Post-2012 climate regime

How industrial and developing nations can help to reduce emissions – assessing emission trends, reduction potentials, incentive systems and negotiation options

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How industrial and developing nations can help to reduce emissions – assessing emission trends, reduction potentials, incentive systems and negotiation options

by

Vicki Duscha
Jakob Graichen
Sean Healy
Joachim Schleich
Katja Schumacher

Öko-Institut e.V. (Berlin)

Fraunhofer-Institut für System- und Innovationsforschung (ISI, Karlsruhe)

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Germany
Phone: +49-340-2103-0
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Healy, Sean
Schleich, Joachim
Schumacher, Katja

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16. Abstract
This report analyses the emissions reduction targets submitted under the Copenhagen Accord by developed and developing countries in matters of four key questions:

- Do the pledges add up to the emission reductions required necessary by science?
- What are the costs associated with meeting the given targets?
- Are the proposed emission reduction efforts of Annex I parties comparable?
- What would comparable efforts look like taking country-specific socio-economic indicators into account?

Secondary to these questions this report explores the economic and environmental implications of the submitted pledges and NAMAs. Furthermore, we analyze and assess the comparability of efforts of Annex I mitigation pledges compared to a range of socio-economic indicators that may provide a basis for a "fair" effort sharing agreement to achieve a given target.

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Copenhagen Accord, mitigation pledges, nationally appropriate mitigation actions, NAMA, abatement costs, comparability of efforts

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Dieser Bericht untersucht die von Industriestaaten und Entwicklungsländern im Rahmen der Kopenhagen Vereinbarung eingereichten Emissionsminderungsvorschläge in Bezug auf vier Kernfragen:
• Entsprechen die Selbstverpflichtungen den wissenschaftlich als notwendig anerkannten Emissionsminderungen?
• Welche Kosten sind mit der Zielerreichung verbunden?
• Sind die vorgesehenen Anstrengungen der Annex-1-Staaten zur Emissionsreduktion vergleichbar?
• Wie können vergleichbare Anstrengungen unter Einbeziehung länderspezifischer sozioökonomischer Indikatoren aussehen?
Neben diesen Fragen werden die ökonomischen und ökologischen Auswirkungen der eingegangenen Selbstverpflichtungen und NAMAs diskutiert. Darüber hinaus wird die Vergleichbarkeit der Emissionsminderungsanstrengungen von Annex-1-Staaten analysiert und anhand einer Reihe von sozioökonomischen Indikatoren, die als Grundlage einer „gerechten“ Lastenverteilung zur Erreichung eines gegebenen Ziels herangezogen werden könnten, bewertet.</td></tr>
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Glossary of Terms

BAU	Business As Usual
CDM	Clean Development Mechanism
ClimStrat	Climate Strategies Tool
COP	Conference of Parties
EU	European Union
GDP	Gross Domestic Product
GHG	Greenhouse Gases
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land Use, Land Use Change and Forestry
NAMAs	Nationally appropriate mitigation measures
POLES	Partial equilibrium energy system model: Prospective Outlook on Long-term Energy Systems
REDD	Reducing emissions from deforestation and degradation
REDD-Plus	Reducing emissions from deforestation and degradation, conservation of existing carbon stocks and enhancement of carbon stocks
UNFCCC	United Nations Framework Convention on Climate Change

Zusammenfassung

Nach dem vierten Sachstandsbericht des Weltklimarates (IPCC 2007) müssen die globalen Kohlendioxidemissionen bis 2050 um mindestens 50 bis 85 Prozent unter das Niveau von 2000 gesenkt werden, um den weltweiten Temperaturanstieg auf maximal 2° Celsius gegenüber dem vorindustriellen Niveau zu begrenzen. Neben diesem Langfristziel schlägt der IPCC Zwischenziele für alle Treibhausgase für das Jahr 2020 vor, darunter Emissionsminderungen für Annex-1-Staaten in Höhe von 25 bis 40 Prozent gegenüber 1990 sowie eine erhebliche Abweichung vom Referenzniveau in den Ländern Lateinamerikas, des Nahen Ostens, Asiens und Zentralasien (IPCC 2007). Für Entwicklungsländer wurden die Vorgaben des IPCC mit Minderungszielen in Höhe von 15 bis 30 Prozent unter der Baseline-Entwicklung quantifiziert (den Elzen und Höhne 2008).

Obwohl im Dezember 2009 auf der UN-Klimakonferenz in Kopenhagen (COP 15) kein internationales Abkommen mit verbindlichen Zielvorgaben zur Verringerung der Treibhausgasemissionen beschlossen wurde, hat die Mehrheit der Annex-1-Staaten im Rahmen der Kopenhagen-Vereinbarung (UNFCCC 2009) quantifizierte Emissionsreduktionsziele zugesagt. Einige Entwicklungsländer haben zudem national angemessene Emissionsminderungsmaßnahmen (NAMAs) zur Eintragung in den zweiten Anhang der Kopenhagen-Vereinbarung eingereicht. Für die meisten Länder sind die Selbstverpflichtungen der Kopenhagen-Vereinbarung den bereits vor der 15. Vertragsstaatenkonferenz vorgelegten Erklärungen ziemlich ähnlich.

Mit diesem Ansatz der „Verpflichtung und Überprüfung“ zur Ermittlung von Emissionsminderungszielen ergeben