and remainder of southern Africa.

[61] For the EU, the −20% unilateral target includes the emissions from aviation, making our target more stringent. For instance, when including emission from aviation EU, emissions would have gone down only by 6.8% in 2005 compared to 1990. When excluding these emissions, EU emissions declined by 7.9% in 2005 compared to 1990.

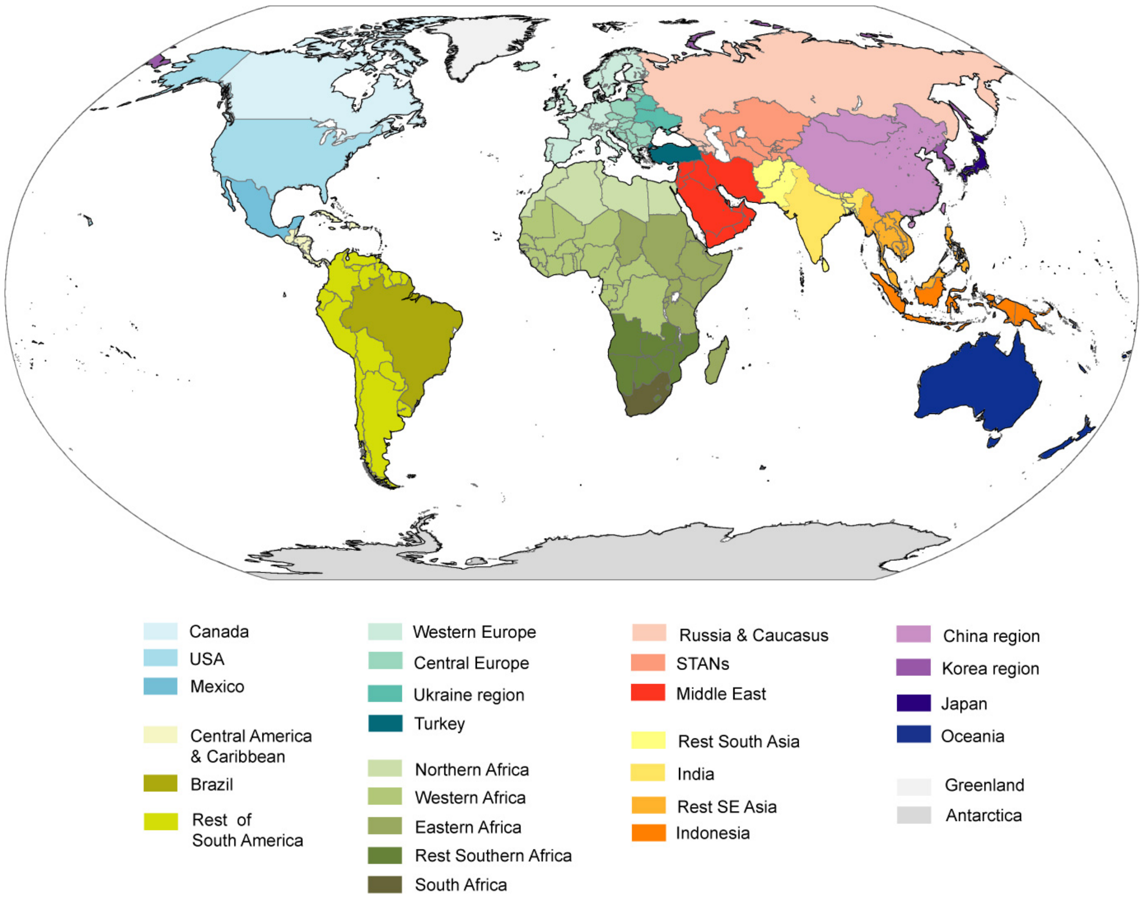

Figure 4.1. Map of regions used in the FAIR 2.2 model

- Carbon credits from *forest management* are included, based on a conservative, low estimate taken from an extension of the Marrakesh Accords. This corresponds to about 392 $MtCO_2$/yr for Annex I (den Elzen and de Moor, 2002a) and 147 $MtCO_2$/yr for non-Annex I (van Vuuren et al., 2003). The reductions for specific regions were assumed as follows:

– Canada	44	– Ukraine region	4
– USA	103	– Kazakhstan region	0
– Mexico	4	– Russian Federation	121
– Rest of Central America	3	– Middle East	0
– Brazil	43	– India	7
– Rest of South America	31	– Korea region	0
– Northern Africa	0	– China region	7
– Western Africa	29	– Mekong region	0
– Eastern Africa	7	– Indonesia region	0
– South Africa	6	– Japan	48
– Western Europe	22	– Oceania	37
– Central Europe	17	– Southern Asia	0
– Turkey	0	– Rest of Southern. Africa	6

- *Starting point for future targets* − The efforts of Annex I countries to reach their assumed targets in 2020 are influenced by aspects such as the emission pathway during the period 2013−2020. Two options are put forward in the international negotiations. This was implemented in the FAIR model with the starting point of 2010 (middle of the first commitment period); it should be either the target as determined by the Kyoto Protocol, or the starting point should be the actual emission level of a more recent year. We decided to use the minimum of the Kyoto target and the 2010 baseline emission for all Annex I countries, excluding the USA. For the Russian Federation, the Ukraine region and Central Europe this implies using the 2010 baseline as a starting point, which basically means that no new hot air will occur by 2015 (middle of second commitment period).

- For the costs calculations of the first commitment period (Kyoto), we made the following assumptions:
  - The Kyoto reduction targets are applied at the base-year emissions, which may differ from the 1990 emissions (Australia, Canada, Japan, etc.);
  - In addition to the carbon credits from forest management for the Annex I countries, carbon credits for agricultural management and ARD and sinks under CDM (i.e. limited to 1% of the base-year emissions) are included under the limitations as specified in Bonn Agreement and the Marrakech Accords, as calculated using the methodology of den Elzen and de Moor (2002a; 2002b).

4.2 Baseline

The baseline without the impact of the economic crisis was based on an updated IMAGE implementation of the IPCC SRES B2 scenario, as developed for the "Reference Concentration Pathways" (RCPs)[62] project'. Throughout the report this referred to as the RCP baseline, as reported in van Vuuren et al. (2009b). This scenario assumes medium development for population growth, economic growth and energy trends for the 21st century. For the first 30 years, the assumptions are consistent with IEA's World Energy Outlook 2008. The main features (e.g. population, GDP per capita, GHG emissions) of the baseline are presented in Appendix B.

4.3 Historical and future emissions of greenhouse gases

Historical emissions for the three GHGs (CO_2, CH_4 and N_2O) for the period 1990 to 2005 were based on national emission inventories, submitted to the UNFCCC (UNFCCC, 2008) and, where not available (i.e. all non-Annex I countries), other sources, i.e. CO_2 emissions from fuel combustion were taken from the International Energy Agency (IEA, 2006) and CH_4 and N_2O emissions from EDGAR database version 4.0 (http://edgar.jrc.ec.europa.eu/). In earlier work we used simulated historical and future (1990-2100) emissions data from the IMAGE and TIMER models.[63] These updated historical GHG emissions also influence the GHG emission projections over the time period 2006-2020. This section describes how we first calculated the historical GHG emissions from 1990 to 2005 and second, the future or projected data that corresponds to emissions from 2006 to 2100.

This updated methodology was not used for the F-gases. For the regional emissions (period 1990-2020) of the F-gases included in the Kyoto Protocol – Hydrofluorocarbons (HFCs and HCFCs), Perfluorocarbons (PFCs) and Sulphur hexafluoride (SF_6) – were based on the IMAGE2.2 implementation of the IPCCC SRES A1 scenario (IMAGE-team, 2001).

The methodology was also used for the LULUCF CO_2 emissions with the RCP baseline. However for the default costs calculation of the scenarios including LULUCF and REDD, for the LULUCF CO_2 emissions we used the deforestation baseline emissions from the G4M model (formerly DIMA) (Kindermann et al., 2008; Kindermann et al., 2006; Rokityanskiy et al., 2007) in order to be consistent with the assumed MAC of REDD. Note that the IMAGE model does not include MAC information of REDD.

[62] http://www.iiasa.ac.at/web-apps/tnt/RcpDb/dsd?Action=htmlpage&page=welcome

[63] These models have been calibrated with the historical GHG emissions of the historical emissions datasets of IEA (CO_2) and EDGAR (non-CO_2).

Historical greenhouse gas emissions data (1990-2005)
A new emission datasets has been compiled with results for all UN countries, three GHGs (CO_2, CH_4 and N_2O) and eight sectors[64] :

- **Industry sector** ('Energy: Manufacturing Industries and Construction' plus 'Industrial processes' as one sector (CO_2, CH_4, N_2O)
- **Domestic sectors** (CO_2, CH_4 and N_2O emissions from fossil fuel combustion from the residential, commercial, agriculture and (inland) transport sectors.
- **Power sector** (CO_2, CH_4,N_2O emissions from electricity and heat production)
- **Fossil fuel production**
- **Agriculture**
- **Waste**
- **Land-use emissions** (Including LULUCF emissions for CO_2 and agricultural waste burning and savannah burning emissions for CH_4 and N_2O)
- **Bunkers (**International marine bunkers emissions**)**

This data were further aggregated at the level of 26 regions.[65] A detailed description of the emission sources included in these eight sectors for the three datasets (UNFCCC, IEA and EDGAR) is given in Appendix C.

The emissions database was compiled by first collecting historical emission estimates by country or region, by gas and by sector from the following sources and ordering them in the following hierarchy based on expert judgement. The datasets vary in their completeness and sectoral split:

1. National submissions to the UNFCCC as collected by the UNFCCC secretariat and published in the GHG emission database available at their web site. For Annex I countries we used data from 1990 to 2005 (UNFCCC, 2008).
2. CO_2 emissions from fuel combustion as published by the International Energy Agency[66]. It usually covers the years 1970 to 2005 (IEA, 2008), and we used data from 1990 to 2005 for non-Annex I countries.[67]
3. CO_2 (from industrial processes like cement production and feedstocks, and LULUCF CO_2 emissions), CH_4 and N_2O, emissions for the period 1990−2005 from the updated EDGAR database version 4.0 (http://edgar.jrc.ec.europa.eu/).[68]

The new database was then completed by applying an algorithm to the hierarchy. The data source was selected which is highest in hierarchy and for which emission data are available. All available data points were chosen as the basis for absolute emissions. The emissions data are obviously affected by uncertainties; these uncertainties are larger for emissions in the past than in the present, and are also larger for the non-CO_2 GHGs than for CO_2.

Future greenhouse gas emissions data (2006-2100)

Future emissions for 26 regions, three GHGs (CO_2, CH_4 and N_2O) and eight sectors (as described above) for the period 2006 to 2100 were based on the RCP baseline scenario, as described in Section 4.2. For 2005 a "mismatch" between the modelled emissions from TIMER and IMAGE and the estimate of the historical dataset can occur. This difference is primarily due

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[64] Guam, Serbia and Montenegro and Mayotte emissions are added to the emissions of The Northern Mariane Islands, Federal Republic of Yugoslavia and Comoros correspondingly.
[65] Antigua and Barbuda and Norfolk Island emissions for CH_4 and N_2O were not added into any of the 26 regions.
[66] The CO_2 emissions from the IEA dataset were chosen, as this dataset is the most comprehensive one available at the present time, and the emissions it contains are calculated from official energy balances provided by the countries. This dataset does not include process CO_2 and non-CO_2 emissions. The only global dataset available for these is the EDGAR database (for the years 1990, 1995 and 2000).
[67] The IEA calculation is less detailed than national calculations and may be treating distribution losses and feedstock differently.
[68] The hydrofluorocarbons (HFCs and HCFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) emissions can be based on EDGARV32FT2000 (Olivier et al., 2005).

to the calibration of the models to different historical datasets. In order to provide consistent emissions pathways between the modelled and the historical data in this study, we used a simple harmonisation or “scenario adjustment” method. This is similar to the one used by the Integrated Assessment Modelling Consortium (IAMC)[69] during its development of the RCP scenarios[70]. It consists of finding harmonisation ratios between the historical data and the modelled data and applying these harmonisation ratios to the original modelled data so that the outcome is scaled and harmonised. Harmonisation ratios are defined so that they converge to the original modelled outcome in 2100, meaning that they become 1 at the end of the century.
This method is useful when the harmonisation ratios are not so large, i.e. when harmonisation ratios are close to 1. When this is not the case, it is necessary to correct the emissions from the original outcomes of the models by creating an offset value that allows harmonisation ratios no higher than a certain acceptable value (e.g. set/based on experts’ criteria). The offset consists of the amount of emissions allowing large ratios minus the emissions allowing only acceptable ratios for the harmonisation year, in this case 2005. This amount is kept constant and added through time to the regions and sectors that present this type of behaviour (e.g. large harmonisation ratios, so large differences between modelled and historical data). It is important to keep in mind that the consistency with the original scenario is important as well as the transparency in reporting the differences for some sectors/regions that might result in different outcomes.

The methodology is described in more detail in Appendix D. Furthermore, there are implications of this procedure on the costs calculations that are also explored in Appendix E.

In Figure 4.2 we present the outcomes of the non-harmonised (i.e. original TIMER / IMAGE outcome) and harmonised GHG emissions excluding LULUCF CO_2 emissions for the United States and China as relevant examples.

For model analyses of policymakers, the historical emissions based on national emission inventories, submitted to the UNFCCC, are evidently preferred to the simulated historical emissions calculated from the IMAGE and TIMER models. However, this also leads to inconsistency in the costs calculation. Applying the MAC curves to the reductions below the harmonised RCP baseline emissions instead of the original non-harmonised baseline emissions may lead to higher or lower costs projections for some regions. This is analysed in more detail Appendix E. In general, higher baseline emissions will lead to a greater relative reduction below baseline, although keeping the same target below a year such as 1990 and using a lower baseline will lead to lower costs and a smaller relative reduction below baseline.

[69] http://emf.stanford.edu/docs/modeling_consortium/
[70] Available at:
http://www.pnl.gov/gtsp/publications/2008/presentations/20080922_smith_emissions_harmonization_update.pdf

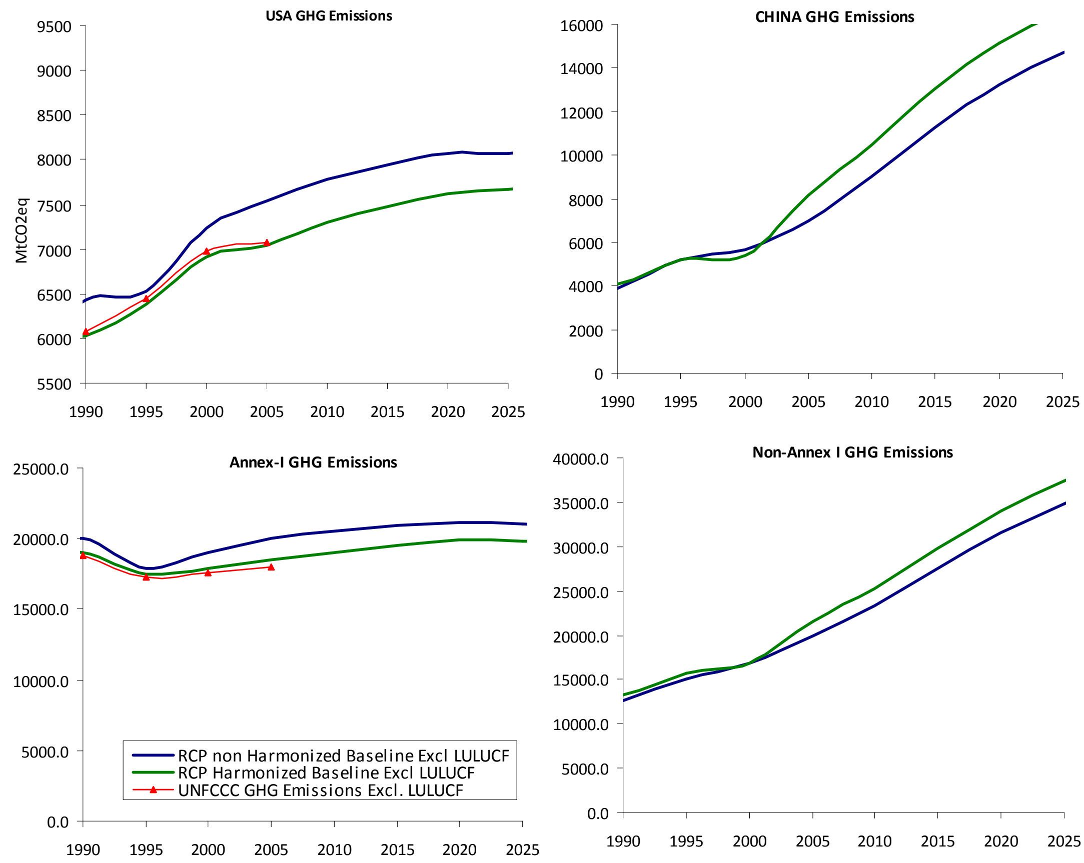

Figure 4.2. Harmonized and un-Harmonized RCP baseline GHG emissions (excluding LULUCF CO_2) for United States, China, Annex-I and non-Annex I

5 Scenario analysis of the Annex I reduction pledges

In this Chapter we analyse the emissions and costs implications of the low, high and comparable effort scenario for the Annex I countries, with the assumed reduction targets specified in Table 3.1 (Chapter 3).

5.1 Emission implications excluding REDD/LULUCF CO_2 emissions

Table 5.1 presents the reductions *excluding* REDD/LULUCF CO_2 emissions relative to 1990 and 2005 levels for Annex I regions, based on pledges and comparable effort reductions. The Table also shows the results for the baseline emissions. Oceania (Australia and New-Zealand), Canada and the USA have much higher baseline emissions compared to the other Annex I regions. The aggregate reductions for all Annex I countries (including the USA) as a group excluding REDD/LULUCF CO_2 emissions range from 10% to 15% compared to 1990 for the low and high scenario, which is lower than the 30% reduction for the comparable effort scenario, falling short of the reductions that are needed to reach a 450 ppm GHG stabilisation pathway, i.e. 25% to 40% reduction below 1990 levels.

For Russia, Ukraine and Belarus, the baseline emissions are lower than the proposed targets, which indicate that their pledges will result in a surplus of AAUs or "new" hot air in 2020, (e.g. 618 for Russia and 340 $MtCO_2eq$ for Ukraine for the high pledge). If the surplus AAUs of Russia and Ukraine (due to pledges baseline levels) are forfeited, or not used, the Annex I reduction increases from 10-15% towards 14-19% below 1990 levels.

As mentioned in Chapter 4, we assumed that Russia and Ukraine will adopt an optimal banking strategy to optimise their financial revenues in the first commitment period and in the period 2013-2023. For the low and high scenarios, an optimal strategy for the period up to 2020 implies releasing the banked hot air of the first period in 2015 and 2020 in equal amounts. For the second commitment period (2013-2018), the "new" hot air is forfeited. A strategy of curtailing and banking permit supply benefits the dominant sellers Russia and Ukraine (it increases the carbon price on the international carbon market and increases their gains). It also indirectly benefits the non-Annex-I regions by the higher carbon price, with higher gains from their financial revenues from CDM and emissions trading.

Table 5.1 also presents the reductions *including* REDD/LULUCF CO_2 emissions. The reductions presented here should be used cautiously, as these depend on projections of emissions from land use and land-use changes and forestry (LULUCF) and the post-2012 LULUCF accounting rules, which may be different than the current Kyoto accounting rules. Both factors are highly uncertain. The accounting rules for LULUCF are currently under discussion and can also have a large impact. Different land-use accounting rules could affect the outcomes, particularly for Annex I countries with a significant share in these emissions, such as Australia, Canada and the Russian Federation. For most Annex I regions, the UNFCCC emissions dataset (www.unfccc.int) shows negative net CO_2 emissions from LULUCF sources (sinks dominate), except for the regions Oceania (due to Australia) and Russia, which have positive net LULUCF CO_2 emissions. The regions Canada and Ukraine show a decreasing trend in the negative emissions, whereas for the other regions the negative net CO_2 emissions from LULUCF decrease further, indicating increasing sinks. In the calculations for all Annex I countries, we assumed a conservative negative estimate of the LULUCF CO_2 emissions, based on the same land-use accounting rules in the Kyoto Protocol and the Bonn and Marrakech Amendments, and also the same sink estimates for the various sources as used in the Kyoto period, as calculated using the methodology of den Elzen and de Moor (2002a; 2002b) (see Chapter 4).[71] For the USA and the region Oceania (including Australia), the high pledges (the numbers in parenthesis – see Table 5.1) include the extra REDD reductions and the sinks.

[71] Carbon credits from forest management (limited by Appendix Z numbers) and agricultural management and ARD.

Table 5.1. Individual and aggregate reductions (excluding REDD and LULUCF CO_2 emissions) in % for Annex I regions for the three scenarios. Numbers in parenthesis show the reductions incl. REDD/LULUCF CO_2 emissions. Reductions are positive increase is negative.*

	1990			2005			Baseline 2020 compared to	
	Low ambition	Higher ambition	Comparable effort	Low ambition	Higher ambition	Comparable effort	*1990*	*2005*
Canada	3 (−4)	3 (−4)	28 (21)	22 (17)	22 (17)	42 (37)	31 (31)	5 (5)
USA[1]	0 (−2)	3 (15)	15 (27)	14 (13)	17 (27)	27 (38)	26 (26)	8 (8)
EU27	20 (18)	30 (29)	35 (34)	21 (20)	31 (30)	36 (35)	9 (9)	8 (8)
Japan	8 (5)	8 (5)	23 (15)	15 (12)	15 (12)	29 (25)	14 (15)	1 (1)
Russian Federation	10 (7)	15 (12)	50 (47)	−38 (−43)	−30 (−35)	24 (18)	−33 (−33)	3 (3)
Ukraine[2]	20 (20)	20 (20)	61 (61)	−68 (−69)	−68 (−69)	18 (17)	−51 (−51)	3 (3)
Oceania[3]	2 (−3)	17 (16)	25 (15)	12 (7)	26 (24)	24 (24)	34 (34)	20 (20)
Annex I	10 (8)	15 (18)	31 (34)	6 (4)	11 (14)	28 (31)	3 (3)	7 (7)

* Emissions from deforestation are included only in the total emissions from Australia and the European Community (for four member States only) because for Australia and for four Parties that are member States to the European Union, the LULUCF sector was a net source of emissions in 1990 and these Parties therefore meet the criteria of Article 3, paragraph 7, of the Kyoto Protocol for including emissions from deforestation for the purposes of calculation of the base year emissions (see informal note of UNFCCC secretariat, released 11 August, 2009).

1 In the comparable effort scenario, we assumed that the USA starts in 2010 at its baseline emissions. Assuming a different starting point, like its Kyoto target, requires significantly more stringent reductions by 2020. USA reduction targets (below 1990 levels) for 2020 would be 15-20 percentage points more stringent.

2 Ukraine and Belarus together

4 Australia and New Zeeland together.

For more detailed results on absolute reductions see Appendix F for Annex I and non-Annex I countries as a group, and see Appendix G for the individual Annex I regions.

Comparing the reduction targets under the low and high scenarios (Scenarios 1 and 2) with the reductions for the comparable effort scenario (hereinafter referred to as 'comparable effort' reductions – Scenario 3) shows that:

1. The pledges of Canada, Russia and Ukraine are far below the comparable effort reductions. For Canada even 25 percentage points. The pledges of Russia and Ukraine are more than 35 points too low. Russia and Ukraine will also have "new" hot air or surplus of AAUs by 2020 given their assumed pledges. This amount corresponds to 1132 and 958 $MtCO_2eq$ for the low and high scenario correspondingly.
2. The high pledges of the EU, USA and Japan are less remote from comparable effort reductions; 5, 12 and 15 percentage points lower respectively.
3. For the USA, the reduction under the comparable effort approaches depends on the assumed starting point of the 2010 emissions. If we assume in the comparable effort calculations that the USA starts at the Kyoto-level instead of starting at their reference emissions[72], the resulting reductions are 15-20 percentage points lower in 2020. This would imply that also their high pledge is far below the comparable effort reduction.

Note that the comparable effort reductions are highly dependent on the model and parameter assumptions. For instance, assuming the MAC curves of the energy model POLES instead of the default MAC curves of the energy model TIMER, which lowers the costs projection of the USA and increases those of EU, would imply that the high pledge of the EU is about the same as the comparable effort reduction target, and the high pledge of the USA is even further below the comparable effort reduction target.

In Figure 5.1, Figure 5.2 and Figure 5.3, the information contained in Table 5.1 is presented in graphs. Here the hot air of the Russian and Ukraine region is shown more explicitly, along with the targets achieve by the different regions/countries for the high, low and comparable scenario.

[72] As used in comparable effort calculations

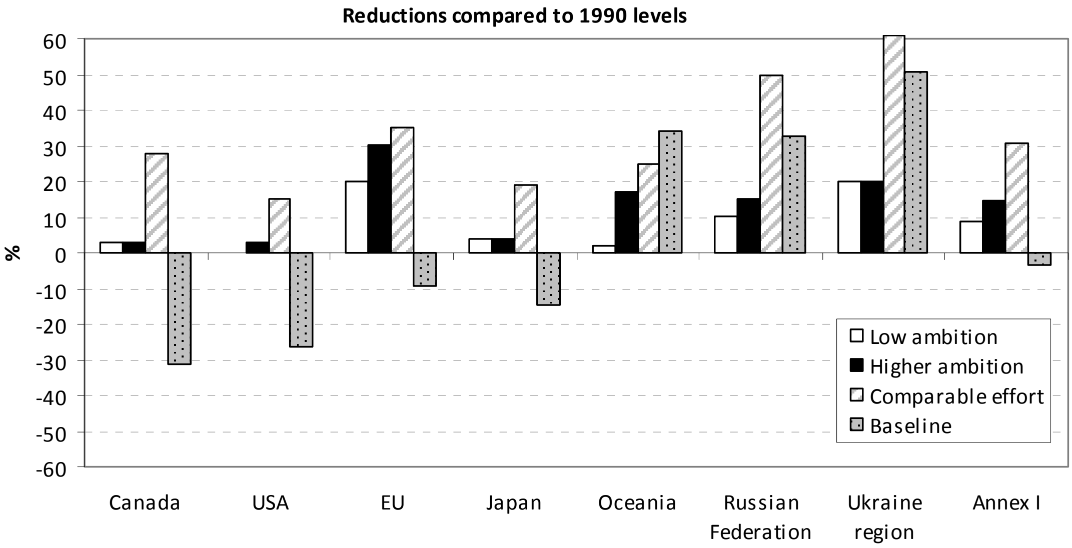

Figure 5.1. Emission reductions in 2020 (excluding LULUCF CO_2 emissions) compared to 1990 levels for Annex I countries

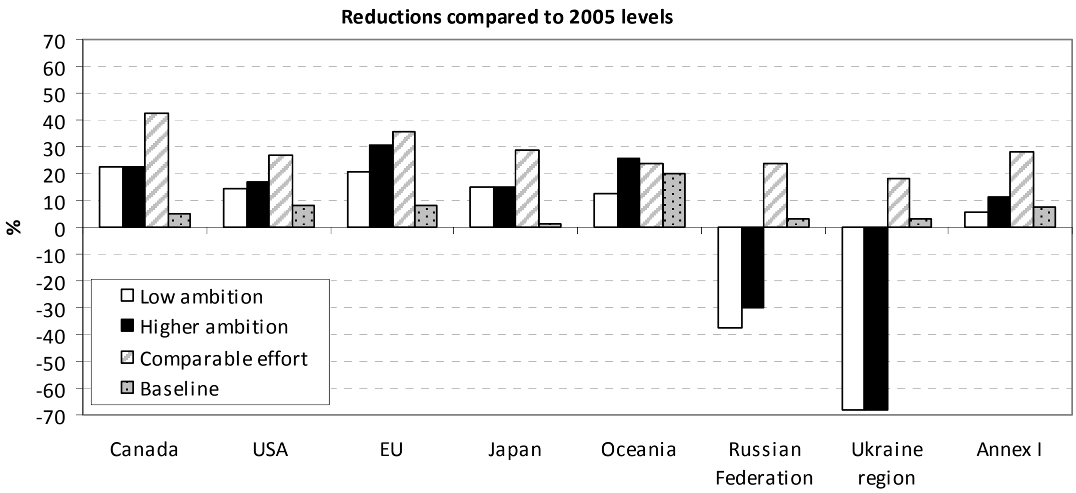

Figure 5.2. Emission reductions in 2020 (excluding LULUCF CO_2 emissions) compared to 2005 levels for Annex I countries

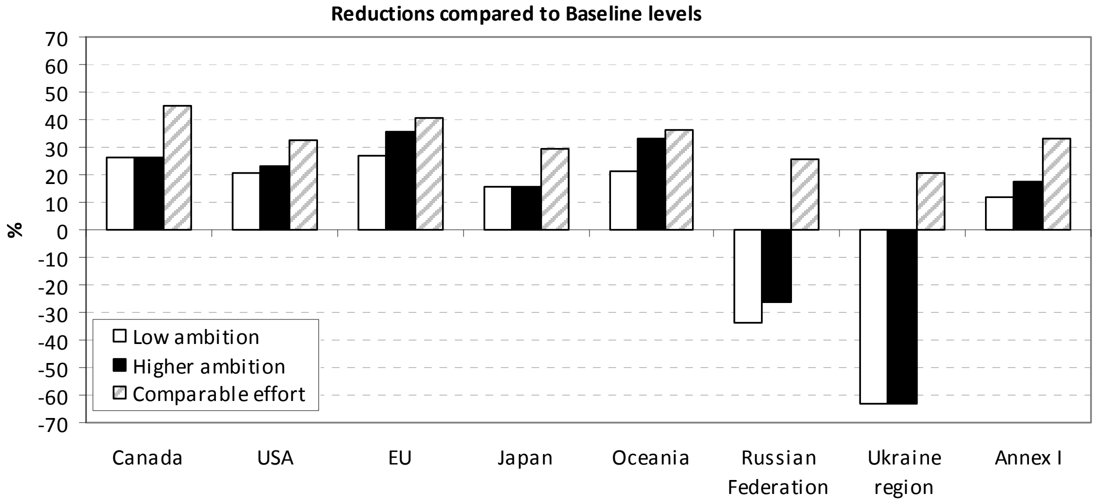

Figure 5.3. Emission reductions in 2020 (excluding LULUCF CO_2 emissions) compared to the baseline levels for Annex I countries

5.2 Cost implications (excluding REDD financing)

In this section we focus on the cost indicators for the low, high and comparable scenarios (excluding REDD/LULUCF CO_2), which means that for those regions where there are specific proposals for LULUCF and REDD, we have not accounted for these associated costs in the cost projections. This will be analysed in Chapter 7.

Carbon Price

The estimated carbon price is 4 and 15 US$/t$CO_2$eq for the low and higher ambition scenarios, respectively, and 58 US$/t$CO_2$eq for the comparable effort scenario, which can be considered as rather low (e.g. compared to price levels in the EU ETS). This is the cumulative effect of the following causes:

- The conservative ECN MAC curve leads to relatively low NAMA-based emission reductions of 4-8% for the non-Annex I countries (See table 6.1), so the developing countries still have a potentially abundant source of relatively low cost abatement options, which can be used for offsetting reductions in Annex I countries, which lowers the carbon price. There are also some non-Annex I regions like the Middle East for which low or none domestic mitigation action is assumed, which means they can offer all of their mitigation potential to the carbon market.
- Allowing banking of hot air from the Kyoto period (from Russia and Ukraine) results in the release of 1.1-1.3 GtCO_2 hot air to the market by 2020, which also lowers the price.
- “New” hot air induced by low post-2012 targets by 2020 for Russia and Ukraine for the low and higher ambition scenario further increases the supply of carbon credits, and lowers the price.

Abatement cost

Table 5.2 shows the average abatement costs for the countries when meeting their pledges with trade (default calculations) and without trade. For the scenarios with trade, the table shows the average cost at which domestic reductions take place. For most Annex I regions the average cost is lower than the no-trade average cost because they do a part of their reductions abroad in the trade case.

For the scenarios without trade, we found that the reduction target under the higher ambition scenario becomes infeasible for Oceania and the EU in our model framework because the marginal abatement cost reach the maximum level of 1000$/tC (= 273$/tCO_2) as assumed in our model. Therefore the reduction target cannot be achieved with domestic abatement actions only. For the comparable effort scenario this also happens for Canada. The average abatement costs for domestic reductions in large emitting countries are the highest for Japan, Canada, the USA and the EU. The costs curves in 2020 increase rapidly, so the average costs are much lower than the marginal abatement cost for the last tonne reduced in most of the Annex I regions

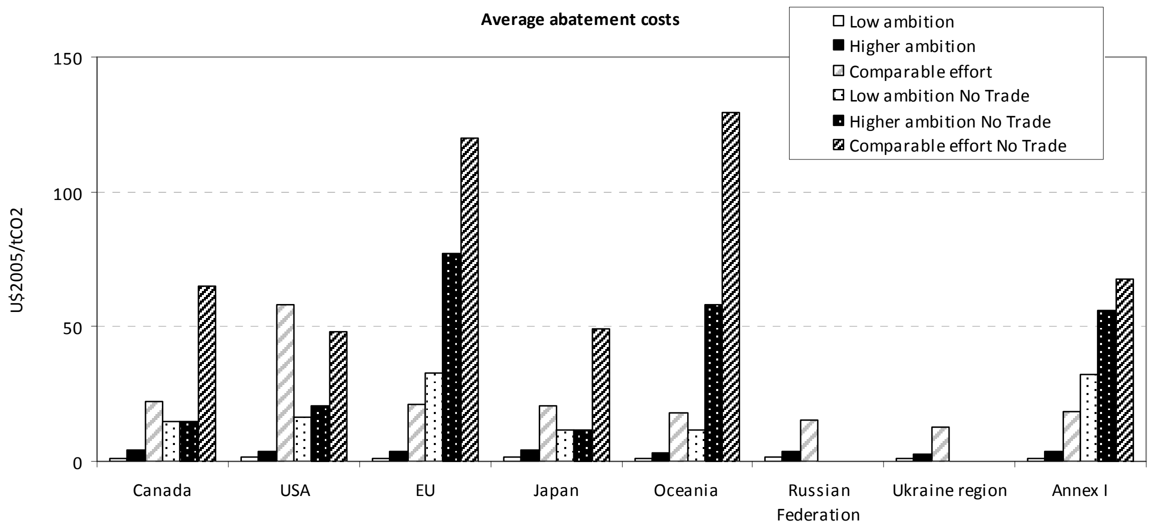

Figure 5.4. Average abatement Costs for Annex I countries.

Table 5.2. Average abatement costs (US\$/tonneCO_2) for Annex I regions

	Trade			No Trade		
US\$/tCO_2	**Low ambition**	**Higher ambition**	**Comparable effort**	**Low ambition**	**Higher ambition**	**Comparable effort**
Canada	1.3	4.0	22	15	15	65
USA[3]	1.4	3.8	19	16	21	48
EU	1.3	3.7	21	33	77	120
Japan	1.4	4.1	21	12	12	49
Oceania[2]	1.2	3.2	18	12	58	130
Russian Federation	1.4	3.7	15	0	0	0
Ukraine region[1]	0.9	2.7	13	0	0	0
Annex I	1	4	19	32	56	67
Carbon price	4	15	58			

[1] Ukraine and Belarus together
[2] Australia and New Zeeland together. Additional reductions proposed purchases of REDD are not included.
[3] Additional reductions from (WM bill) proposed purchases of REDD and requirements for 20% extra reduction from international offsets are not included

Total costs and absolute emissions before and after trade

Although a comparison of resulting marginal abatement costs provides information on the cost-effectiveness, total mitigation costs as percentage of GDP are more relevant for comparisons of the economic efforts for different countries. In Table 5.3 the costs for the Annex I regions are shown in absolute terms (i.e. MUS\$$_{2005}$). This table also presents the domestic costs to meet their own reduction target and financial flows, i.e. total revenues or expenditure for carbon trade. Russia and Ukraine do not have a reduction target under the low and high pledge (surplus of AAUs), and basically operate as sellers on the international carbon market. The other Annex I countries operate as buyers on the carbon market in particular the EU and USA. Carbon trading increases for Annex I regions due to the banking and trading of hot air from the first commitment period, so there is more trade within Annex I (i.e. from Russia and Ukraine to other Annex I regions). At the same time the carbon price drops due to more available credits in the market.

Table 5.3 also shows the target, the trade (i.e. buyers and sellers), sinks and 1990 levels for Annex I countries.

Table 5.3 Costs for Annex I regions in MUS$$_{2005}$ and Emissions in $MtCO_2eq$

Low ambition	Emissions ($MtCO_2eq$)					Costs (in MUS$$_{2005}$)			
	1990 level	Target 2020	Domestic Incl. Trade and Sinks	Trade	Sinks	Domestic costs	Financial flows	Total costs of Abatement	Costs as % of GDP
Canada	596	578	48	113	44	61	547	609	0.04
USA	6030	6030	522	967	103	729	4696	5425	0.03
EU27	4338	3470	316	930	22	412	4514	4926	0.03
Japan	1207	1162	65	107	48	91	520	612	0.01
Russia	3484	3136	203	–953	121	277	–4025	–3748	–0.22
Ukraine	1098	879	57	–337	4	54	–1422	–1368	–0.49
Oceania*	650	637	59	76	37	69	369	438	0.03
Annex I	18925	17109	1392	560	395	1828	3748	5576	0.01

Higher ambition	Emissions ($MtCO_2eq$)					Costs (in MUS$$_{2005}$)			
	1990 level	Target 2020	Domestic Incl. Trade and Sinks	Trade	Sinks	Domestic costs	Financial flows	Total costs of Abatement	Costs as % of GDP
Canada	596	578	76	85	44	303	1348	1651	0.10
USA	6030	5849	775	895	103	2941	14245	17186	0.09
EU27	4338	3036	457	1223	22	1695	19452	21147	0.12
Japan	1207	1162	101	71	48	413	1131	1543	0.03
Russia	3484	2962	346	–1095	121	1290	–16500	–15210	–0.87
Ukraine	1098	879	79	–359	4	214	–5404	–5190	–1.84
Oceania*	650	539	84	149	37	268	2375	2643	0.17
Annex I	18925	16070	2117	700	395	7889	12604	20492	0.04

Comparable effort	Emissions ($MtCO_2eq$)					Costs (in MUS$$_{2005}$)			
	1990 level	Target 2020	Domestic Incl. Trade and Sinks	Trade	Sinks	Domestic costs	Financial flows	Total costs of Abatement	Costs as % of GDP
Canada	596	429	176	134	44	3933	7921	11854	0.74
USA	6030	5126	1569	824	103	30335	48834	79169	0.42
EU27	4338	2820	947	949	22	19775	56213	75987	0.42
Japan	1207	977	206	151	48	4235	8965	13200	0.22
Russia	3484	1742	564	–711	121	8608	–40928	–32320	–1.86
Ukraine	1098	428	114	–283	4	1433	–16305	–14872	–5.27
Oceania*	650	488	148	136	37	2646	8051	10697	0.71
Annex I	18925	12999	4020	729	395	74958	45683	120641	0.24

*Oceania's 1990 level is corrected with Australia's UNFCCC LULUCF emissions for 1990

The fraction of the total abatement realised domestically is shown in Table 5.4, which clearly shows that under the assumed cost-effective implementation and with no limitations on the use of CDM and trade, most Annex I countries (except Russia and Ukraine) are realising at least 50% domestically, except for the EU for the low and high scenario (about 30%) and the USA (about 40-50%). This lower domestic realisation in the EU might have to do with Europe's relatively higher reduction ambitions compared to the other Annex I countries. In reality the use of CDM, JI and trade may be more limited, due to restrictions in CDM and JI, or as countries might prefer to realise more of their reduction target domestically. Table 5.4 also shows that the domestic fraction (i.e. domestic abatement divided by the total abatement) increase for the more ambitious scenarios is due to rising carbon prices and more stringent reduction targets for all Annex I countries. For Russia and Ukraine the domestic fraction exceeds 100% for the comparable effort scenario, which means that these regions act as seller and their domestic abatement includes additional domestic reductions to offset reductions in other Annex I countries. More detailed results are presented in Appendix G.

Table 5.4. Domestic Abatement for Annex I regions in % of the total abatement, excluding trade and sinks

	Low ambition	Higher ambition	Comparable effort
Canada	45%	59%	62%
USA	39%	49%	67%
EU27	27%	28%	51%
Japan	51%	68%	63%
Russian Federation	N.R.	N.R.	218%
Ukraine	N.R.	N.R.	357%
Oceania	56%	45%	58%
Annex I	76%	79%	89%

N.R.: not relevant, as these countries do not have a reduction target given the low and high pledge.

In Table 5.5 and Figure 5.5 the total costs as a percentage of GDP are shown. The costs for the USA are slightly lower than those of the EU for all scenarios excluding the LULUCF CO_2. However it is important to bear in mind that the comparison does not take into account any additional costs for purchases of REDD (see Chapter 7). Russia and Ukraine are benefiting from the revenues, leading to gains higher than 0.5% of their GDP. Hot air banking and trading result in major revenues for these countries.

For most of the countries, the targets can be met at relatively low cost, which is reduced even further with trading. Due to the high surplus of AAUs, the Russian Federation together with Ukraine and Belarus are able to generate large windfall profits with trade.

We have also calculated the costs assuming no trade, and this clearly shows that the costs are increased by a factor between 4 and 13 for the Annex I countries as a group compared to the trade cases. For the EU, the costs can triple. This shows that the presented costs are highly dependent on the assumptions and whether or not the targets can be met through trading.

For more detailed results on costs, see Appendix F for Annex I and non-Annex I countries as a group, and see Appendix G for the individual Annex I regions.

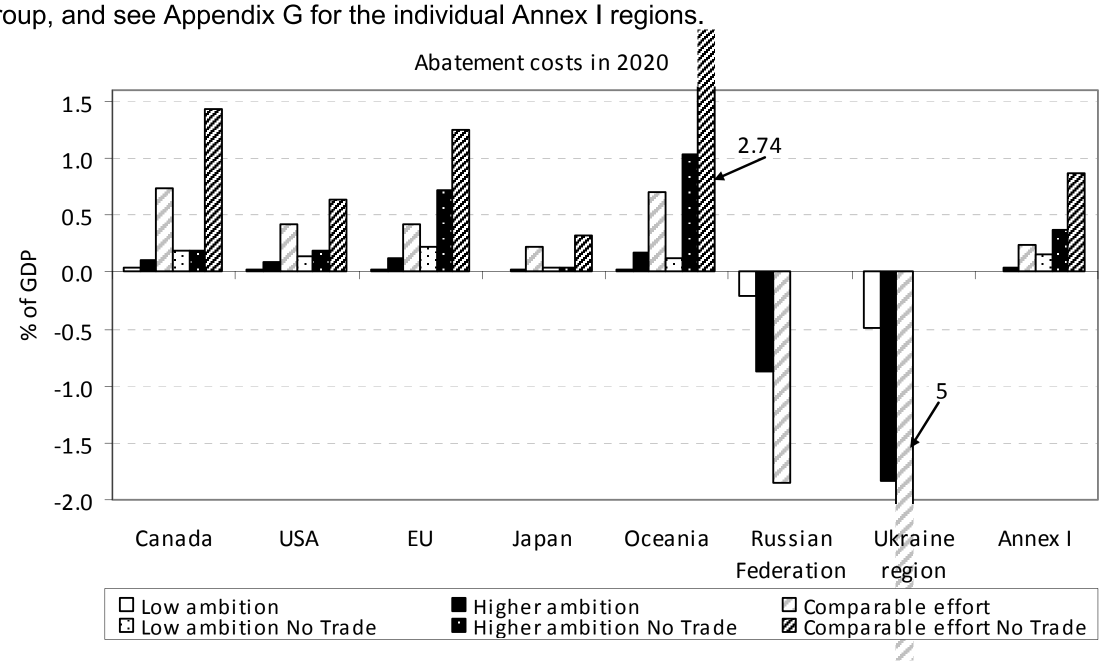

Figure 5.5. Abatement costs as % of GDP for Annex I regions

Table 5.5. Abatement costs as % of GDP for Annex I regions

Costs as % of GDP	Trade			No Trade		
	Low ambition	Higher ambition	Comparable effort	Low ambition	Higher ambition	Comparable effort
Canada	0.04	0.10	0.74	0.19	0.19	1.44
USA	0.03	0.09	0.42	0.14	0.19	0.64
EU	0.03	0.12	0.42	0.23	0.72	1.26
Japan	0.01	0.03	0.22	0.04	0.04	0.33
Oceania[1]	0.03	0.17	0.71	0.13	1.03	2.74
Russian Federation[2]	–0.22	–0.87	–1.86	0.00	0.00	0.00
Ukraine region[2,3]	–0.49	–1.84	–5.27	0.00	0.00	0.00
Annex I	0.01	0.04	0.24	0.15	0.38	0.88

[1] Australia and New Zeeland together. Additional reductions involving proposed purchases of REDD are not included..
[2] The abatement costs for Russia and Ukraine, as this is highly dependent on the assumptions about banking of credits from the first commit period, and whether you take the baseline emissions or the position of the country (with emissions above their baseline emissions)
[3] Ukraine and Belarus together.

Emissions per capita

Table 5.6 and Figure 5.6 show the per capita emissions for the proposed pledges for single countries as well as for the Annex I group as a whole. The proposed targets would lead to a considerable downward trend in per capita emissions between 1990 and 2020. The downward trend from 1990 in the EU is greater than that for Australia. On the other hand, the trend in the USA, Australia and Canada results from a strong population increase, while the population remains constant in the EU during that period of time.

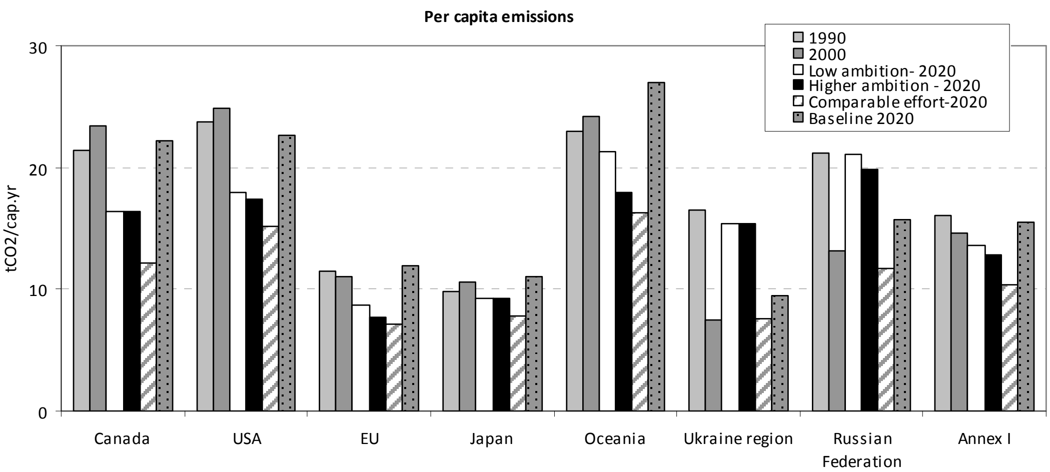

Figure 5.6. Per capita emissions for Annex I countries

Table 5.6. Per capita emissions for Annex I countries

Per capita emissions			2020			2020
(tCO_2/cap.yr)	1990	2000	Low ambition	Higher ambition	Comparable effort	Baseline
Canada	21	23	16	16	12	22
USA	24	25	18	17	15	23
EU	12	11	9	8	7	12
Japan	10	11	9	9	8	11
Oceania	23	24	21	18	16	27
Russian Federation	21	13	21	20	12	16
Ukraine region	17	7	15	15	8	9
Annex I	16	15	14	13	10	15

6 Scenario analysis of non-Annex I mitigation action

In this Chapter we analyse the emissions and costs implications of the three scenarios for the non-Annex I countries, with the NAMA-based emission reductions for the low and higher ambition scenario, and assumed reduction levels for the comparable effort scenario as specified in Table 3.2 and Table 3.3 (see Chapter 3).

6.1 Emission implications

This analysis is based on the NAMA-based emission reductions for the emerging economies (Table 3.2) and the reductions assigned to other non-Annex I regions (Table 3.3). The individual and aggregate reductions for non-Annex I regions are shown in Table 6.1 and Table 6.2. The baselines have a large impact on the results, so they are also shown on Table 6.2. Note the high baselines for China, Korea, India and Indonesia compared to 1990 levels.

The aggregate reduction for the non-Annex I countries as a group (including all non-Annex I regions) ranges from 4% to 8% for the low and higher ambition scenarios, excluding LULUCF CO_2 emissions, compared to their baseline emissions in 2020. Note that these figures are not directly comparable to those in Chapter 3 (i.e. 5-11% reduction compared to baseline for the low and high scenario); they include reductions for other non-Annex I regions that the NAMAs described in Chapter 3 do not (e.g. Rest of Central America and Kazakhstan region). Nevertheless we can see that they are in the same order or magnitude.

This reduction is lower than the aggregate 16% reduction relative to baseline for the comparable effort scenario. All regions/countries are projected to have increased emissions in 2020 compared to 1990 levels (See Figure 6.1). Under the higher ambition scenario however, South Africa achieves positive reductions which brings its emissions to a level below 2005 levels (See Figure 6.2). The comparable effort scenario shows emissions below 2005-level for both South Africa and Brazil.

When comparing the 2020 levels to the baseline (i.e. reductions below baseline), we indeed see reductions in emissions, not increases. These numbers correspond to the NAMAs-induced reduction below baseline presented in Table 3.2 for the low, high and comparable effort scenario (see also Figure 6.3). For more detailed results on absolute emission reductions, see Appendix F and Table 6.5.

Table 6.1 Individual and aggregate reductions excluding REDD/LULUCF CO_2 emissions in % below baseline levels for non-Annex I regions for the three scenarios. Numbers in parenthesis show the reductions incl. REDD/LULUCF CO_2 emissions. Reductions are positive, increases are negative.

	Reduction below baseline emissions		
	Low ambition	**Higher ambition**	**Comparable effort**
Mexico	5 (9)	11 (18)	20 (25)
Rest of South America	3 (8)	6 (17)	20 (26)
Brazil	8 (37)	16 (41)	20 (42)
China*	5 (5)	11 (11)	20 (20)
India	5 (6)	11 (13)	10 (12)
Indonesia**	2 (8)	4 (17)	10 (21)
Korea	2 (3)	5 (5)	20 (20)
South Africa	8 (8)	17 (16)	20 (19)
Non-Annex I	4 (7)	8 (12)	16 (19)

* Includes Mongolia & Taiwan
** Includes Papua New Guinea, Timor

Table 6.2 Individual and aggregate emissions excluding REDD/LULUCF CO_2 emissions in % compared to 1990 and 2005 levels for non-Annex I regions for the three scenarios by 2020. Numbers in parenthesis show the reductions incl. REDD/LULUCF CO_2 emissions.[73] Reductions are positive, increases are negative.

2020	Baseline		Scenarios					
	compared to		Compared to 1990 levels			Compared to 2005 levels		
	1990	2005	Low ambition	Higher ambition	Comparable effort	Low ambition	Higher ambition	Comparable effort
Mexico	91 (57)	41 (22)	80 (43)	70 (29)	53 (18)	33 (11)	26 (0)	13 (–9)
Rest of SAM	71 (23)	36 (6)	66 (13)	61 (2)	37 (–10)	31 (–2)	27 (–12)	8 (–22)
Brazil	87 (21)	21 (2)	72 (–23)	57 (–28)	50 (–30)	12 (–38)	2 (–41)	–3 (–43)
China*	273 (272)	85 (85)	253 (251)	232 (231)	198 (197)	75 (75)	65 (64)	48 (47)
India	144 (143)	58 (58)	131 (127)	118 (112)	120 (113)	50 (48)	41 (38)	43 (39)
Indonesia**	137 (62)	46 (9)	132 (48)	127 (35)	114 (28)	43 (0)	40 (–9)	31 (–13)
Korea	149 (145)	39 (35)	143 (139)	137 (132)	99 (95)	36 (35)	33 (31)	11 (10)
South Africa	34 (32)	13 (13)	22 (22)	11 (11)	7 (7)	–4 (–4)	–6 (–5)	–9 (–9)
Non-Annex I	154 (105)	57 (40)	143 (91)	133 (81)	113 (67)	50 (31)	44 (24)	32 (14)

*Includes Mongolia & Taiwan
** Includes Papua New Guinea, Timor

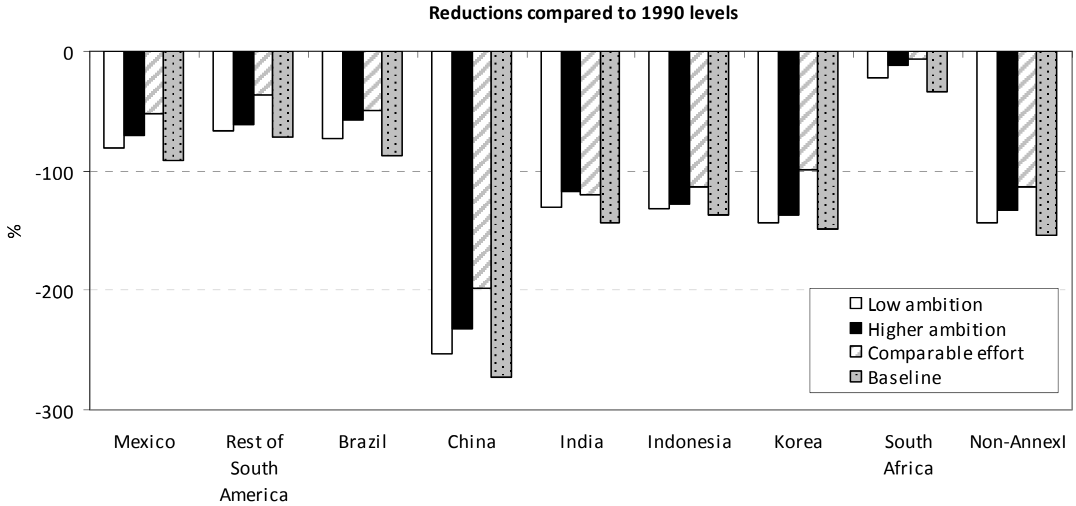

Figure 6.1. Emission reductions (excl. REDD/LULUCF CO_2) in 2020 compared to 1990 levels for non-Annex I regions/countries (negative value in graph means growth compared to 1990 levels)

[73] The numbers in parenthesis take into account the total REDD reduction for non-Annex I regions as presented in tables 3.4 and 3.5 (i.e. numbers in parenthesis). In Chapter 7, we make a differentiation between the financed and non-financed share of REDD and the costs for each set of reductions.

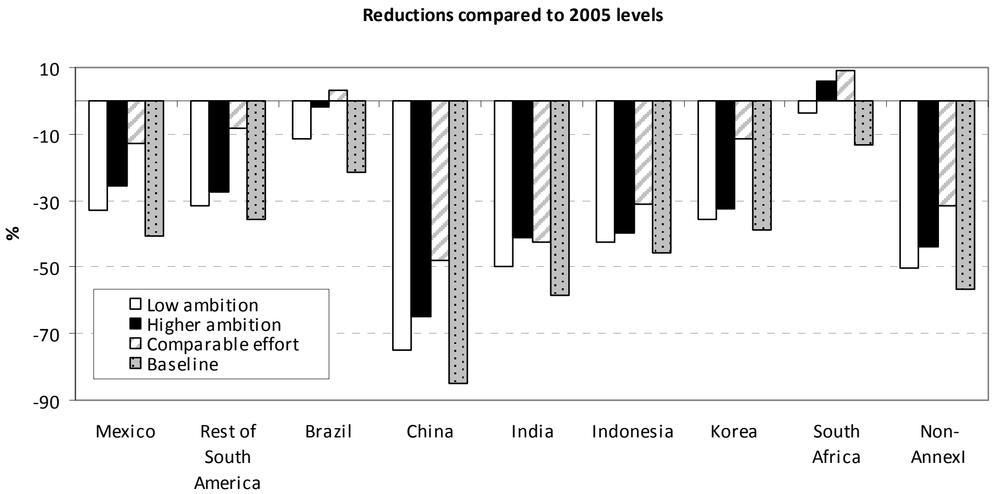

Figure 6.2. Emission reductions (excl. REDD/LULUCF CO_2) in 2020 compared to 2005 levels for non-Annex I regions/countries (negative value means growth compared to 2005 levels)

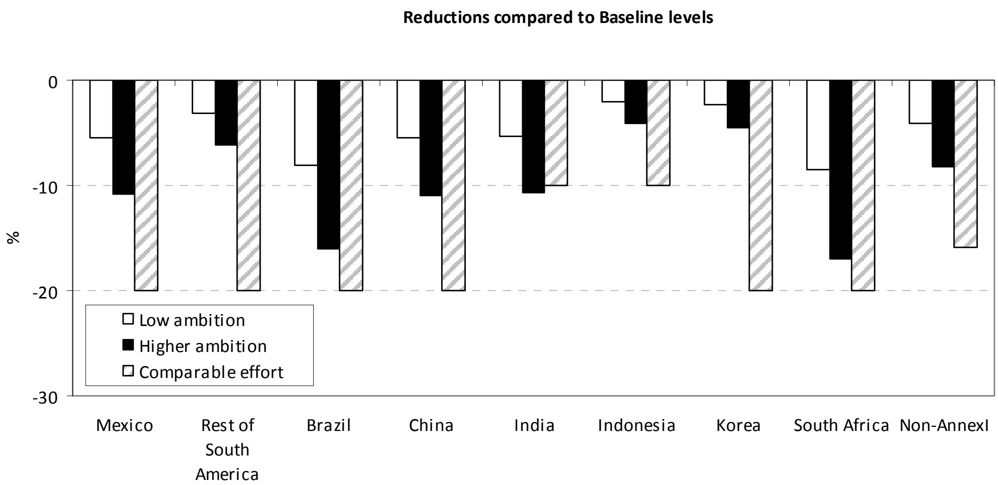

Figure 6.3. Emission reductions (excl. REDD/LULUCF CO_2) in 2020 compared to baseline emissions for non-Annex I regions countries (negative value means reductions compared to baseline emission levels).

6.2 Abatement costs excluding REDD financing

In this section we present the cost results for the non-Annex I countries excluding costs of REDD. Only the scenario variants excluding REDD/LULUCF CO_2 emissions are presented here. In Chapter 7 we will go into more detail for the scenario variants including REDD/LULUCF CO_2 emissions.

Abatement cost

Table 6.3 shows the average abatement costs for the non-Annex I countries when achieving the calculated emission reductions without trade and with trade. For the scenarios with trade, the table shows the average costs at which domestic reductions take place. For most non-Annex I regions, which act as sellers of carbon credits, the average abatement costs are higher than the no-trade average costs given that their domestic action for the trade scenario includes, besides

domestic action to meet their own reduction target, also additional domestic reductions to offset reductions in Annex I countries.
However, this is not always the case. In the higher ambition scenario we see (for some regions, i.e. Mexico, Brazil and South-Africa) that the domestic costs for the no trade scenario are higher than the domestic costs for the trade scenarios. This implies that these regions act as buyers of carbon credits on the carbon market. This can be explained by the relatively higher reduction targets for these regions (Figure 6.3), compared to the somewhat lower reduction targets for other non-Annex I regions (estimated with the conservative ECN cost curves).Some other non-Annex I regions, such as Africa and some Asian regions, act as sellers due to their cheaper available mitigation potential. The differences in average costs for most of the regions/countries between the comparable effort scenario and high NAMA scenario for the trade cases are highly significant, especially for regions like Korea and China. The main reason for this are the higher reduction efforts (e.g. reductions below baseline emissions) assumed in the comparable effort scenario (Figure 6.3).

For non-Annex I as a region, under a no-trade assumption for both the low and high scenarios, the average abatement costs (in US$/tonne CO_2) do not reach even one-tenth of those for the Annex I region. These costs are 1 (low) and 4 (high) for non-Annex I as a group and 32 (low) and 56 (high) for Annex I as a group. For the comparable effort scenarios, the average costs for Annex I are more than five times the non-Annex I costs: 12 for non-Annex I and 67 for Annex I.

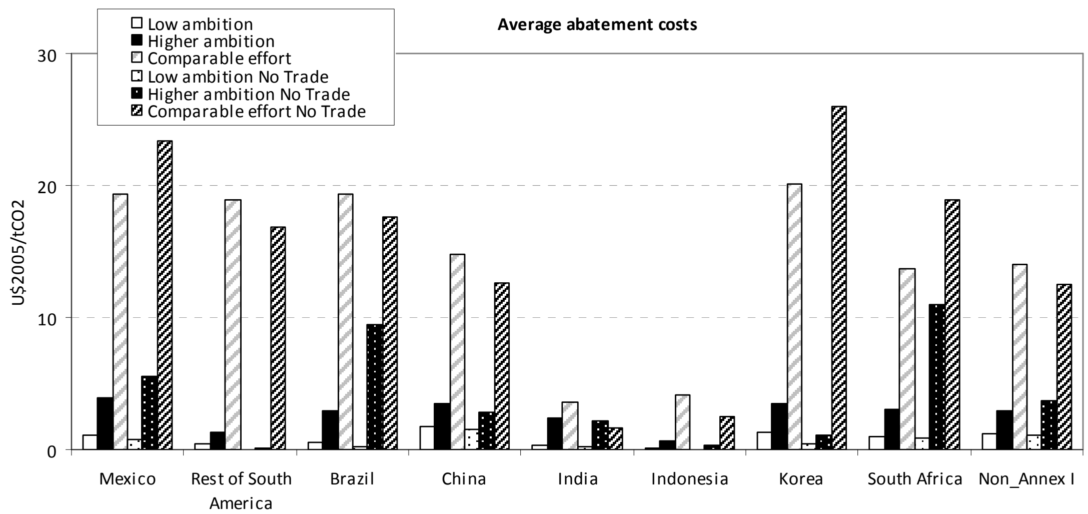

Figure 6.4. Average abatement costs for non-Annex I regions/countries

Table 6.3. Average abatement costs (US$/tonne CO_2) for non-Annex I regions

U$2005/tCO2	Trade Low ambition	Trade Higher ambition	Trade Comparable effort	No Trade Low ambition	No Trade Higher ambition	No Trade Comparable effort
Mexico	1.1	3.9	19	0.8	5.5	23
Rest of South America	0.4	1.3	19	0.0	0.1	17
Brazil	0.5	3.0	19	0.2	9.5	18
China	1.7	3.4	15	1.5	2.9	13
India	0.4	2.4	4	0.2	2.2	2
Indonesia	0.1	0.7	4	0.0	0.3	3
Korea	1.3	3.4	20	0.4	1.1	26
South Africa	1.0	3.0	14	0.9	11.0	19
Non-Annex I	1.2	2.9	14	1.1	3.7	12
Carbon price	4	15	58			

* Includes Mongolia & Taiwan
** Includes Papua New Guinea, Timor

Total costs and absolute emissions before and after trade
Table 6.5 shows the domestic costs (i.e. costs stemming from domestic reduction efforts and additional domestic costs to offset reductions in Annex I countries) and financial flows (i.e. total revenues or expenditure for carbon trade) for the non-Annex I regions in absolute terms (i.e. MUS$). Also, the domestic fractions (i.e. domestic abatement divided by the total abatement) are shown on Table 6.6. Most non-Annex I countries act as sellers on the carbon market, based on restrictions on trade (see Table 4.1). Our estimate for the availability of credits from non-Annex I regions on the carbon market is rather optimistic, limiting only 40% of the total potential for most of the non-Annex I regions. There are large differences in abatement costs between the ADCs and LDCs. The advanced developing countries may have costs as high as 0.3-0.5% of their GDP for the comparable effort scenario, but rather low costs for the low and higher ambition scenario. The LDCs have net gains from CDM for all three scenarios.

A general observation is that South Africa is the region with the highest abatement costs as a percentage of GDP, followed by Brazil. South Africa has high costs even compared to the Annex I regions/countries, due to their 20% reduction target, while some other non-Annex I regions generate profits even under the high emission reduction assumptions, such as the Rest of South America, China, Indonesia and Korea. For non-Annex I countries as a group, the assumed reductions under the low and high scenarios imply no costs as a percentage of GDP, while the comparable effort scenario shows costs of about 0.2% of GDP. The difference between a situation with trade and without trade is significant for countries such as Brazil and South Africa. It is important to mention that we did not include REDD in these scenarios. More detailed results are presented in Appendix G.

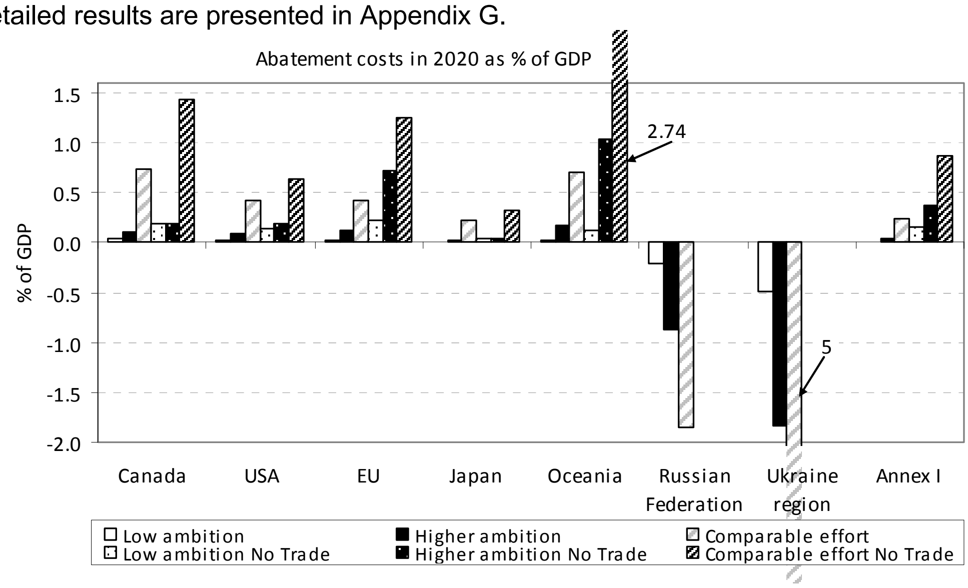

Figure 6.5. Abatement Costs as % of GDP for non-Annex I regions/countries

Table 6.4. Abatement costs as % of GDP for non-Annex I regions

	Trade			No Trade		
US$/tCO$_2$	**Low ambition**	**Higher ambition**	**Comparable effort**	**Low ambition**	**Higher ambition**	**Comparable effort**
Mexico	0.00	0.04	0.30	0.00	0.04	0.31
Rest of South America	−0.02	−0.05	0.40	0.00	0.00	0.40
Brazil	0.00	0.11	0.39	0.00	0.17	0.39
China	0.01	0.03	0.39	0.01	0.05	0.41
India	0.00	0.05	−0.16	0.00	0.05	0.03
Indonesia	−0.01	−0.03	−0.12	0.00	0.00	0.04
Korea	0.00	−0.01	0.31	0.00	0.00	0.31
South Africa	0.01	0.20	0.67	0.01	0.34	0.70
non-Annex I	0.00	0.00	0.18	0.01	0.04	0.29

Table 6.5. Costs for non-Annex I regions in MUS$ and emissions in $MtCO_2eq$

Low ambition	**Emissions ($MtCO_2eq$)**					**Costs (in $MUS\$_{2005}$)**			
	1990 level	**Target 2020**	**Domestic Incl. Trade and Sinks**	**Trade**	**Sinks**	**Domestic costs**	**Financial flows**	**Total costs of Abatement**	**Costs as % of GDP**
Mexico	472	851	50	−5	4	56	−23	33	0.00
Rest of South America	822	1366	70	−57	31	28	−242	−214	−0.02
Brazil	759	1309	82	−10	43	45	−44	1	0.00
China	4053	14293	924	−107	7	1566	−453	1113	0.01
India	1425	3291	200	−20	0	71	−87	−15	0.00
Indonesia	472	1097	37	−14	0	4	−59	−55	−0.01
Korea	484	1174	62	−35	0	80	−147	−67	0.00
South Africa	446	547	45	0	6	47	0	47	0.01
non-Annex I	13556	32956	1845	−574	143	2152	−2418	−266	0.00

Higher ambition	**Emissions ($MtCO_2eq$)**					**Costs (in $MUS\$_{2005}$)**			
	1990 level	**Target 2020**	**Domestic Incl. Trade and Sinks**	**Trade**	**Sinks**	**Domestic costs**	**Financial flows**	**Total costs of Abatement**	**Costs as % of GDP**
Mexico	472	802	81	12	4	318	197	515	0.04
Rest of South America	822	1323	101	−45	31	133	−680	−547	−0.05
Brazil	759	1195	124	62	43	366	992	1358	0.11
China	4053	13468	1860	−218	0	6375	−3289	3087	0.03
India	1425	3104	371	−5	0	873	−77	796	0.05
Indonesia	472	1074	64	−17	0	41	−255	−214	−0.03
Korea	484	1147	95	−40	0	328	−608	−279	−0.01
South Africa	446	496	68	28	6	204	448	652	0.20
non-Annex I	13556	31559	3368	−700	143	9878	−10452	−574	0.00

Comparable effort	**Emissions ($MtCO_2eq$)**					**Costs (in $MUS\$_{2005}$)**			
	1990 level	**Target 2020**	**Domestic Incl. Trade and Sinks**	**Trade**	**Sinks**	**Domestic costs**	**Financial flows**	**Total costs of Abatement**	**Costs as % of GDP**
Mexico	472	720	157	19	4	3027	1147	4174	0.30
Rest of South America	822	1128	251	0	31	4740	0	4740	0.40
Brazil	759	1139	233	9	43	4505	518	5023	0.39
China	4053	12094	3218	−202	0	47725	−11615	36110	0.39
India	1425	3130	416	−75	0	1511	−4341	−2830	−0.16
Indonesia	472	1009	135	−23	0	551	−1306	−755	−0.12
Korea	484	962	209	32	0	4208	1876	6085	0.31
South Africa	446	478	101	13	6	1374	789	2162	0.67
non-Annex I	13556	28889	6067	−729	143	85169	−41827	43342	0.18

The domestic reductions and costs, plus the financial flows and trade for the eight emerging economies and non-Annex I as a group, are shown in Table 6.5. For the low ambition scenario we see that indeed most non-Annex I regions are acting as sellers on the carbon market. The total supply of reductions for non-Annex I is 30% for the low and high ambition scenarios and 40% for the comparable effort and China is the main supplier. For the high and comparable effort scenario, some regions (i.e. Mexico, Brazil and South Africa for the high scenario) are playing the role of buyers of credits. In our calculations, the banking and trading of hot air from the first commitment period, plus rather low reduction targets below baseline (due to the conservative estimates based on ECN cost curves), influence the role of non-Annex I on the carbon market and reduces the financial flows from Annex I to non-Annex I, not to mention the influence on the carbon prices (that drop considerably due to more available credits). Non-Annex I regions as a group shows that the total revenues of carbon trade exceed the costs of domestic mitigation measures, resulting in gains in the low and higher ambition scenario, whereas in the comparable effort scenario the total revenues cover about half of the domestic costs.

Table 6.6 Domestic Abatement for non-Annex I regions in % of the total abatement, excluding trade and sinks

	Low ambition	**Higher ambition**	**Comparable effort**
Mexico	111%	87%	89%
Rest of South America	231%	152%	100%
Brazil	109%	73%	97%
China	113%	113%	107%
India	111%	101%	122%
Indonesia	159%	136%	120%
Korea	226%	173%	87%
South Africa	100%	72%	89%
non-Annex I	141%	125%	113%

Emissions per capita
The first noticeable aspect in Figure 6.6 is the increasing trend in per capita emissions from 1990 to 2020 for the high and low NAMAs. In the comparable effort scenario, some countries/regions, like the rest of South America and Brazil, stay at the same levels or reduce their emissions compared to 2000 levels. India and Indonesia show very low per capita emissions due to their high populations and low emissions. China and Korea show the largest increases compared to 2000 levels for the low and higher ambition scenarios.

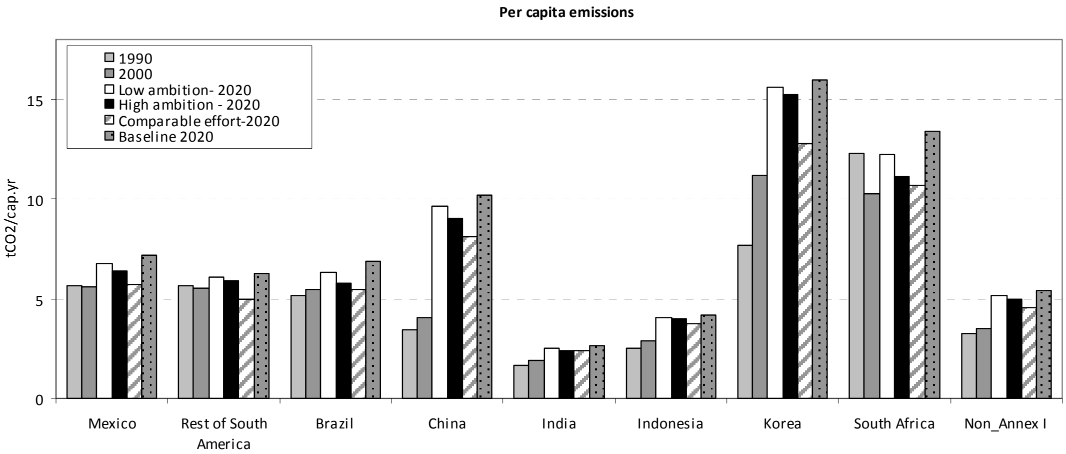

Figure 6.6. Per capita emissions for non-Annex I countries according to RCP baseline excluding LULUCF.

Table 6.7. Per capita emissions for non-Annex I countries

Per capita emissions			**2020**			**2020**
(tCO_2/cap.yr)	**1990**	**2000**	**Low ambition**	**Higher ambition**	**Comparable effort**	**Baseline**
Mexico	5.7	5.6	6.8	6.4	5.7	7.2
Rest of South America	5.6	5.5	6.1	5.9	5.0	6.3
Brazil	5.2	5.5	6.3	5.8	5.5	6.9
China	3.4	4.1	9.6	9.1	8.1	10.2
India	1.7	1.9	2.5	2.4	2.4	2.7
Indonesia	2.5	2.9	4.1	4.0	3.7	4.2
Korea	7.7	11.2	15.6	15.2	12.8	16.0
South Africa	12.3	10.2	12.2	11.1	10.7	13.4
Non-Annex I	3.3	3.5	5.2	5.0	4.5	5.4

7 Analysis of the reduction, costs and financial flows associated with financing REDD measures outside the carbon market

In Chapter 5 and 6 we have presented the results for the Annex I and non-Annex I regions and countries for those scenarios excluding REDD/LULUCF CO_2 emissions and reductions. In the scenarios excluding LULUCF CO_2 the REDD actions are not included in the reductions presented, and in the scenarios including LULUCF CO_2 the REDD actions are *additional* reductions (for the mitigation actions by non-Annex I countries, and for the reduction proposals for the USA and Australia).

This chapter analyses the scenarios including REDD/LULUCF CO_2 emissions, i.e. the reductions, and abatement costs and financial flows associated with REDD. The costs for REDD action are calculated separately, and do not influence the abatement costs, the carbon price and financial flows of the carbon market. For the scenarios including REDD and LULUCF CO_2 emissions, we assumed that non-Annex I regions will finance 20% of the REDD reductions domestically and the remaining 80% is financed by Annex I regions or other non-Annex I regions.

7.1 Analysing the reductions of REDD actions

In Chapter 2 the various pledges for Annex I countries and assumed NAMAs-based emission reductions for non-Annex I countries were described. For the low-pledge proposals of Annex I countries, it was shown that none of the low pledges of Annex I parties include additional reductions related to REDD. This is not the case for the high-pledge Annex I proposals. The USA has proposed a purchase of REDD credits, thereby increasing their reduction target by an additional 14% below 1990 levels (844 $MtCO_2$). Australia has also formulated its targets including land-use emissions and has proposed purchasing international credits (REDD) to realise an additional reduction of 5% below 2000 levels (32 $MtCO_2$). In their pledges, the USA and Australia have indicated that REDD reductions will take place outside the carbon market. Furthermore, it was shown in Sections 3.2 and 3.3 that there is considerable avoided deforestation potential for some emerging economies. Brazil has proposed reducing its deforestation emissions 70% below baseline in 2020 (1066 $MtCO_2$), to be financed externally.

In combination with the defined scenarios in section 3.1 this provides several variants for Annex I pledges and non-Annex I NAMAs. In the present section we discuss how we deal with these targets and calculations of costs under the various scenarios.

The reductions of the LULUCF emissions are based on the G4M MAC in Table 3.2 and Table 3.3 (in parenthesis). For the comparable effort scenario reductions on REDD are assumed to the same as under the higher ambition scenario. For these reductions we assumed that non-Annex I regions will finance 20% of these reductions domestically, and that the remaining 80% of reductions will be financed by Annex I regions or other non-Annex I regions. The pledges of USA and Australia only account for a part of this supply, as will be analysed in this Chapter.

An overview of supply and demand of REDD credits is shown in Table 7.1. Under the supply we assume all actions being taken by non-Annex I regions with REDD mitigation potential. With demand we assume for the non-Annex I regions with REDD their own domestic actions (i.e. 20%), and for the other regions the financing of REDD actions in other regions (i.e. 80%).

There are different opinions on how these REDD credits should be accounted for. The USA and Australia claim the REDD credits as additional reductions. Other Annex I regions may also finance REDD, but do not claim these credits as additional reductions for themselves.

In the analysis presented here, we have included the reductions and costs that are not attributed to any particular Party in the group 'Other Parties', which includes other Annex I countries as well as non-Annex I countries. The present chapter does not analyse possible attribution rules for REDD financing.

Table 7.1. Supply and demand (in parentheses) of REDD credits under the various scenarios ($MtCO_2$).

	1a. Low ambition (excl. REDD)	1b. Low ambition (incl. REDD)	2a. Higher ambition (excl. REDD)	2b. Higher ambition (incl. REDD)	3a. Comparable effort (excl. REDD)	3b. Comparable effort (incl. REDD)
Non-Annex I regions						
Mexico	0	59 (12)	0	117 (24)	0	117 (24)
Rest of South America	0	146 (29)	0	291 (58)	0	291 (58)
Brazil	0	1066 (213)	0	1066 (213)	0	1066 (213)
China	0	1 (0)	0	3 (1)	0	3 (1)
India	0	3 (1)	0	6 (1)	0	6 (1)
Indonesia	0	111 (22)	0	222 (44)	0	222 (44)
South Korea	0	3 (1)	0	7 (1)	0	7 (1)
South Africa	0	0 (0)	0	0 (0)	0	0 (0)
'Other Parties'	0	0 (1112)	0	0 (494)	0	0 (494)
Annex I regions						
USA	0	0 (0)	0	0 (844)	0	0 (844)
Oceania	0	0 (0)	0	0 (32)	0	0 (32)
non-Annex I	0	1390 (278)	0	1712 (343)	0	1712 (343)
Annex I	0	0 (1112)	0	0 (1370)	0	0 (1370)

In converting the demand for REDD into costs, we have distinguished the following three cases:

1. Demand for REDD credits from Annex I only. Emissions reductions are financed at *marginal* costs. There are no net profits for REDD credits supplying countries. (Figure 7.1, left)
2. Demand for REDD credits from both Annex I and non-Annex I regions. With priority for domestic action and supply to other regions at *marginal costs*. More specifically, a REDD supplying region first takes care of its own target, and then reduces for the supply of credits to the other countries. There are no net profits for REDD credits supplying countries. (Figure 7.1, middle).
3. Demand for REDD credits from both Annex I and non-Annex I regions. With priority for domestic action and supply to other regions at *REDD-'market' price* (i.e. the abatement costs of the last avoided tonne of carbon through REDD) There are net profits for REDD credits supplying countries (shaded area) (Figure 7.1, right)

A scenario where REDD in non-Annex I countries is not financed by other countries is not analysed here.

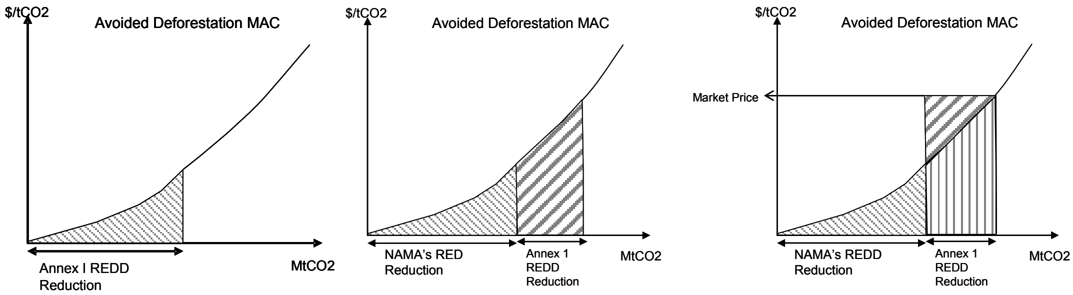

Figure 7.1. Methodology for converting demand for REDD credits into costs. Demand from Annex I only (left), priority for NAMA demand and Annex I supply at marginal abatement costs (middle), and priority for NAMA demand and Annex I supply at REDD 'market' price (i.e. maximum marginal costs of last abated tonne of carbon from REDD) (right).

Implications for the low ambition scenario

- **Scenario 1b Marginal abatement cost – Low including REDD/LULUCF CO_2 emissions:** We assumed that the domestic financing of non-Annex I countries corresponds to 20% of REDD action (i.e. 25% of the MAC potential of REDD). In addition, we assumed that the remaining 80% of REDD action is financed by Annex I or other non-Annex I countries. In this scenario we calculated the costs assuming that non-Annex I reductions are made at the marginal abatement cost and that the remaining reductions are financed by the 'Other parties' at the marginal abatement cost (Figure 7.1, middle).
- **Scenarios 1b Market price – Low including REDD/LULUCF CO_2 emissions:** For this scenario we made the same assumptions as for 1b Marginal abatement cost except that the costs of the credited part of the REDD reductions were calculated using the 'REDD market' price (i.e. maximum marginal costs of last abated tonne of carbon from REDD) as shown in Figure 7.1, right.

Implications for the higher ambition scenario:
In terms of emission reductions, the higher ambition scenario for Annex I represents differences for those countries that have made a specific proposal for LULUCF and REDD: Australia and the USA. For non-Annex I regions, the targets are shown in Table 7.1. For the cost calculation we used the same two methodologies as for the low ambition scenarios:

- **Scenario 2b Marginal abatement cost – High including REDD/LULUCF CO_2 emissions:** We assumed that the domestic financing of non-Annex I countries corresponds to 20% of REDD action (i.e. 50% of the MAC potential of REDD). In addition, we assumed that the remaining 80% of REDD action is financed by Annex I or other non-Annex I countries. In this scenario, we calculated the costs assuming that non-Annex I countries reductions are made at the marginal abatement cost and that the remaining reductions are financed by the 'Other parties' at the marginal abatement cost (Figure 7.1, middle).
- **Scenarios 2b Market price – High including REDD/LULUCF CO_2 emissions:** For this scenario we made the same assumptions as for Scenario 2b Marginal abatement cost (above) except that the costs of the credited part of the AD reductions were calculated using the 'market' price as shown in Figure 7.1, right.

Implications for the comparable effort scenario
The assumptions mentioned in the beginning of this chapter imply that costs for financing REDD action are equal to the higher ambition scenario including REDD/LULUCF CO_2. For the latter, there is again the distinction between financing by Annex I regions of REDD action at the marginal abatement cost or 'market' price.

7.2 Demand and supply of REDD credits and the costs of financing REDD outside the carbon market

Each of the two cases for the higher ambition scenario including REDD/LULUCF CO_2 is shown in Figure 7.2. Brazil is clearly the largest supplier of REDD credits, both because of its 70% mitigation target and its large potential. Indonesia and the rest of South America are other main suppliers, with about one-fourth of the total credits. Considering the demand for REDD credits, the amount of credits that lack specific party financing stands out. A total of about 500 $MtCO_2$, with total costs of 4.6 or 6.4 billion US$ (depending on 'marginal abatement cost' or 'market price' assumptions) has not been attributed to a specific party.

The pledge of the USA clearly dominates the demand for and financing of REDD credits. Assuming financing for REDD credits at the REDD market price has significant cost implications. The costs increase by about 40%, creating a net trading benefit of 4.9 billion US$. These gains will benefit the suppliers of credits. The specific financial flows to each region depend on the relative contributions of regions and on the shape of their cost curves. We have not analysed these flows in this report; our current modelling framework is unable to accurately represent regional flows in REDD credits and financing for both a general carbon market and a REDD market simultaneously. As a result, calculations are done under simplified market assumptions where all non-Annex I regions pay an equal price for reductions. The market price for REDD credits is not affected.

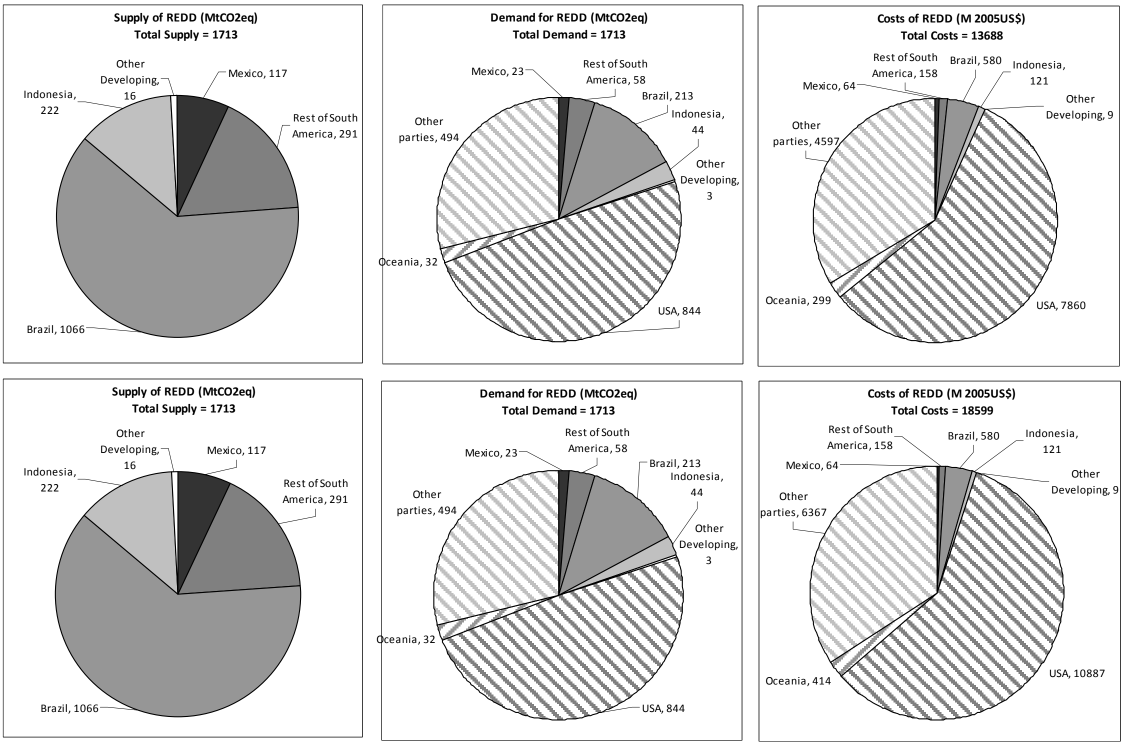

Figure 7.2. Domestic reduction, demand and costs for REDD reductions under the higher ambition scenario. The upper row is based on 'marginal abatement cost' assumptions and the lower row on 'market price' assumptions for Annex I financing.

Under low ambition scenario assumptions, the total reductions by REDD (except Brazil) decreases as expected (assuming 25% reduction of the regional MAC curve instead of 50%). Another important difference is that in the low ambition scenario, no specific REDD financing by USA and Oceania is included (Table 7.1). Therefore, all demand and financing not assigned to non-Annex I regions can only be attributed to the 'Other parties' category (which now also includes the USA and Australia). The total amount of credits in this category is about 600 $MtCO_2$ greater than under high assumptions (1100 $MtCO_2$ total), which also results in higher costs (9.2-

12.3 billion US$) under both financing options (Table 7.2). The relative cost increase under market assumptions is similar to that in the high case. Market price assumptions create a net trading benefit of 3.2 billion US$ for non-Annex I regions as a group.

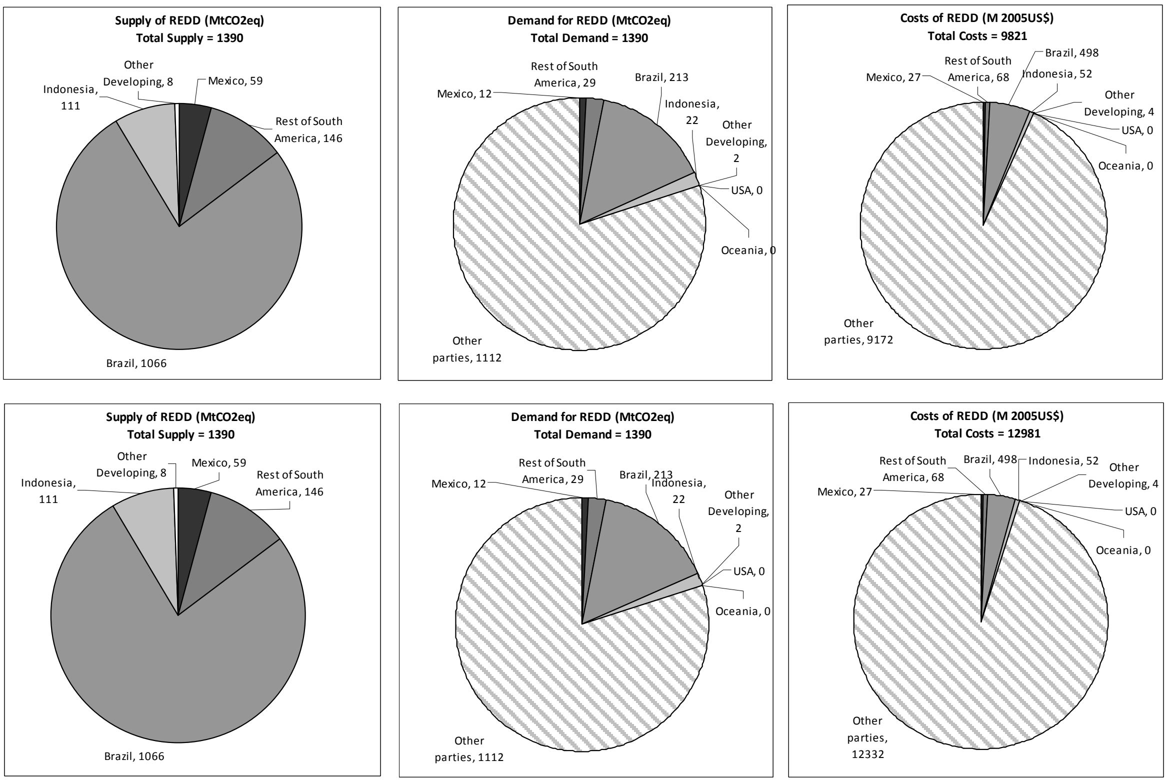

Figure 7.3. Supply, demand and costs for REDD reductions under lower ambition scenario assumptions. The upper row is based on 'marginal abatement cost' assumptions and the lower row on 'market price' assumptions for Annex I financing.

The results of scenarios discussed above are also shown in Table 7.2 and Table 7.3.

Table 7.2. Costs for financing REDD (MUS$) for Parties under various scenario assumptions

Reductions in MUS$	1b-marginal abatement cost	1b-market price	2b-marginal abatement cost	2b-market price	3b-marginal abatement cost	3b-market price
Mexico	27	27	64	64	27	64
Rest of South America	68	68	158	158	68	158
Brazil	498	498	580	580	498	580
China	1	1	2	2	1	2
India	1	1	3	3	1	3
Indonesia	52	52	121	121	52	121
Korea	2	2	4	4	2	4
South Africa	0	0	0	0	0	0
USA	0	0	7860	10887	0	10887
Oceania	0	0	299	414	0	414
Other Parties	9172	12332	4597	6367	12332	6367
non-Annex I	649	649	931	931	649	931
Annex I	9172	12332	12757	17668	12332	17668

Table 7.3. Costs (% of GDP) of countries under scenario assumptions. Note that for 'other parties' no percentage can be calculated.

Costs (% of GDP)	1b-marginal abatement cost	1b-market price	2b-marginal abatement cost	2b-market price	3b-marginal abatement cost	3b-market price
Mexico	0.002	0.002	0.005	0.005	0.005	0.005
Rest of South America	0.014	0.014	0.033	0.033	0.033	0.033
Brazil	0.039	0.039	0.045	0.045	0.045	0.045
China	0	0	0	0	0	0
India	0	0	0	0	0	0
Indonesia	0.008	0.008	0.018	0.018	0.018	0.018
Korea	0	0	0	0	0	0
South Africa	0	0	0	0	0	0
USA	0	0	0.042	0.058	0.042	0.058
Oceania	0	0	0.020	0.027	0.020	0.027
Other Parties	N/A	N/A	N/A	N/A	N/A	N/A
Non-Annex I	0.003	0.003	0.004	0.004	0.004	0.004
Annex I	0.019	0.025	0.026	0.036	0.026	0.036

The average abatement costs of REDD are defined as the total abatement costs (i.e.: domestic costs of REDD activities in non-Annex I countries to meet their 20% target, and costs of buying REDD credits or financing 80% of the REDD activities in non-Annex I countries by Annex I countries or other non-Annex I countries) divided by the total abatement of REDD. Table 7.4 shows the average abatement costs of REDD and the costs of reductions of non-REDD measures on the carbon market. Only for the comparable effort scenario the average costs of REDD is below that of the average costs of non-REDD measures. For the low and higher ambition scenario, the average price for REDD is clearly above that of non-REDD reductions.

The European Commission (2009) reported higher reductions at lower prices than those presented here. The main cause of this difference is that our study exclude the REDD reductions from the African and South Eastern Asian regions, because the REDD credits supply from these regions is quite restricted by 2020 in our model. Including REDD potential of these regions would increase the available potential and lower prices.

Table 7.4. Average global prices of reductions on the Carbon Market and for REDD credits.

Average price (US$/tonne$CO_2$)	Low ambition	Higher ambition	Comparable effort
Carbon market	1	3	16
REDD	7	8	8

Main findings:

Given the assumption that Annex I countries would finance 80% of REDD activities in non-Annex I countries at the REDD market price[74], the costs would be around 18 billion US$ for Annex I countries, while non-Annex I countries would earn around 4 billion US$ by 2020 despite of its 20% own contribution. This would lead to halving the emissions from deforestation.

The calculations assume that REDD action is additional and financial flows are independent of the financial flows in the carbon market.

- Given the already low carbon prices for the low and higher ambition scenario, REDD is only a relatively low cost option in the comparable effort scenario.
- More specifically, the average abatement costs[75] of REDD for the low and higher ambition scenario (about 7-8 US$/tonne) are above the average abatement costs of the (used) non-

[74] I.e.: the marginal costs of last abated tonne of carbon from REDD

[75] Average costs are defined as the total abatement costs (i.e.: domestic costs of REDD activities in non-Annex I countries to meet their 20% target, and costs of buying REDD credits or financing 80% of the

REDD mitigation options (about 1-3 US$/tonne). The average costs for REDD (about 8 US$/tonne) are lower than the average abatement costs of the non-REDD mitigation options for the comparable effort scenario (about 16 US$/tonne).

We have two options for the financing of REDD: (1) against the REDD market price, and (2) against the marginal abatement costs.

- When REDD projects are directly financed against the REDD market price, which is higher than the marginal abatement costs, total abatement costs (total domestic costs plus gains from trading) for non-Annex I regions are negative (-2.5 to 4 billion $US\$_{2005}$ for the three scenarios). For Annex I regions the costs are about 12 to 18 billion $US\$_{2005}$.
- When REDD projects are directly financed against the marginal abatement costs, there are domestic costs from REDD to meet their own 20% target for non-Annex I regions of about 0.5 to 1 billion $US\$_{2005}$, and costs for Annex I are about 9 billion and 13 billion $US\$_{2005.}$
- There is still a significant quantity of REDD action (as part of the 80% external financing) that is currently not supported under the reduction proposals from the Annex I countries (0.5-1.1 $GtCO_2$).

7.3 Total mitigation costs and financial flows

Table 7.5 and Figure 7.4 give an overview of the costs, financial flows and benefits that are associated with the carbon market and reductions through REDD.

Table 7.5. Costs, financial flows and benefits associated with low, high and comparable effort scenarios (billion US$).

Low ambition

Mitigation costs and financial flows (billion 2005 US$)		Domestic costs	Domestic costs for trade	Total revenue or expenditure for carbon trade/REDD	Transaction costs	Total costs	Net trading benefit *
Annex I	reductions exl. REDD	1.8	0.0	2.4	1.3	5.6	69.4
	REDD	0.0	0.0	12.3	0.0	12.3	0.0
	total	1.8	0.0	14.8	1.3	17.9	69.4
Non Annex I	reductions exl. REDD	1.5	0.6	-2.4	0.0	-0.3	1.8
	REDD	0.6	9.2	-12.3	0.0	-2.5	3.2
	total	2.2	9.8	-14.8	0.0	-2.8	4.9

High ambition

Mitigation costs and financial flows (billion 2005 US$)		Domestic costs	Domestic costs for trade	Total revenu or expenditure for carbon trade/REDD	Transaction costs	Total costs	Net trading benefit *
Annex I	reductions exl. REDD	7.9	0.0	10.5	2.2	20.5	168.0
	REDD	0.0	0.0	17.7	0.0	17.7	0.0
	total	7.9	0.0	28.1	2.2	38.2	168.0
Non Annex I	reductions exl. REDD	10.3	-0.4	-10.5	0.0	-0.6	10.9
	REDD	0.9	12.8	-17.7	0.0	-4.0	4.9
	total	11.2	12.4	-28.1	0.0	-4.6	15.8

Comparable effort

Mitigation costs and financial flows (billion 2005 US$)		Domestic costs	Domestic costs for trade	Total revenu or expenditure for carbon trade/REDD	Transaction costs	Total costs	Net trading benefit *
Annex I	reductions exl. REDD	75.0	0.0	41.8	3.9	120.6	313.3
	REDD	0.0	0.0	17.7	0.0	17.7	0.0
	total	75.0	0.0	59.5	3.9	138.3	313.3
Non Annex I	reductions exl. REDD	68.4	16.8	-41.8	0.0	43.3	25.1
	REDD	0.9	12.8	-17.7	0.0	-4.0	4.9
	total	69.3	29.5	-59.5	0.0	39.4	30.0

* Annex I regions also benefit from emission trading if we compare the costs with the costs under a scenario where no trade is assumed (see Appendix F).

REDD activities in non-Annex I countries by Annex I countries or other non-Annex I countries) divided by the total abatement of REDD.

Under the current proposals (low and higher ambition scenario), the annual estimated mitigation costs, including financing REDD activities, for the developed region would vary between 18 billion to 38 billion US$ in 2020. The developing countries would gain 3 billion to 5 billion US$. For the comparable effort scenario, the costs would be 138 US$ for developed and 40 billion US$ for developing countries.

Mitigation costs for Annex I in all three scenarios largely consist of expenditure for carbon trade and REDD. With more ambitious scenario assumptions, the share of domestic costs (costs excluding REDD) decreases from 80% of total costs for the low ambition scenario to 40% for the comparable effort scenario. The decreasing shares are caused by increasing carbon prices on the carbon market for the more ambitious scenarios.

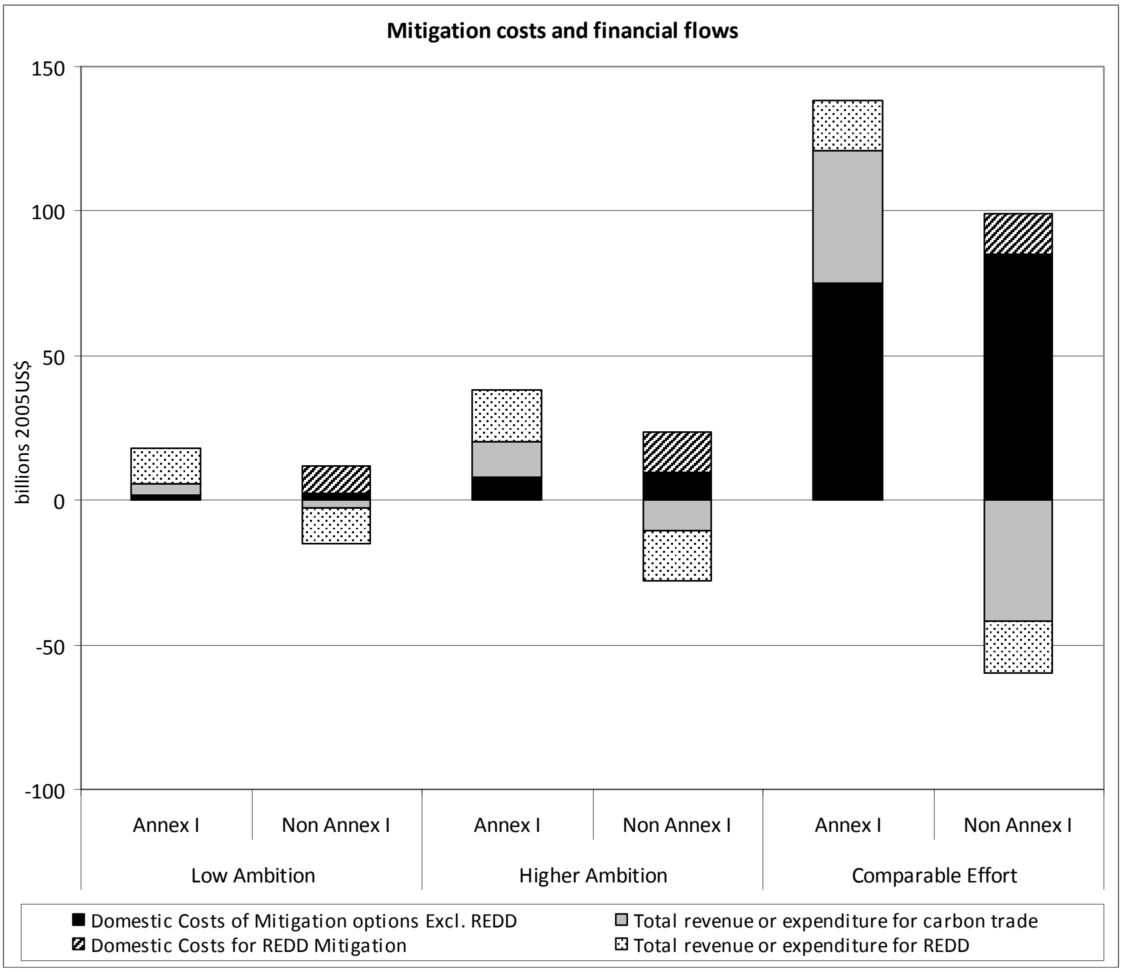

Figure 7.4. Mitigation costs and financial flows associated with the various scenarios.

The non-Annex I regions receive more financing from Annex I (total revenue or expenditure for carbon trade and REDD: 15 to 60 billion US$) than is necessary to invest in domestic action for trade (10 to 30 billion US$), and they therefore end up with net gains. In non-Annex I regions, for the low and higher ambition scenarios the net trading benefits outweigh domestic costs, resulting in negative total costs (−3 to −5 billion US$). For the comparable effort scenario, domestic costs outweigh the net trading benefits, resulting in total costs of 39 billion US$.

For non-Annex I, the domestic costs for trade are rather low (low ambition scenario) or even negative (higher ambition scenario). These low values are the result of significant trade also taking place within non-Annex I. This is likely to be caused by low and disproportionate targets for non-Annex I regions. As already discussed earlier in the report the ECN MAC curves are conservative, resulting in relatively low reduction targets. If this effect varies between non-

Annex I regions (relatively higher reduction targets for some, and lower reduction targets for other regions) this enhances trading. Also, some regions may have a disproportionately low target (such as for the Middle East that has no reduction target) which further encourages trading within the non-Annex I region. This trading reduces domestic costs for some individual non-Annex I countries and leads to a distorted result for domestic costs for trading within non-Annex I as a group. Expanding current calculations (as presented in Table 7.5) to a regional level would provide more insight into this aspect; this data is available in Appendix G.

In Table 7.5, there are net trading benefits presented for Annex I regions. What is presented here is the reduction of costs compared to a regime where no trade is assumed (for full data, see Appendix G). In comparison to such a scenario, total Annex I costs would increase by 200-400% (70 to 313 billion US$), thereby marginalising the apparently large benefits for non-Annex I regions.

Table 7.6 Global next-tonne or market prices of reductions on the carbon market and for REDD credits. .

Next-tonne (market) Marginal price (US$/tonne$CO_2$)	Low ambition	High ambition	Comparable effort
Carbon market	4	15	58
REDD	11	13	13

Main findings:

Under all scenarios, large financial flows exist from Annex I to non-Annex I through the carbon market and REDD financing, representing 40-80% of the total mitigation costs for Annex I

- In addition to expenditure for carbon credits, another important cost category for Annex I countries is financing of REDD (together with the domestic costs they account for the total mitigation costs). The expenditure of carbon credits through carbon trade and REDD financing form 80% of the total mitigation cost of Annex I in the low and higher ambition scenario, and 40% in comparable effort scenario (see Figure S.2). The higher shares in the low and higher ambition scenario can be explained by the relatively low reductions of the non-Annex I regions of 4-8% below the baseline emissions, and the availability of low costs mitigation options in these regions.
- The costs of mitigation and REDD for the Annex I region range from 18 billion to 138 billion US$. For the non-Annex I region, the total costs are negative for the low and higher ambition scenarios (−3 to −5 billion $US\$_{2005}$), while for the comparable effort scenario the net costs are about 40 billion $US\$_{2005}$.
- There are large financial flows from Annex I to non-Annex I through the expenditure for carbon credits and REDD financing by Annex I of 15 to 60 billion $US\$_{2005}$ for the three scenarios, which exceed the domestic costs in non-Annex I of additional reductions to offset reductions in Annex I countries and REDD reductions of about 10 to 30 billion $US\$_{2005}$. The resulting net gains are in the order of 5 to 30 billion $US\$_{2005}$.
- When compared to a scenario with no trade, total Annex I costs would increase by 200-400% (70 to 313 billion US$), somewhat marginalising the large benefits for non-Annex I regions.
- The market price for carbon credits on the carbon market in 2020 can be considered as rather low. This is the cumulative effect of the following causes
    - The conservative ECN MAC curve leads to relatively low NAMA-based emission reductions of 4-8% for the non-Annex I countries, so the developing countries still have a potentially abundant source of relatively less expensive abatement options, which can be used for offsetting reductions in Annex I countries, which lowers the carbon price. There are also some non-Annex I regions like the Middle East for which low or none domestic mitigation action is assumed, which means they can offer all of their mitigation potential to the carbon market.

- Allowing banking of hot air from the Kyoto period (from Russia and Ukraine) results in the release of 1.1-1.3 $GtCO_2$ hot air credits to the market by 2020, which also lowers the price.
- “New” hot air induced by low post-2012 targets by 2020 for Russia and Ukraine for the low and higher ambition scenario further increases the supply of carbon credits, and lowers the price.

8 The impact of the economic crisis

In this chapter, we present our analysis of the implications of the three scenarios for the emission reductions and abatement costs for the Annex I and non-Annex I countries as a group (Section 8.2) and as individual regions (Section 8.3), assuming an underlying baseline without crisis (default calculations) and with crisis. But first we will briefly describe the baseline with crisis. It is important to note that this aspect is still surrounded by many uncertainties related to the length of the crisis, the recovery afterwards and the overall impact of the crisis on GHG emissions.

8.1 Baseline with crisis

The default scenario used in this analysis was updated to account for the economic crisis of 2008/2009. The adjustments for 2008, 2009 and 2010 were based on the IMF publications in June 2009. This led on average to a negative adjustment for the 2009 growth rate in each world region by 3-5% and a smaller impact in 2010. During this period, in Annex I regions the economic crisis leads to negative growth rates; in non-Annex I regions with rapid economic growth (such as China) this leads to lower economic growth projections. In 2010, we assumed a growth reduction of 1-2% (also following the IMF indications). A crucial question is, what will be the impact on long-term growth? Several assumptions are possible: a full recovery (where growth is even faster after the crisis), a recovery to the original long-term growth rates (where the crisis has a long-term impact) or perhaps even a reduction in long-term growth rates. Here, we decided to use the second option and assume that after 2010 growth will return to the original long-term rates. This implies a long-term impact on emissions (see below). If instead one assumes increased growth after the crisis, the impact over the longer term would obviously be much smaller (and the crisis would significantly impact only the period from 2009 until perhaps 2020).

Besides reducing economic growth, we also reduced oil and natural gas prices from their 2007 levels to their early 2009 levels and assumed that they will return to the original scenario in about 5-10 years. The lower oil and gas prices imply that more gas is used in the power sector (and less coal), and that more oil is used in transport (and less biofuel).

Main finding:

- The economic crisis results in a decrease in GHG baseline emissions without climate policy of about 10% by 2010 and 8% by 2020 compared to the baseline emissions without the crisis. This is caused by our assumption that the crisis results in a reduction in GDP growth in 2009 and 2010 and a return to the original growth path after this period. If instead one assumes increased growth after the crisis, the impact over the longer term will obviously be much smaller (and the crisis would only really impact the period 2009 until perhaps 2020), and the emission differences could become zero after 2020.

8.2 Results for Annex I and non-Annex I countries as a group

Table 8.4 presents in detail the reductions and costs for the three scenarios with an underlying baseline without crisis (default calculations) and with crisis on the emission reductions and abatement costs for the Annex I and non-Annex I countries as a group, and for the world. For more detailed results, see Appendix F.

The main findings related to the impact of the crisis (See Table 8.1):

- The crisis leads to lower final global emissions of about 5% compared to 1990 levels. For example, for the higher ambition scenario the global emissions reach a reduction of 43% instead of 47% above 1990 levels, but are still unable to meet the concentration target of

450ppm CO_2eq. The GHG emission reduction targets for the Annex I countries compared to 1990 levels do not change (See Table 8.4).

- The surplus of AAUs, or hot air in the first commitment period, increases by 20%, to 3.0 $GtCO_2$eq, which represents about 8% of the 1990 emissions of the Annex I countries. The optimal banking conditions (i.e. maximal revenues for Russia and Ukraine) lead to banking of 25% of the total surplus of AAUs from the first commitment period to the second and the third. The surplus of AAUs or hot air in 2020 is higher under the crisis scenario, up to 1.4 and 1.1 $GtCO_2$eq/year for the low and high scenario, respectively. For the comparable effort scenario, the crisis does not lead to hot air.
- Due to the lower baseline levels, the reduction targets for both the Annex I and the non-Annex I countries decrease
- The carbon price decreases by 12-16% for the low and higher ambition scenarios and 30% for the comparable effort scenario.
- The abatement costs for the Annex I countries as a group decrease by about 30-35% for the low and higher ambition scenario and 65% for the comparable effort scenario. The domestic abatement for the Annex I countries is lower in absolute terms ($MtCO_2$eq), but not in relative terms for the comparable effort scenario (see domestic fraction, i.e. domestic abatement divided by the total abatement, in Appendix F).
- The carbon flow traded from the non-Annex I countries to the Annex I countries for offsetting declines by 20-25% for the low and higher ambition scenarios. In combination with the lower prices, this leads to lower financial flows of 2, 8 and 3 billion US$ for the low, high- and comparable effort scenarios relative to the no-crisis scenario, equivalent to decreases of around 40%, 35% and 93% compared to the flows under the no crisis scenario.
- Due to the lower traded volumes and financial flows, the gains for the non-Annex I countries for the low and higher ambition scenarios become much smaller than in the no-crisis situation. The domestic costs for meeting their targets and the financial gains from trading appear to balance each other.
- The global abatement costs decline by about 25-30% for the low and higher ambition scenarios and 45% for the comparable effort scenario.
- For the comparable effort scenario, the achieved reductions for Annex I countries after trade increase to 31% (instead of 27%) below 1990 levels. This assumes that 100% of the hot air from the first commitment period is banked and traded, and “new” hot air is forfeited, for the benefit of the selling Parties, i.e. Russia and Ukraine (Appendix F).

8.3 Cost implications for individual Annex I countries

In this section we focus on Annex I due to the stronger impact of the crisis on this regions. Table 8.3 presents the reductions of emissions and costs of abatement for the three scenarios assuming an underlying baseline with crisis for the Annex I countries and Annex I as a group. For individual Annex I regions, we made similar findings to those for Annex I as a group, as can be seen in the tables below (see also Appendix G). We also ascertained large differences in costs between the Annex I regions.

Table 8.1 Results for Annex I, non-Annex I and the world in 2020 for scenarios excluding REDD/LULUCF CO_2 emissions.

	Default baseline without impact of the crisis			Baseline with impact of the crisis		
	Low ambition	Higher ambition	Comparable effort	Low ambition	Higher ambition	Comparable effort
TARGETS BEFORE TRADE	**2020**	**2020**	**2020**	**2020**	**2020**	**2020**
Annex I						
Baseline emissions ($MtCO_2eq$) excl. LUCF CO_2	19436	19436	19436	18081	18081	18081
Reduction target (% compared to 1990 level)	−10%	−15%	−31%	−10%	−15%	−31%
Reduction target (% compared to baseline)	−12%	−17%	−33%	−5%	−11%	−28%
Non-Annex I						
Baseline emissions ($MtCO_2eq$) excl. LUCF CO_2	34370	34370	34370	32770	32770	32770
Reduction target (% compared to 1990 level)	143%	133%	113%	132%	122%	103%
Reduction target (% compared to baseline)	−4%	−8%	−16%	−4%	−8%	−16%
Global						
Baseline emissions ($MtCO_2eq$) excl. LUCF CO_2	53806	53806	53806	50850	50850	50850
Reduction target (% compared to 1990 level)	55%	47%	30%	50%	43%	25%
Reduction target (% compared to baseline)	−7%	−11%	−22%	−5%	−9%	−20%
TRADING PRICE	**2020**	**2020**	**2020**	**2020**	**2020**	**2020**
Carbon price (in US$/$tCO_2$)	4	15	58	4	13	42
Costs	**2020**	**2020**	**2020**	**2020**	**2020**	**2020**
Annex I						
Domestic costs (in MUS$)	1828	7889	74958	1452	5764	38087
Financial flows (in MUS$)	3748	12604	45683	2308	8294	3392
Total costs (in MUS$)	5576	20492	120641	3760	14057	41479
Costs as % of GDP	0.01	0.04	0.24	0.01	0.03	0.09
Non-Annex I						
Domestic costs (in MUS$)	2152	9878	85169	1699	8447	50958
Financial flows (in MUS$)	−2418	−10452	−41827	−1778	−7572	−305
Total costs (in MUS$)	−266	−574	43342	−79	875	50653
Costs as % of GDP	−0.00	−0.00	0.18	−0.00	0.00	0.22
Global						
Costs (in MUS$)	5309	19919	163983	3681	14932	92133
Costs as % of GDP	0.01	0.03	0.22	0.01	0.02	0.14

Table 8.2 Reductions compared to 1990 levels for individual Annex I countries and Annex I as a group. They correspond to those presented in Chapter 5.

	Compared to 1990		
% Reduction	**Low ambition**	**Higher ambition**	**Comparable effort**
Canada	3%	3%	28%
USA	0%	3%	15%
EU	20%	30%	35%
Japan	4%	4%	19%
Russian Federation	10%	15%	50%
Ukraine region	20%	20%	61%
Oceania	2%	17%	25%
Annex I	10%	15%	31%

Table 8.3. Detailed Results for Annex I in 2020 for scenarios excl. REDD/LULUCF CO_2 emissions.

Low ambition	Emissions ($MtCO_2eq$)					Costs (in MUS$)			
	1990 level	Target 2020	Domestic Incl. Trade and Sinks	Trade	Sinks	Domestic costs	Financial flows	Total costs of Abatement	Costs as % of GDP
Canada	596	578	44	72	44	51	312	364	0.02
USA	6030	6030	475	595	103	603	2573	3176	0.02
EU27	4338	3470	284	531	22	341	2297	2637	0.02
Japan	1207	1162	55	−5	48	63	−20	43	0.00
Russia	3484	3136	174	−475	121	203	−1759	−1556	−0.10
Ukraine	1098	879	51	−131	4	40	−486	−447	−0.18
Oceania*	650	637	52	24	37	50	104	154	0.01
Annex I	18925	17109	1242	419	395	1452	2308	3760	0.01
Higher ambition	**Emissions ($MtCO_2eq$)**					**Costs (in MUS$)**			
	1990 level	Target 2020	Domestic Incl. Trade and Sinks	Trade	Sinks	Domestic costs	Financial flows	Total costs of Abatement	Costs as % of GDP
Canada	596	578	68	48	44	225	647	872	0.06
USA	6030	5849	694	557	103	2183	7453	9636	0.06
EU27	4338	3036	397	853	22	1195	11416	12611	0.08
Japan	1207	1162	87	−37	48	276	−466	−190	0.00
Russia	3484	2962	309	−610	121	998	−7675	−6677	−0.43
Ukraine	1098	879	71	−152	4	160	−1915	−1755	−0.72
Oceania*	650	539	75	99	37	201	1328	1529	0.12
Annex I	18925	16070	1871	560	395	5764	8294	14057	0.03
Comparable effort	**Emissions ($MtCO_2eq$)**					**Costs (in MUS$)**			
	1990 level	Target 2020	Domestic Incl. Trade and Sinks	Trade	Sinks	Domestic costs	Financial flows	Total costs of Abatement	Costs as % of GDP
Canada	596	429	133	133	44	1970	5712	7682	0.53
USA	6030	5126	1246	729	103	16577	31412	47989	0.29
EU27	4338	2820	684	782	22	8945	33714	42659	0.26
Japan	1207	977	151	84	48	1941	3621	5562	0.10
Russia	3484	1742	459	−843	121	4693	−35172	−30479	−1.96
Ukraine	1098	428	94	−332	4	724	−13834	−13110	−5.38
Oceania*	650	488	110	114	37	1152	4917	6069	0.46
Annex I	18925	12999	3117	20	395	38087	3392	41479	0.09

*Oceania's 1990 level is corrected with Australia's UNFCCC LULUCF emissions for 1990

Table 8.4 Abatement costs as % of GDP for Annex I regions. The numbers in parentheses indicate the costs with the crisis baseline and outside parenthesis without crisis

	Trade			No Trade		
	Low ambition	Higher ambition	Comparable effort	Low ambition	Higher ambition	Comparable effort
Canada	0.04 (0.02)	0.10 (0.06)	0.74 (0.53)	0.19 (0.09)	0.19 (0.09)	1.44 (0.96)
USA	0.03 (0.02)	0.09 (0.06)	0.42 (0.29)	0.14 (0.06)	0.19 (0.10)	0.64 (0.40)
EU27	0.03 (0.02)	0.12 (0.08)	0.42 (0.26)	0.23 (0.09)	0.72 (0.32)	1.26 (0.60)
Japan	0.01 (0.00)	0.03 (0.00)	0.22 (0.10)	0.04 (0.0)	0.04 (0.0)	0.33 (0.13)
Russian Federation	−0.22 (−0.10)	−0.87 (−0.43)	−1.86 (−1.96)	0.00 (0.0)	0.00 (0.0)	0.0 (0.0)
Ukraine	−0.49 (−0.18)	−1.84 (−0.72)	−5.27 (−5.38)	0.00 (0.0)	0.00 (0.0)	0.0 (0.0)
Oceania	0.03 (0.01)	0.17 (0.12)	0.71 (0.46)	0.13 (0.02)	1.03 (0.41)	2.74 (1.36)
Annex I	0.01 (0.01)	0.04 (0.03)	0.24 (0.09)	0.15 (0.06)	0.38 (0.17)	0.88 (0.46)

Table 8.5 Abatement costs as % of GDP for non-Annex I regions. The numbers in parenthesis indicated the costs for the crisis baseline

	Trade			No Trade		
	Low ambition	**Higher ambition**	**Comparable effort**	**Low ambition**	**Higher ambition**	**Comparable effort**
Mexico	0.00 (0.00)	0.04 (0.03)	0.30 (0.27)	0.00 (0.00)	0.04 (0.04)	0.31 (0.31)
Rest of South America	−0.02 (−0.02)	−0.05 (−0.04)	0.40(0.37)	0.00 (0.00)	0.00 (0.00)	0.40 (0.39)
Brazil	0.0 (0.00)	0.11 (0.09)	0.39(0.36)	0.00 (0.00)	0.17 (0.17)	0.39 (0.39)
China	0.01 (0.01)	0.03 (0.04)	0.39(0.40)	0.01 (0.01)	0.05 (0.05)	0.41 (0.40)
India	0.0 (0.00)	0.05 (0.04)	−0.16(−0.05)	0.00 (0.00)	0.05 (0.04)	0.03 (0.03)
Indonesia	−0.01 (−0.01)	−0.03 (−0.02)	−0.12(−0.03)	0.00 (0.00)	0.00 (0.00)	0.04 (0.04)
Korea	0.0 (0.00)	−0.01 (−0.01)	0.31(0.29)	0.00 (0.00)	0.00 (0.00)	0.31 (0.34)
South Africa	0.01 (0.01)	0.2 (0.18)	0.67(0.58)	0.01 (0.01)	0.34 (0.35)	0.70 (0.71)
non-Annex I	0.0 (0.00)	0.0 (0.0)	0.18(0.22)	0.01 (0.01)	0.04 (0.04)	0.29 (0.28)

9 Discussion of caveats of study

In this study we used an integrated modelling framework (FAIR) to explore the regional emission reduction targets and abatement costs for the Annex I countries. However, there are a few important limitations to the study that are essential to interpreting the results.

1. The results are based on model data and projections. Our projections do not always represent national projections of the UNFCCC, in particular for LULUCF CO_2 emissions. This is because models are simplified representations of reality that do not cover all sectors and are not always calibrated at the national level. Consequently, models can only partially reproduce these data. This is not only true for the IMAGE set of models, but also for most regional and global models. This shortcoming could be mitigated by including official national data and projections, but the inclusion of such information would result in internal inconsistencies (e.g. between baselines and MACs).

2. The reductions *including* REDD/LULUCF CO_2 emissions presented here should be used cautiously, as these depend on projections of emissions from land use and land-use changes and forestry (LULUCF), possibly based on different land-use accounting rules than the Kyoto ones, which are both are rather uncertain. Different land use accounting rules could affect the outcomes, particularly for Annex I countries with a significant share in these emissions, such as Australia, Canada and the Russian Federation. The accounting rules for LULUCF are currently under discussion, and could also have a large impact. In addition, there are significant uncertainties surrounding LULUCF CO_2 emission projections for the non-Annex I countries and REDD MAC curves.

3. The mitigation potentials and costs for reducing emissions from deforestation (REDD) are subject to many uncertainties, as analysed in more detail in den Elzen et al. (2009b). We used the LULUCF CO_2 emissions projections from IIASA's G4M land-use model (deforestation Baseline and MAC) for the non-Annex I regions, and the UNFCCC LULUCF CO_2 emissions data for Australia. For the rest of Annex I countries, we assumed no LULUCF CO_2 emissions.

4. The NAMA-based reductions for non-Annex I countries are based on bottom-up MAC curves for the non-Annex I region that include much detail but are not exhaustive. The ECN MAC curve does not cover all abatement options in all countries, which leads to an underestimation of the total mitigation potential in the non-Annex I region. The results presented here should thus be interpreted as being very conservative.

5. The cost concept used in this study refers to direct abatement costs, based only on MAC curves derived from underlying expert models. It does not capture the macroeconomic impacts of climate policy. Macroeconomic cost measures (such as consumption or GDP losses, but also sectoral impacts) may be larger in some cases; they also include effects such as the loss of competitiveness, impacts on fuel trade, and the combined effects of climate policy and existing taxes, among many others. Conversely, they could also be smaller, since there will always be sectors and industries that profit from climate policy, and there may be benefits from recycling the revenues of carbon taxes.

6. We included the effect of historic prices through price-induced learning, price-based technology choice and system inertia for energy-related CO_2 MAC curves.[76] For long-term

[76] The modelling framework used in this report (TIMER and FAIR) aims to capture the dynamics between carbon price history and current marginal carbon price. The historic price development influences the shape of the MAC curve. The most important effect is the limit on the rate of implementation. A higher sustained price is obviously more successful at inducing change in the energy system. Another dynamic effect that is included in this model is price-induced learning. Technology development under higher sustained carbon prices will be more rapid than under low prices. Finally, the modelling framework captures the effect of technology depletion (limited to the time horizon in this study). For example, there

assessments, these effects are well captured and robust. However, for short-term assessments, the effects are more sensitive. Very little price history is available, so short-term cost assessments simply have more uncertainty than long-term ones. Specifically, the dynamic effects and system inertia referred to above were not implemented in the MAC curves for non-CO_2 gasses and those for REDD. Assuming higher levels of available potential and/or at lower prices, the calculations could therefore be overly optimistic.

7. Finally, there is a need for much more extensive model comparison. In our analyses, we used our own IMAGE/TIMER cost and baseline emission estimates. Therefore, in order to arrive at more robust outcomes, we have concluded that it would be better − in terms of arriving at more robust results − to include the results of calculations carried out as part of other energy system or macroeconomic models or, alternatively, based on baselines and MAC curves derived from these models.

are limits to the total wind generation capacity in the energy system. Under higher sustained prices, this limit is reached at an earlier time, thereby increasing the costs for this technology. To capture this effect, the FAIR model interpolates between three typical price development pathways that are implemented in TIMER for a wide range of carbon prices, while emission reductions are recorded (van Vliet et al., 2009). The price pathways consist of a linear growth pathway (linear growth to the end level), a block pathway (tax instantaneously at the end level) and an exponential pathway (after sustained low levels, rapid growth occurs at the end of the time period).

10 Conclusions

In our study we analysed the Reduction Proposals for developed countries (i.e. country Pledges for Annex I countries) and the Nationally Appropriate Mitigation Action (NAMA) strategies for developing countries and their impacts on the carbon market. The analysis focused on two main aspects and their implications for carbon market dynamics. First, the abatement or reduction in absolute terms (i.e. in $MtCO_2eq$) and in relative terms (e.g. compared to 1990, 2005 and baseline levels) and second, the costs of abatement in terms of the average and market costs and the relative costs to GDP for the various proposals for developed and developing countries.

We developed three main scenarios with two main variants. The three main scenarios refer to the ambition of the pledges for the Annex I countries and NAMA-based mitigation action for the non-Annex I countries (i.e. low, high and comparable effort scenario – the latter one being used as a reference for the 2-degree warming target given its recent political relevance). The first variant of these three scenarios is the inclusion or exclusion of the Land Use Change and Forestry Emissions (LULUCF CO_2 emissions), and the second is the method of cost calculations (marginal cost or market cost). This last variant was only taken into account for scenarios including LULUCF CO_2 emissions.

The main findings of the study are as follows:

- As of August 2009, the low and high pledges for GHG reductions of Annex I countries (including the US) respectively imply for 2020 a reduction of 10-15%[77] below 1990 levels when excluding REDD and LULUCF CO_2, which is far less than the 25-40% reduction required to meet the 2 degree climate target. If the surplus AAUs of Russia and Ukraine (due to pledges above baseline levels) are forfeited, or not used, the Annex I reduction increases to 14-19% below 1990 levels.
- The high pledges of the EU, USA and Japan[78] are less distant from the comparable effort reductions to meet a 30% aggregated Annex I reduction target, than the pledges of Canada, Russia and Ukraine, which are far below the comparable effort reductions.
- Conservatively estimated, NAMA-based mitigation actions (excluding REDD/LULUCF CO_2) could reduce the emissions of eight emerging economies[79] to 5-11% below baseline levels by 2020, and 4-8% for the non-Annex I countries as a group. This is less than the 15-30% reduction below baseline emissions by 2020 that may be needed to realise a global emissions pathway consistent with limiting warming to about 2 °C (i.e. together with 25-40% Annex I reduction below 1990 levels).
- The abatement costs for the Annex I countries as a group are about 0.01-0.04% of GDP in 2020 for the low and higher ambition scenarios, and 0.24% for the comparable effort scenario, if use of emissions trading and CDM are allowed. If all Annex I pledges and comparable efforts must be implemented domestically (no emissions trading), the total abatement costs increase by a factor of 4-13. There are large differences in total costs between countries.
- The abatement costs expressed as a percentage of GDP of mitigation action in non-Annex I regions are lower than the costs of the Annex I countries. With the current pledges of Annex I regions the non-Annex I countries may even have net gains after emissions trading. In this study, we do not make assumptions on who should bear the cost of mitigation action in non-Annex I countries (except for REDD). Non-Annex I actions could also be partly financed by Annex I, in which case there would be no costs for non-Annex I, and only net gains from the carbon market.

[77] The new pledge from Japan (September 2009) of 25% reduction below 1990 levels in 2020 has not been taken into account – it would mean a reduction of 11-16 % below 1990 levels by 2020 instead of 10-15 %.

[78] This is based on pledge by previous government, i.e. not taking into account the proposed target announced in September 2009.

[79] Mexico, Rest of South America, Brazil, China, India, Indonesia, Korea and South Africa.

- The estimated carbon price in 2020 is 4 and 15 US$/t$CO_2$eq for the low and higher ambition scenarios, respectively, and 58 US$/t$CO_2$eq for the comparable effort scenario, which can be considered as rather low. Due to hot air, the main sellers on the carbon market would be Russia and the Ukraine; the main buyers would be the EU and USA.
- Given the assumption that Annex I countries would finance 80% of REDD activities in non-Annex I countries at the REDD market price[80], the costs would be around 18 billion US$ for Annex I countries, while non-Annex I countries would earn around 4 billion US$ by 2020 despite of its 20% own contribution. This would lead to halving the emissions from deforestation.
- Under all scenarios, large financial flows exist from Annex I to non-Annex I through the carbon market and REDD financing, representing 40-80% of the total mitigation costs for Annex I
- The economic crisis decreases the carbon prices for all scenarios. The Annex I countries have much lower costs during the crisis due not only to the lower price, but also to the lower reduction effort that is required (lower baseline, but same target). The domestic abatement cost in non-Annex I countries is somewhat lower but so are the revenues from carbon trading.

The findings in our report are based on modelled calculations, so they are highly dependent on the various assumptions made for different parameters and the data used as input for the calculations. Parameters and data that can significantly affect the results include the assumptions about Marginal Abatement Costs Curves, baselines, hot air/“new” hot air (e.g. traded, banked and forfeited) and the accounting rules for land-use emissions.

[80] I.e.: the marginal costs of last abated tonne of carbon from REDD

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Appendix A Avoided deforestation emission: implementation for the scenarios calculations

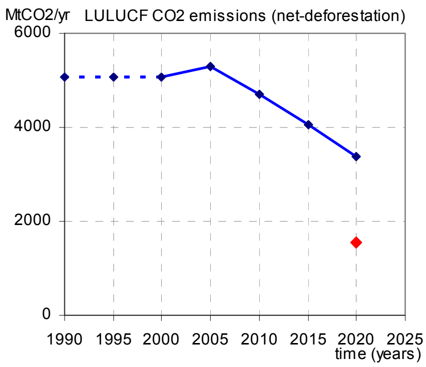
The avoided deforestation (AD) potential is calculated based on two methods. First, it is based on a bottom-up approach using the ECN MAC curve in which the mitigation potential for some developing countries is calculated as described in Appendix C (Bakker et al., 2007). This methodology leads to the AD and net deforestation emissions for non-Annex I shown in the graph below (top) for 2020 and marked with the red dots (i.e. 1700 $MtCO_2$ and 1600 $MtCO_2$, respectively).

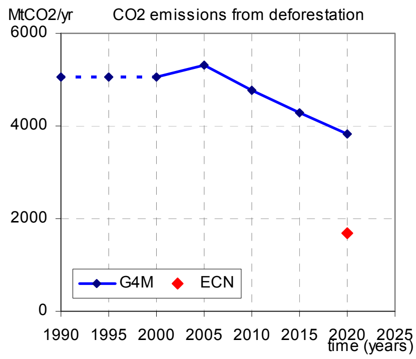
The absence of an historical path from the AD potential creates a technical limitation, so there was a need to look for an alternative for using it in the FAIR model, which requires an historical path. To solve this technical limitation, we applied the reduction below the baseline found by the NAMAs method (described in Section 3.2) to a complete dataset in 2020, thereby obtaining new reductions.

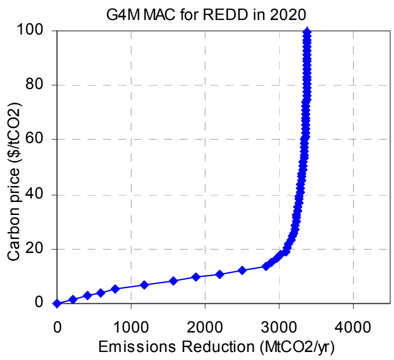
Second, the AD potential is calculated using the new, more complete dataset of the G4M model as briefly described in Kindermann et al (2008). The G4M data has an historical path from 2000 and projections until 2020; it also includes a marginal abatement cost curve for 2020, as shown in the graph below (bottom left). As can be seen in the graph below (top), in 2020 G4M is more than double the ECN baseline for deforestation and net deforestation.

We applied the initial reduction potentials directly to the MAC of the G4M model and found a whole new set of reductions below baseline. These reductions correspond to 25% and 50% of the mitigation potential, and are shown in Table 3.4 and Table 3.5 (for the low and higher ambition scenario) under column AD and in parentheses. In this way, extra scaling of baselines and cost curves (which would be an alternative methodology for implementation) is avoided.

In general, given the large difference between the deforestation baseline in the two methods (ECN or G4M) leads to large AD reductions.







Appendix B The main characteristics of the baseline

The table below shows global population, GDP per capita and anthropogenic GHG emissions for 1990, 2000 and 2020 for the default baseline (IMAGE) before harmonisation to historical data (van Vuuren et al., 2009b).

	Population			GDP			GHG emissions		
	(in million inhabitants)			(1000 US$ per capita)			($GtCO_2eq$ per year)		
	1990	2000	2020	1990	2000	2020	1990	2000	2020
Annex I regions									
Canada	28	31	35	26.6	31.7	45.3	0.6	0.67	0.73
USA	254	279	337	31.2	38.6	55.5	6.48	7.2	8.49
Western Europe	377	389	397	26.1	31.1	46	4.63	4.54	4.76
Central Europe	131	130	125	4.6	5.1	11.3	1.58	1.18	1.38
EU27*	508	519	522	20.3	24.3	37	6.21	5.72	6.14
Ukraine region	66	65	57	2.3	1.2	5	1.06	0.53	0.63
Russian Federation	164	165	149	5.3	3.5	11.7	3.39	2.15	2.31
Japan	124	127	125	30.7	34.4	48.4	1.34	1.39	1.46
Oceania	22	25	30	26.6	33.4	50.7	0.8	0.93	1.04
non-Annex I regions									
Mexico	83	99	125	6.1	7.2	11	0.49	0.59	0.86
Rest of Central America	62	74	96	3.0	3.5	5	0.55	0.3	0.37
Brazil	147	170	207	3.7	4.2	6.2	1.3	1.42	1.25
Rest of South America	146	174	225	2.9	3.6	5.2	1.54	1.71	1.76
Northern Africa	118	146	201	1.4	1.5	2.1	0.38	0.48	0.77
Western Africa	242	322	514	0.6	0.6	0.7	0.29	0.60	1.5
Eastern Africa	152	196	312	0.4	0.4	0.5	0.40	0.57	0.71
South Africa	36	45	45	4.6	4.6	7.2	0.52**	1.19**	1.21**
Rest of Southern Africa	81	108	149	0.6	0.6	1.1			
Turkey	58	70	88	3.7	4.4	6.4	0.26	0.30	0.46
Kazakhstan region	51	57	69	1.6	1.1	5.8	0.7	0.45	0.7
Middle East	134	174	263	4.4	4.9	6.5	1	1.57	2.34
India	857	1016	1311	0.4	0.6	1.3	2.19***	2.84***	5.03***
Korea region	63	70	75	5.6	9.0	26.5	0.49	0.68	1.09
China region	1184	1325	1486	0.6	1.4	6.2	6.24	7.14	13.00
Mekong region	258	308	398	1.1	1.6	3	1.02	1.21	1.9
Indonesia region	188	218	270	0.9	1.1	2.4	0.87	0.8	1.09
Southern Asia	275	346	522	0.4	0.5	1.2			
World	5302	6128	7611	5.6	6.2	9.4	38.38	40.93	56.58

* It is assumed that the EU27 covers Western and Central Europe.
** Includes Emissions of South Africa and the rest of Southern Africa
*** Includes Emissions of India and the rest of Southern Asia

Appendix C Historical Emission Data

The emission sectors distinguished are:

Sectors	UNFCCC	EDGAR	IEA
Industry:			
Autoproducer Electricity Plants			+
Manufacturing Industries and Construction	1AA2	1A2	+
Energy - Manufacturing Industries and Construction - Other	1AA2F		+
Feedstocks and Non-Energy Use of Fuels	1AD		
Industrial Processes	2A		+
Chemical Industry	2B	2B	
Chemical Industry - Ammonia Production	2B1		
Chemical Industry - Carbide Production	2B4		
Chemical Industry - Nitric Acid Production	2B2	2B2	
Chemical Industry - Adipic Acid Production	2B3	2B3	
Chemical Industry - Other	2B5		
Metal Production	2C	2C	
Metal Production - Iron and Steel Production	2C1		
Metal Production - Ferroalloys Production	2C2		
Metal Production - Aluminium Production	2C3		
Metal Production - Other	2C5		
Pulp and paper	2D1		
Cement Production	2A1	48	2A1(EDGAR)
Lime Production	2A2		
Soda Ash Production and Use	2A4		
HFC, PFC and SF_6 use from a range of sources (semi-conductors, industrial refrigeration and air conditioning equipment)	2F6, 2F1, 2F8, 2F2, 2F7, 2C, 2F6, 2C3,		H11, H12, H14, H21, H24,H27, H28, H31, H35, H40, H45, H50, H55, H60
Electricity			
Energy Industries	1AA1	1A1bc	+
Power generation (public and auto; including co-generation)	1AA1A	1A1a	
Main Activity Electricity and Heat Production			+
Domestic			
Transport	1AA3		+
Transport road	1AA3B	1A3b	
Transport - Railways	1AA3C	1A3c	
Transport - Civil Aviation	1AA3A		
Transport - Navigation	1AA3D	1A3d	
Transport - Other Transportation	1AA3E	1A3e	
Other Sectors - Commercial - Institutional	1AA4		+
Other Sectors - Residential	1AA4A	1A4	
Other Sectors - Agriculture - Forestry - Fisheries	1AA4B		
Other Stationary and Mobile	1AA5		
HFC, PFC and SF_6 use from a range of sources (domestic refrigeration and air conditioning equipment, fire extinguishers, solvents and aerosol applications)	2F3, 2F1, 2F4, 2F5,		H13, H22, H23, H25, H26
Fossil fuel production			
Fugitive Emissions of Fuels	1B		+
Fugitive Emissions of Fuels - Coal	1B1	1B1	
Fugitive Emissions of Fuels - Oil and Natural Gas	1B2	1B2	
Agriculture (non-energy related emissions)			
Agricultural Soils (fertilizer use)	4D		
Rice Cultivation	4C	4C	
Animals (Enteric Fermentation)	4A	4A	
Animal waste management (Manure Management)	4B	4B	
Biomass burning			
Savannah burning		4E	4E (incl. CO_2 from organic carbon) 1)
Direct soil emissions		4D1	
Manure in pasture/range/paddock		4D2	
Indirect N2O from agriculture		4D3	
Other direct soil emissions			4D4
Waste (waste disposal and processing)			
Solid Waste Disposal on Land	6A	6A	
Wastewater Handling	6B	6B	
Waste – Other	6D	6D	
Waste incineration		6C	6C
Biomass Burning			
Field Burning of Agricultural Residues	4F	4F	4F (EDGAR)
CO_2 emissions from Biomass	1C3		

Forest Land	5A	5A	5A (EDGAR)
Cropland	5B		
Grassland	5C	5C	5C (EDGAR)
Settlements	5E		
Other	5G		
Forest Fires-Post burn decay		5F2	5F2 (EDGAR)
Bunkers			
International Bunkers	1C1		
International Bunkers – Aviation	1C1A	6	1C1(EDGAR)
Domestic aviation		1A3a	
International Bunkers – Marine	1C1B	18	1C2(EDGAR)

1) No net contribution to increasing atmospheric CO_2 assumed (short carbon cycle with regrowth within one year)

New in EDGARV40 (source http://edgar.jrc.it):

Large biomass burning emissions changed substantially, mainly due to the inclusion of post-burn decay emissions, but also because of different activity data (annual satellite data of areas burned instead of decadal data on the area deforested). For more information on sectoral differences in 2000, see Table 1.

5A. For large-scale biomass burning (category 5A), activity data for forest fires are now based on annual satellite data of grid areas burned (tropical and non-tropical forest fires, savannah fires, grassland fires), thereby including the large interannual variation in burning intensity. Previously, smoothed decadal average deforestation rates per country from the FAO were used to estimate these emissions. Although global total CO_2 emissions are of the same order of magnitude, differences may be very large for 'peak' years and for individual countries.

Peat fires (mainly in Indonesia) have been included in forest fires: for Indonesia an amount equivalent to 1400 Tg CO_2 was moved in 2005 from savannah fires to forest fires, with a trend back in time similar to the area of palm oil plantations as proxy for the peat area drained.

5F2. Post-burn decay after forest fires and deforestation (5F2) was calculated assuming that 50% of the above-ground biomass is oxidised or removed; thus the same amount remains behind on the land. Furthermore, assuming a 15-year linear decay of the remaining biomass, the activity data was calculated as the 15-year moving average of the past 15 years of forest fires multiplied by 0.47 kg C/kg dm tropical forest (default in 2006 IPCC Guidelines). Using the 15-year moving average of the forest fire activity data automatically includes the decay of drained peat lands (see 5A above).

Appendix D Updating the emissions dataset of the FAIR model

For the update of the emissions used in the FAIR model, we used the RCP baseline (IMAGE) and the historical dataset compiled for this report, as described in Chapter 4.

First of all, we would like to make three remarks on the methodology:
1. The methodology was applied at the level of 24 regions, because the IMAGE baseline is at the level of 24 regions and at the level of 8 sectors (i.e. industry, electricity, domestic, fossil fuel production, agriculture, waste, biomass burning and bunkers), since the FAIR model uses input at the level of these 8 sectors. The emissions for the India region and South Africa region needed additional downscaling into four smaller regions: India, Rest of South Asia, South Africa and Rest of Southern Africa, given their different economic and social developments, to obtain the match with the 26 FAIR regions (Figure 4.1). For the downscaling procedure we used ratios based on population developments in each region, and we applied these ratios to the land-use sectors. For the "fossil fuel" emission sectors (e.g. Industry, domestic, electricity, fossil fuel production and bunkers), the downscaling was based on ratios found with the original energy emissions scenario from TIMER for CO_2, N_2O and CH_4, which has emission projections for the four regions under consideration.
2. The emissions of international bunkers were not included in the calculations. The emissions for biomass burning were also not included in these calculations, since we used another dataset for deforestation and LULUCF CO_2 emissions (See Appendix A).
3. The cost calculations in the FAIR model are at level of 23 sources for three gases (only 6 energy sources and the rest non-CO_2 sources). The harmonisation methodology was also applied to these 23 sources and at the level of the 8 sources mentioned in point 1.

Harmonisation concept

The graph below illustrates the situation which was solved using the harmonisation procedure. The gap in 2005 is then bridged by using the harmonisation ratios. This gap arose due to the use of an improved historical dataset instead of the historical dataset from the TIMER emissions. By means of harmonisation ratios, the TIMER emissions were scaled in 2005 and a consistent dataset was obtained. This methodology is acceptable when the ratios do not completely change the original scenario, hence when ratios are close to one. When this was not the case, we used an offset value that maintains the difference between acceptable ratios (set by expert criteria) and the original emissions. This difference was then added throughout the whole (2005-2100) trend, scaling it up and preserving the trend. It is important to emphasise that this procedure was only applied to the sectors and regions with large differences between the historical data and TIMER emissions.

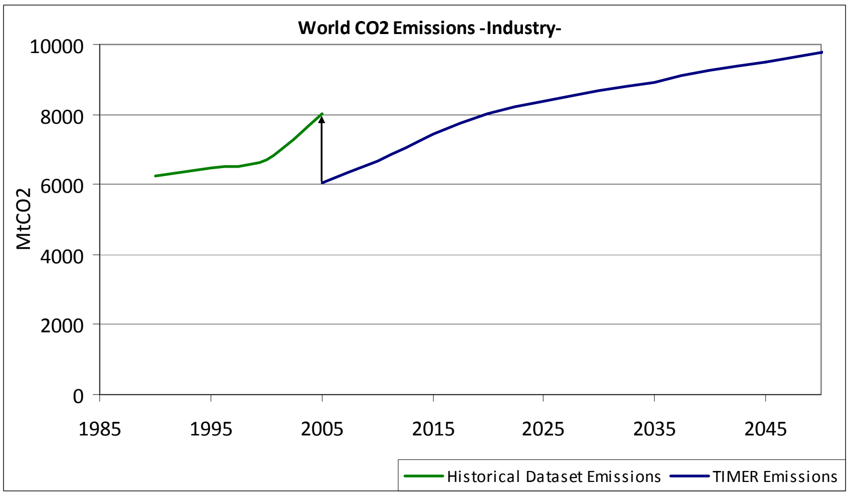


Figure D.1. Energy-related CO_2 emissions simulated with the TIMER model and the emissions trend of the historical dataset from 1990 to 2005. The emissions in 2005 should correspond to the historical data.

The table below shows some general patterns for the harmonisation ratios. For the Annex I regions, the simulated data are more in correspondence with the historical data than for the non-Annex I regions. In particular some smaller regions, like African regions with low emissions, show rather high or rather low ratios. The major emitting sectors, (i.e. CO_2 emissions from industry, electricity and domestic) show a better match. The non-CO_2 emissions sectors show large differences, but most of these emissions only amount to a small share of the total regional emissions. For some gases and sectors there are clear trends in the simulated emissions with respect to the historical data (e.g. N_2O domestic sector is slightly lower; CH_4 domestic is slightly higher), and for others the calibration was quite optimal for the comparison with the historical dataset used in the current report (e.g. most CO_2 sectors and CH_4 agricultural sector).

It is also important to keep in mind that the absolute emissions of some sectors for specific regions and gases are much lower than other sectors, so a very high harmonisation ratio does not always affect the regional total emissions very much. These amounts are shown for the global totals per sector per gas, to give an idea of the relevance of each sector in the total emissions.

Table D.1. Harmonisation ratios, i.e. defined as 2005 emissions data from historical datasets (UNFCCC, IEA or EDGAR) divided by simulated 2005 emissions data.

	INDUSTRY	ELECTRICITY	DOMESTIC	Fos.Fuel Prod. OIL	AGRICULTURE	WASTE	Total Per Region
				CO_2			
Canada	0.9	1.2	1.0	7.1	-	-	1.0
USA	1.2	0.8	0.9	3.5	-	-	0.9
Mexico	1.4	1.1	1.0	3.9	-	-	1.2
Rest Central America	1.7	0.9	1.0	10.2	-	-	1.1
Brazil	1.4	0.6	0.9	2.1	-	-	1.0
Rest South America	1.3	0.9	0.9	0.5	-	-	0.9
Northern Africa	1.4	1.1	0.9	0.2	-	-	1.0
Western Africa	1.1	1.2	0.9	0.1	-	-	0.6
Eastern Africa	1.0	1.0	0.8	16.8	-	-	0.9
South Africa	1.2	0.7	1.2	16.8	-	-	1.0
Western Europe	1.1	1.0	0.9	0.5	-	-	1.0
Central Europe	1.2	0.7	0.9	4.6	-	-	0.8
Turkey	1.1	0.6	0.9	9.7	-	-	0.8
Ukraine region	1.7	0.4	0.9	0.9	-	-	0.8
Kazachstan region	1.0	0.7	0.9	3.5	-	-	0.8
Russian Federation	1.2	0.7	0.7	1.8	-	-	0.8
Middle East	1.2	1.1	0.9	0.1	-	-	1.0
India	1.5	0.9	0.8	4.6	-	-	1.0
Korea region	1.2	0.7	0.7	-	-	-	0.9
China region	1.5	1.1	0.8	15.2	-	-	1.2
Mekong region	1.4	0.8	0.8	3.9	-	-	1.0
Indonesia region	1.3	0.9	0.8	0.9	-	-	1.0
Japan	1.3	0.7	0.9	3.6	-	-	0.9
Oceania	1.1	0.9	0.7	136.4	-	-	0.9
Southern Asia	1.5	1.3	0.5	1.1	-	-	1.0
Rest Southern Africa	0.9	1.7	0.4	2.1	-	-	1.0
World	1.3	0.9	0.9	1.4	-	-	1.0
Emissions MtCO2eq	8011	11422	8662	442	-	-	28537
				CH_4			
	INDUSTRY	ELECTRICITY	DOMESTIC	Fos.Fuel Prod. OIL	AGRICULTURE	WASTE	Total Per Region
Canada	0.2	24.1	1.6	1.0	1.0	0.6	0.9
USA	1.7	0.7	0.7	0.7	0.8	0.5	0.7
Mexico	0.5	1.3	1.1	1.8	1.0	0.7	1.1
Rest Central America	2.6	1.7	1.2	2.9	1.1	0.8	1.1
Brazil	0.7	1.7	1.0	2.9	1.2	1.4	1.4
Rest South America	0.8	1.6	1.1	1.7	1.0	0.8	1.0
Northern Africa	0.6	1.3	0.9	2.6	1.0	0.9	1.6
Western Africa	1.8	1.6	1.8	7.1	1.0	1.0	1.5
Eastern Africa	1.1	4.2	1.5	21.1	1.1	1.0	1.1
South Africa	0.8	0.1	2.0	0.8	0.8	1.1	1.0
Western Europe	0.5	2.2	1.3	0.8	0.8	0.6	0.7
Central Europe	0.9	0.6	1.3	0.4	1.1	1.3	0.7
Turkey	0.2	0.9	0.4	1.7	0.8	1.6	1.0
Ukraine region	0.9	0.3	1.4	1.0	0.9	0.8	0.9
Kazachstan region	0.3	0.4	0.6	0.8	1.4	0.9	1.0
Russian Federation	0.5	0.8	0.3	1.8	1.1	1.5	1.6
Middle East	0.7	1.7	0.9	1.0	1.0	1.0	1.0
India	0.6	0.8	1.3	1.3	0.9	0.9	0.9
Korea region	0.1	0.5	0.4	2.2	0.9	9.0	3.8
China region	0.2	0.4	0.9	1.5	1.1	1.1	1.2
Mekong region	1.3	1.5	1.4	3.5	1.0	1.3	1.3
Indonesia region	1.2	1.1	0.9	1.0	1.0	1.8	1.3
Japan	0.1	0.1	0.5	0.1	0.7	0.2	0.3
Oceania	0.5	2.1	1.3	1.2	0.9	1.6	0.9
Southern Asia	0.8	0.6	1.4	1.3	0.9	0.9	0.9
Rest Southern Africa	1.1	2.3	0.3	1.4	0.8	1.2	1.0
World	0.5	1.2	1.1	1.3	1.0	1.0	1.1
Emissions MtCO2eq	16	9	249	2404	3202	1445	7795
				N_2O			
	INDUSTRY	ELECTRICITY	DOMESTIC	Fos.Fuel Prod. OIL	AGRICULTURE	WASTE	Total Per Region
Canada	0.5	2.4	14.0	-	1.1	1.1	1.1
USA	0.8	0.9	5.6	-	1.3	1.4	1.2
Mexico	7.0	1.6	2.8	-	0.7	0.9	0.8
Rest Central America	0.7	1.6	1.4	-	0.8	0.6	0.8
Brazil	0.5	1.2	1.4	-	0.9	0.9	1.3
Rest South America	2.2	1.6	1.9	-	0.8	0.7	0.9
Northern Africa	1.1	2.3	1.2	-	0.7	0.8	0.7
Western Africa	0.2	3.3	1.9	-	0.7	0.5	1.9
Eastern Africa	0.4	2.3	1.6	-	0.8	0.5	1.1
South Africa	0.7	0.4	2.7	-	0.8	0.5	2.3
Western Europe	1.9	2.4	5.9	-	1.0	1.3	1.1
Central Europe	0.8	0.7	4.8	-	1.0	1.1	1.0
Turkey	2.2	1.6	1.0	-	0.6	1.2	0.7
Ukraine region	0.8	0.4	1.3	-	0.8	1.1	0.8
Kazachstan region	1.8	1.2	1.7	-	1.1	0.9	1.2
Russian Federation	2.2	0.6	0.7	-	1.6	1.3	1.5
Middle East	0.4	2.6	1.9	-	0.6	0.6	0.6
India	1.1	1.5	2.3	-	0.4	0.5	0.4
Korea region	0.3	1.6	1.4	-	0.6	0.8	0.5
China region	1.8	1.6	1.3	-	0.7	0.7	0.7
Mekong region	1.0	1.4	1.5	-	0.8	0.6	1.5
Indonesia region	1.7	1.1	1.0	-	1.4	0.6	2.9
Japan	1.0	0.9	2.9	-	0.7	0.5	0.8
Oceania	0.4	0.6	4.0	-	0.5	1.5	0.5
Southern Asia	0.5	3.2	1.9	-	0.4	0.6	0.4
Rest Southern Africa	0.2	7.2	0.8	-	0.9	0.6	2.4
World	1.0	1.3	2.6	-	0.8	0.8	1.0
Emissions MtCO2eq	163	58	139	0	1868	94	3018

Appendix E Implications for abatement costs and reduction potentials due to harmonisation of the baseline

The harmonisation procedure has several implications in the calculations because it is a scaling procedure that affects – slightly or considerably – the historical and future emissions projections, as it is shown in Appendix D.

Impact on reduction potentials of mitigation actions for non-Annex I regions
In Chapter 3 the mitigation actions for the low ad higher ambition scenario were presented and converted into reductions below baseline. In order to determine the effect of harmonising the baseline emissions on the reduction from mitigation actions, we applied the reduction factors (% below the 'non-harmonised' baseline) to the harmonised baseline emissions (right column), and compared these with the original reductions found by ECN (as shown in Chapter 2 and here in Table E.1). ECN performed the calculations using MAC curves and the so-called ADAM baseline emissions, developed by van Vuuren et al. (2009a). This baseline gives slightly different emission projections than the RCP baseline. The harmonisation has a larger impact on the projected emissions.

Table E.1 shows that most of the differences are attributed to the non-CO_2 emissions and to the deforestation baseline in the case of the reductions, including the avoided deforestation potential.

Table E.1. The reductions of mitigation actions calculated for the 'non-harmonised' (left) and 'harmonised' baseline emissions for four categories (energy efficiency (EE), renewable energy (RE), non-CO_2 GHGs (includes other industrial gases, agricultural emissions and waste emissions) and avoided deforestation (AD). For the AD reductions, we used the G4M mitigation potential.

MtCO2eq	ECN					RCP (Harmonized Baseline)						
50% NAMA	EE/RE	non-CO2	AD	Total Excl. AD	Total Incl. AD	EE/RE	non-CO2	AD G4M	AD ECN to G4M baseline	Total Excl. AD	Total Incl. AD ECN	Total Incl. AD G4M
Mexico	28	55	13	82	95	31	58	117	134	97	140	215
Argentina (un-scaled)	15	9	7	24	31	17	8	291	0	27	42	318
Brazil	146	66	408	212	620	135	78	1066	832	228	894	1294
China	797	637	0	1434	1434	880	722	3	-	1648	1649	1651
India	259	165	0	424	424	245	133	6	-	373	375	379
Indonesia	14	27	36	41	77	14	41	222	215	47	119	269
South Korea	37	3	0	40	40	30	8	7	-	39	39	46
South Africa	65	42	0	107	107	60	44	0	-	102	37	102
Total per measure	1361	1004	463	2365	2828	1412	1091	1713	1180	2561	3297	4274
Relative Diference						4%	8%		61%	8%	14%	34%

MtCO2eq	ECN					RCP (Harmonized Baseline)						
25% NAMA	EE/RE	non-CO2	AD	Total Excl. AD	Total Incl. AD	EE/RE	non-CO2	AD G4M	AD ECN to G4M baseline	Total Excl. AD	Total Incl. AD ECN	Total Incl. AD G4M
Mexico	14	27	6	41	47	16	29	59	67	49	70	107
Argentina (un-scaled)	7	5	4	12	15	9	4	146	0	13	21	159
Brazil	73	33	204	106	310	67	39	1066	416	114	447	1180
China	399	318	0	717	717	440	361	1	-	824	824	825
India	129	83	0	212	212	122	67	3	-	186	188	190
Indonesia	7	14	18	20	38	7	20	111	107	24	59	135
South Korea	19	2	0	20	20	15	4	3	-	20	20	23
South Africa	32	21	0	53	53	30	22	0	-	51	24	51
Total per measure	681	502	232	1182	1414	706	546	1390	590	1280	1654	2670
Relative Diference						4%	8%		61%	8%	15%	47%

EE/RE: Energy Efficiency/Renewable Energy
AD: Avoided Deforestation

The relative differences were calculated between the total reductions of the 'non-harmonised' and harmonised baseline, which resulted in a difference of 6% for the total reductions excluding AD. We assumed that 100% of the reduction potential corresponds to the baseline emissions, hence an increase in baseline emissions will (more or less) proportionally increase the technical mitigation potential, so that the reductions achieved by mitigation actions would not be very different from the figures presented originally by ECN and described in Chapter 2. Indeed, this is what is observed in the Table, and this was one of the reasons for applying the reductions below baseline directly to the harmonised baseline emissions excluding LULUCF CO_2 for non-Annex I regions in this report.
In conclusion, the harmonisation slightly affects the reductions in absolute terms, but the differences are small, and evidently the reductions in relative terms (compared to the baseline) are similar.

For the case of the baseline including LULUCF CO_2, there is a higher difference mainly attributed to the difference in the deforestation baselines used. The RCP harmonised baseline including LULUCF CO_2 used the avoided deforestation baseline originating from the G4M model as described in den Elzen et al. (2009b). ECN used an avoided deforestation baseline (from Bakker et al. (2007)) as described in Appendix F. The total maximum reduction potential of avoided deforestation from the G4M baseline is around 3.5 $GtCO_2$ in 2020 and that from ECN is around 1.6 $GtCO_2$ for 2020.

Due to this enormous difference, we applied a reduction of 50% and 25% to the G4M mitigation potential directly, and used these new AD reductions to calculate the reductions below baseline for the scenarios including LULUCF CO_2 for the non-Annex I regions.

Impact on cost calculations of Annex I and non-Annex I regions

With respect to the possible implications for the costs calculations we needed to look at the two main underlying factors driving the costs, i.e. the baseline emissions and the marginal abatement costs curves. The later was calculated as relative reductions below the baseline emissions, and therefore evidently not affected by harmonisation. The baseline emissions are affected by the harmonisation, and this also affects the costs, as analysed below.

When applying a particular target below 1990 levels and analysing the behaviour of the reductions below baseline, for example in 2020, we used different cases. The first case is where the harmonised baseline is lower than the original baseline. In this case, the reduction below baseline is smaller, hence the costs are also reduced (see graph below for the USA). The second case is where the harmonised baseline is higher than the original baseline, hence the costs will increase (for the same reduction below baseline) because the absolute emissions are higher (see graph below for China). There is also a mixed case where the 1990 levels could increase and the baseline could decrease in 2020 compared to the original baseline. In this case, costs are expected to decrease as a result of the absolute emissions in 2020 that decrease.

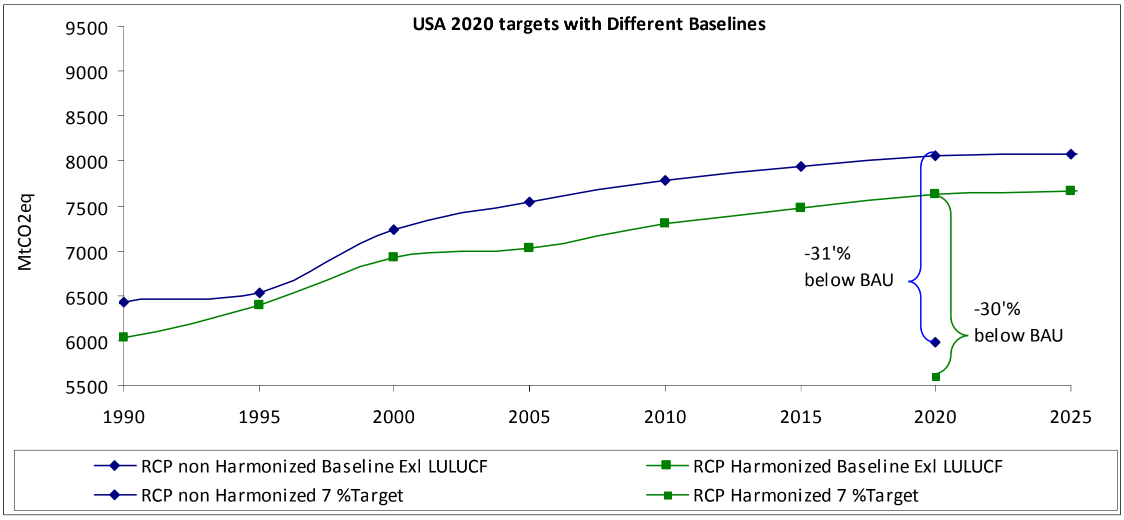


Figure E.1. The effect of harmonisation on the baseline emissions (1990-2020) and the 2020 reduction target for the USA. Note that we applied a 7% target compared to 1990 levels for the USA, which leads to the different reduction targets in 2020 for the harmonised and non-harmonised case. For the harmonised baseline this means a reduction of 30% below baseline, and for the non-harmonised baseline a reduction of 31%.

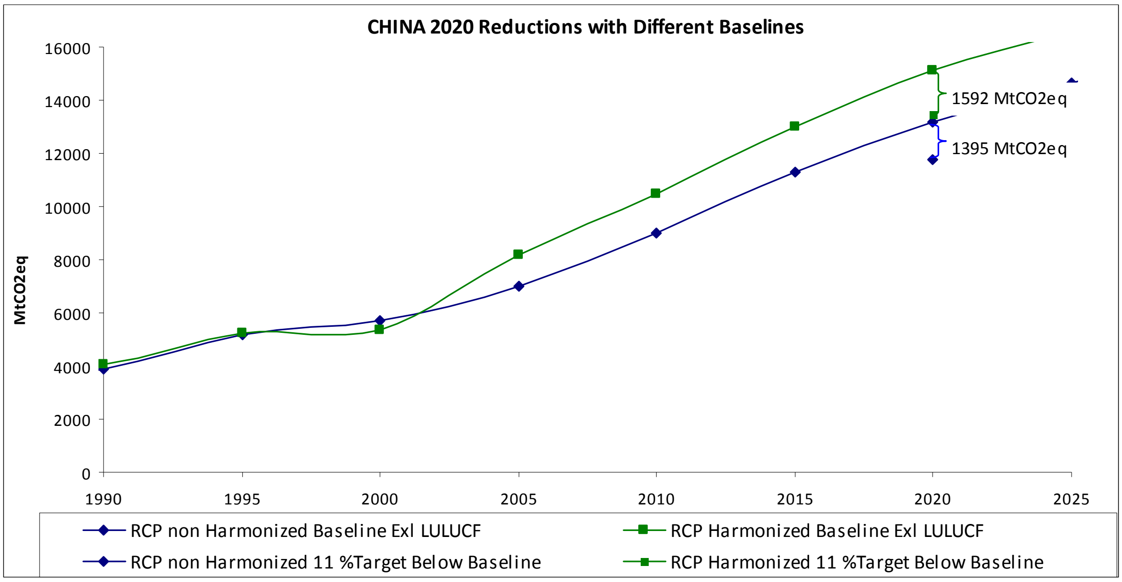


Figure E.2: The effect of harmonisation on the baseline emissions (1990-2020) and the 2020 reduction target for China. Note that we applied the same reduction compared to baseline emissions.

Appendix F Emission and costs implications for the Annex I and non-Annex I countries as a group

The Table below gives the emissions excluding REDD/LULUCF CO_2 and costs implications (excl. costs of REDD) in 2020 for the three scenarios for the baseline without the impact of the crisis, and with the impact of the crisis.

	Default baseline without impact of the crisis			Baseline with impact of the crisis		
	Low ambition	Higher ambition	Comparable effort	Low ambition	Higher ambition	Comparable effort
TARGETS BEFORE TRADE						
Annex I						
Baseline emissions ($MtCO_2eq$) excl. LUCF CO_2	19436	19436	19436	18081	18081	18081
Reduction target (% compared to 1990 level)	−10%	−15%	−31%	−10%	−15%	−31%
Reduction target (% compared to baseline)	−12%	−17%	−33%	−5%	−11%	−28%
Non-Annex I						
Baseline emissions ($MtCO_2eq$) excl. LUCF CO_2	34370	34370	34370	32770	32770	32770
Reduction target (% compared to 1990 level)	143%	133%	113%	132%	122%	103%
Reduction target (% compared to baseline)	−4%	−8%	−16%	−4%	−8%	−16%
Global						
Baseline emissions ($MtCO_2eq$) excl. LUCF CO_2	53806	53806	53806	50850	50850	50850
Reduction target (% compared to 1990 level)	55%	47%	30%	50%	43%	25%
Reduction target (% compared to baseline)	−7%	−11%	−22%	−5%	−9%	−20%
ABATEMENT						
Annex I						
Reduction target ($MtCO_2eq$)	2327	3366	6437	972	2011	5081
Domestic abatement incl. trade, excl. sinks ($MtCO_2eq$)	1392	2117	4020	1242	1871	3117
Domestic abatement (%)	76%	79%	89%	57%	72%	100%
Trade ($MtCO_2eq$)	560	700	729	419	560	20
Sinks ($MtCO_2eq$)	395	395	395	395	395	395
Hot air exchanged ($MtCO_2eq$)	1112	1112	1292	325	325	1549
Hot air forfeited ($MtCO_2eq$)	−1132	−958	0	−1409	−1140	0
Non-Annex I						
Reduction target ($MtCO_2eq$)	1414	2810	5480	1352	2688	5211
Domestic abatement incl. trade, sinks ($MtCO_2eq$)	1845	3368	6067	1692	3154	5089
Domestic abatement (%)	141%	125%	113%	136%	123%	100%
Trade (IET+CDM) ($MtCO_2eq$)	−574	−700	−729	−482	−610	−20
Sinks ($MtCO_2eq$)	143	143	143	143	143	143
Hot air exchanged ($MtCO_2eq$)	0	0	0	0	0	0
Hot air forfeited ($MtCO_2eq$)	0	0	0	0	0	0
Global						
Reduction target ($MtCO_2eq$)	3741	6176	11917	2324	4698	10293
Domestic abatement ($MtCO_2eq$)	3237	5485	10087	2934	5025	8206
Domestic abatement (%)	100%	100%	100%	100%	100%	100%
Trade (IET+CDM) ($MtCO_2eq$)	−14	0	0	−64	−49	0
Sinks ($MtCO_2eq$)	538	538	538	538	538	538
Hot air exchanged ($MtCO_2eq$)	1112	1112	1292	325	325	1549
Hot air forfeited ($MtCO_2eq$)	−1132	−958	0	−1409	−1140	0
TRADING PRICE						

	Default baseline without impact of the crisis			Baseline with impact of the crisis		
Carbon price (in US$/t$CO_2$)	4	15	58	4	13	42
Costs						
Annex I						
Domestic costs (in MUS$)	1828	7889	74958	1452	5764	38087
Financial flows (in MUS$)	3748	12604	45683	2308	8294	3392
Total costs (in MUS$)	5576	20492	120641	3760	14057	41479
Costs as % of GDP	0.01	0.04	0.24	0.01	0.03	0.09
Non-Annex I						
Domestic costs (in MUS$)	2152	9878	85169	1699	8447	50958
Financial flows (in MUS$)	−2418	−10452	−41827	−1778	−7572	−305
Total costs (in MUS$)	−266	−574	43342	−79	875	50653
Costs as % of GDP	−0.00	−0.00	0.18	−0.00	−0.00	0.22
Global						
Costs (in MUS$)	5309	19919	163983	3681	14932	92133
Costs as % of GDP	0.01	0.03	0.22	0.01	0.02	0.14
TARGETS AFTER TRADE						
Annex I						
Baseline emissions (MtCO_2eq) excl. LUCF CO_2	19436	19436	19436	18081	18081	18081
Reduction target (% compared to 1990 level)	−6%	−11%	−27%	−7%	−11%	−31%
Reduction target (% compared to baseline)	−9%	−14%	−29%	−3%	−8%	−28%
Non-Annex I						
Baseline emissions (MtCO_2eq) excl. LUCF CO_2	34370	34370	34370	32770	32770	32770
Reduction target (% compared to 1990 level)	139%	128%	108%	128%	117%	103%
Reduction target (% compared to baseline)	−6%	−10%	−18%	−6%	−10%	−16%
Global						
Baseline emissions (MtCO_2eq) excl. LUCF CO_2	53806	53806	53806	50850	50850	50850
Reduction target (% compared to 1990 level)	55%	47%	30%	50%	43%	25%
Reduction target (% compared to baseline)	−7%	−11%	−22%	−5%	−9%	−20%
Costs No Trade						
Annex I						
Total costs (in MUS$)	74984	188463	433938	26949	75161	202652
Costs as % of GDP	0.15	0.38	0.88	0.06	0.17	0.46
Non-Annex I						
Total costs (in MUS$)	1516	10280	68403	1417	9857	64575
Costs as % of GDP	0.01	0.04	0.29	0.01	0.04	0.28
Global						
Costs (in MUS$)	76501	198743	502340	28367	85018	267227
Costs as % of GDP	0.10	0.27	0.68	0.04	0.13	0.40

Appendix G Emission and costs implications for the Annex I and non-Annex I countries

The Table below gives the emissions excluding REDD/LULUCF CO_2 and costs implications (excl. costs of REDD) in 2020 for the three scenarios for the baseline without the impact of the crisis, and with the impact of the crisis.

	Default baseline without impact of the crisis			Baseline with impact of the crisis		
ABATEMENT	**Low ambition**	**Higher ambition**	**Comparable effort**	**Low ambition**	**Higher ambition**	**Comparable effort**
Annex I regions						
Canada						
Reduction target ($MtCO_2eq$)	204	204	353	160	160	309
Domestic abatement incl. trade, excl. sinks ($MtCO_2eq$)	48	76	176	44	68	133
Domestic abatement (%)	45%	59%	62%	55%	70%	57%
Trade ($MtCO_2eq$)	113	85	134	72	48	133
Sinks ($MtCO_2eq$)	44	44	44	44	44	44
Hot air exchanged ($MtCO_2eq$)	0	0	0	0	0	0
Hot air forfeited ($MtCO_2eq$)	0	0	0	0	0	0
USA						
Reduction target ($MtCO_2eq$)	1,592	1,773	2,496	1,173	1,354	2,077
Domestic abatement incl. trade, excl. sinks ($MtCO_2eq$)	522	775	1,569	475	694	1,246
Domestic abatement (%)	39%	49%	67%	49%	59%	65%
Trade ($MtCO_2eq$)	967	895	824	595	557	729
Sinks ($MtCO_2eq$)	103	103	103	103	103	103
Hot air exchanged ($MtCO_2eq$)	0	0	0	0	0	0
Hot air forfeited ($MtCO_2eq$)	0	0	0	0	0	0
Western Europe						
Reduction target ($MtCO_2eq$)	1,267	1,701	1,918	838	1,271	1,488
Domestic abatement incl. trade, excl. sinks ($MtCO_2eq$)	316	457	947	284	397	684
Domestic abatement (%)	27%	28%	51%	37%	33%	47%
Trade ($MtCO_2eq$)	930	1,223	949	531	853	782
Sinks ($MtCO_2eq$)	22	22	22	22	22	22
Hot air exchanged ($MtCO_2eq$)	0	0	0	0	0	0
Hot air forfeited ($MtCO_2eq$)	0	0	0	0	0	0
Japan						
Reduction target ($MtCO_2eq$)	220	220	405	98	98	282
Domestic abatement incl. trade, excl. sinks ($MtCO_2eq$)	65	101	206	55	87	151
Domestic abatement (%)	51%	68%	63%	105%	138%	70%
Trade ($MtCO_2eq$)	107	71	151	−5	−37	84
Sinks ($MtCO_2eq$)	48	48	48	48	48	48
Hot air exchanged ($MtCO_2eq$)	0	0	0	0	0	0
Hot air forfeited ($MtCO_2eq$)	0	0	0	0	0	0
Russia						
Reduction target ($MtCO_2eq$)	−792	−618	602	−937	−763	456
Domestic abatement incl. trade, excl. sinks ($MtCO_2eq$)	203	346	564	174	309	459
Domestic abatement (%)	−20%	−77%	218%	49%	20%	285%
Trade ($MtCO_2eq$)	−953	−1,095	−711	−475	−610	−843

	Default baseline without impact of the crisis			Baseline with impact of the crisis		
Sinks ($MtCO_2eq$)	121	121	121	121	121	121
Hot air exchanged ($MtCO_2eq$)	628	628	628	180	180	720
Hot air forfeited ($MtCO_2eq$)	−792	−618	0	−937	−763	0
Ukraine						
Reduction target ($MtCO_2eq$)	−340	−340	110	−377	−377	73
Domestic abatement incl. trade, excl. sinks ($MtCO_2eq$)	57	79	114	51	71	94
Domestic abatement (%)	1%	−5%	357%	65%	60%	553%
Trade ($MtCO_2eq$)	−337	−359	−283	−131	−152	−332
Sinks ($MtCO_2eq$)	4	4	4	4	4	4
Hot air exchanged ($MtCO_2eq$)	275	275	275	77	77	306
Hot air forfeited ($MtCO_2eq$)	−340	−340	0	−377	−377	0
Oceania						
Reduction target ($MtCO_2eq$)	172	270	320	113	211	261
Domestic abatement incl. trade, excl. sinks ($MtCO_2eq$)	59	84	148	52	75	110
Domestic abatement (%)	56%	45%	58%	79%	53%	56%
Trade ($MtCO_2eq$)	76	149	136	24	99	114
Sinks ($MtCO_2eq$)	37	37	37	37	37	37
Hot air exchanged ($MtCO_2eq$)	0	0	0	0	0	0
Hot air forfeited ($MtCO_2eq$)	0	0	0	0	0	0
Non-Annex I regions	0	0	0	0	0	0
Mexico						
Reduction target ($MtCO_2eq$)	49	98	180	43	86	158
Domestic abatement incl. trade, excl. sinks ($MtCO_2eq$)	50	81	157	43	67	113
Domestic abatement (%)	111%	87%	89%	110%	83%	74%
Trade ($MtCO_2eq$)	−5	12	19	−4	15	41
Sinks ($MtCO_2eq$)	4	4	4	4	4	4
Hot air exchanged ($MtCO_2eq$)	0	0	0	0	0	0
Hot air forfeited ($MtCO_2eq$)	0	0	0	0	0	0
Rest of South America						
Reduction target ($MtCO_2eq$)	44	87	282	40	80	260
Domestic abatement incl. trade, excl. sinks ($MtCO_2eq$)	70	101	251	64	89	185
Domestic abatement (%)	231%	152%	100%	234%	150%	83%
Trade ($MtCO_2eq$)	−57	−45	−0	−54	−40	45
Sinks ($MtCO_2eq$)	31	31	31	31	31	31
Hot air exchanged ($MtCO_2eq$)	0	0	0	0	0	0
Hot air forfeited ($MtCO_2eq$)	0	0	0	0	0	0
Brazil						
Reduction target ($MtCO_2eq$)	114	229	285	110	221	275
Domestic abatement incl. trade, excl. sinks ($MtCO_2eq$)	82	124	233	77	112	173
Domestic abatement (%)	109%	73%	97%	108%	70%	79%
Trade ($MtCO_2eq$)	−10	62	9	−9	67	59
Sinks ($MtCO_2eq$)	43	43	43	43	43	43
Hot air exchanged ($MtCO_2eq$)	0	0	0	0	0	0
Hot air forfeited ($MtCO_2eq$)	0	0	0	0	0	0
China						
Reduction target ($MtCO_2eq$)	824	1,649	3,023	789	1,579	2,894
Domestic abatement incl. trade, excl. sinks ($MtCO_2eq$)	924	1,860	3,218	795	1,725	2,773

	Default baseline without impact of the crisis			Baseline with impact of the crisis		
Domestic abatement (%)	113%	113%	107%	102%	110%	96%
Trade ($MtCO_2eq$)	−107	−218	−202	−14	−153	114
Sinks ($MtCO_2eq$)	7	7	7	7	7	7
Hot air exchanged ($MtCO_2eq$)	0	0	0	0	0	0
Hot air forfeited ($MtCO_2eq$)	0	0	0	0	0	0
India						
Reduction target ($MtCO_2eq$)	187	373	348	185	370	345
Domestic abatement incl. trade, excl. sinks ($MtCO_2eq$)	200	371	416	196	364	386
Domestic abatement (%)	111%	101%	122%	110%	100%	114%
Trade ($MtCO_2eq$)	−20	−5	−75	−18	−1	−48
Sinks ($MtCO_2eq$)	7	7	7	7	7	7
Hot air exchanged ($MtCO_2eq$)	0	0	0	0	0	0
Hot air forfeited ($MtCO_2eq$)	0	0	0	0	0	0
Indonesia						
Reduction target ($MtCO_2eq$)	23	47	112	22	44	106
Domestic abatement incl. trade, excl. sinks ($MtCO_2eq$)	37	64	135	34	59	121
Domestic abatement (%)	159%	136%	120%	156%	133%	115%
Trade ($MtCO_2eq$)	−14	−17	−23	−12	−15	−15
Sinks ($MtCO_2eq$)	0	0	0	0	0	0
Hot air exchanged ($MtCO_2eq$)	0	0	0	0	0	0
Hot air forfeited ($MtCO_2eq$)	0	0	0	0	0	0
Korea						
Reduction target ($MtCO_2eq$)	28	55	240	25	50	219
Domestic abatement incl. trade, excl. sinks ($MtCO_2eq$)	62	95	209	56	82	155
Domestic abatement (%)	226%	173%	87%	223%	163%	71%
Trade ($MtCO_2eq$)	−35	−40	32	−31	−32	63
Sinks ($MtCO_2eq$)	0	0	0	0	0	0
Hot air exchanged ($MtCO_2eq$)	0	0	0	0	0	0
Hot air forfeited ($MtCO_2eq$)	0	0	0	0	0	0
South Africa						
Reduction target ($MtCO_2eq$)	51	101	119	49	98	116
Domestic abatement incl. trade, excl. sinks ($MtCO_2eq$)	45	68	101	41	61	84
Domestic abatement (%)	100%	72%	89%	96%	68%	78%
Trade ($MtCO_2eq$)	−0	28	13	2	31	26
Sinks ($MtCO_2eq$)	6	6	6	6	6	6
Hot air exchanged ($MtCO_2eq$)	0	0	0	0	0	0
Hot air forfeited ($MtCO_2eq$)	0	0	0	0	0	0
CARBON PRICE						
Carbon price (in US$/$tCO_2$)	4	15	58	4	13	42
Costs						
Annex I Regions						
Canada						
Domestic costs (in MUS$)	61	303	3,933	51	225	1,970
Financial flows (in MUS$)	547	1,348	7,921	312	647	5,712
Total costs (in MUS$)	609	1,651	11,854	364	872	7,682
Costs as % of GDP	0.04	0.10	0.74	0.02	0.06	0.53
USA						

	Default baseline without impact of the crisis			Baseline with impact of the crisis		
Domestic costs (in MUS$)	729	2,941	30,335	603	2,183	16,577
Financial flows (in MUS$)	4,696	14,245	48,834	2,573	7,453	31,412
Total costs (in MUS$)	5,425	17,186	79,169	3,176	9,636	47,989
Costs as % of GDP	0.03	0.09	0.42	0.02	0.06	0.29
Western Europe						
Domestic costs (in MUS$)	412	1,695	19,775	341	1,195	8,945
Financial flows (in MUS$)	4,514	19,452	56,213	2,297	11,416	33,714
Total costs (in MUS$)	4,926	21,147	75,987	2,637	12,611	42,659
Costs as % of GDP	0.03	0.12	0.42	0.02	0.08	0.26
Japan						
Domestic costs (in MUS$)	91	413	4,235	63	276	1,941
Financial flows (in MUS$)	520	1,131	8,965	−20	−466	3,621
Total costs (in MUS$)	612	1,543	13,200	43	−190	5,562
Costs as % of GDP	0.01	0.03	0.22	0.00	0.00	0.10
Russia						
Domestic costs (in MUS$)	277	1,290	8,608	203	998	4,693
Financial flows (in MUS$)	−4,025	−16,500	−40,928	−1,759	−7,675	−35,172
Total costs (in MUS$)	−3,748	−15,210	−32,320	−1,556	−6,677	−30,479
Costs as % of GDP	−0.22	−0.87	−1.86	−0.10	−0.43	−1.96
Ukraine						
Domestic costs (in MUS$)	54	214	1,433	40	160	724
Financial flows (in MUS$)	−1,422	−5,404	−16,305	−486	−1,915	−13,834
Total costs (in MUS$)	−1,368	−5,190	−14,872	−447	−1,755	−13,110
Costs as % of GDP	−0.49	−1.84	−5.27	−0.18	−0.72	−5.38
Oceania						
Domestic costs (in MUS$)	69	268	2,646	50	201	1,152
Financial flows (in MUS$)	369	2,375	8,051	104	1,328	4,917
Total costs (in MUS$)	438	2,643	10,697	154	1,529	6,069
Costs as % of GDP	0.03	0.17	0.71	0.01	0.12	0.46
Non-Annex I Regions						
Mexico						
Domestic costs (in MUS$)	56	318	3,027	42	205	1,384
Financial flows (in MUS$)	−23	197	1,147	−16	194	1,764
Total costs (in MUS$)	33	515	4,174	26	399	3,148
Costs as % of GDP	0.00	0.04	0.30	0.00	0.03	0.27
Rest of South America						
Domestic costs (in MUS$)	28	133	4,740	21	98	2,112
Financial flows (in MUS$)	−242	−680	−0	−200	−506	1,940
Total costs (in MUS$)	−214	−547	4,740	−179	−407	4,052
Costs as % of GDP	−0.02	0.05	0.40	−0.02	−0.04	0.37
Brazil						
Domestic costs (in MUS$)	45	366	4,505	36	257	1,915
Financial flows (in MUS$)	−44	992	518	−34	891	2,548
Total costs (in MUS$)	1	1,358	5,023	2	1,149	4,462
Costs as % of GDP	0.00	0.11	0.39	0.00	0.09	0.36
China						
Domestic costs (in MUS$)	1,566	6,375	47,725	1,190	5,559	31,491
Financial flows (in MUS$)	−453	−3,289	−11,615	−52	−1,932	4,899

	Default baseline without impact of the crisis			Baseline with impact of the crisis		
Total costs (in MUS$)	1,113	3,087	36,110	1,138	3,627	36,389
Costs as % of GDP	0.01	0.03	0.39	0.01	0.04	0.40
India						
Domestic costs (in MUS$)	71	873	1,511	67	826	1,091
Financial flows (in MUS$)	−87	−77	−4,341	−67	−18	−2,011
Total costs (in MUS$)	−15	796	−2,830	−0	808	−919
Costs as % of GDP	−0.00	0.05	−0.16	−0.00	0.04	−0.05
Indonesia						
Domestic costs (in MUS$)	4	41	551	3	36	432
Financial flows (in MUS$)	−59	−255	−1,306	−46	−185	−644
Total costs (in MUS$)	−55	−214	−755	−43	−149	−213
Costs as % of GDP	−0.01	−0.03	−0.12	−0.01	−0.02	−0.03
Korea						
Domestic costs (in MUS$)	80	328	4,208	68	227	2,091
Financial flows (in MUS$)	−147	−608	1,876	−114	−399	2,734
Total costs (in MUS$)	−67	−279	6,085	−47	−172	4,825
Costs as % of GDP	−0.00	−0.01	0.31	−0.00	−0.01	0.29
South Africa						
Domestic costs (in MUS$)	47	204	1,374	39	161	776
Financial flows (in MUS$)	−0	448	789	9	416	1,101
Total costs (in MUS$)	47	652	2,162	48	577	1,877
Costs as % of GDP	0.01	0.20	0.67	0.01	0.18	0.58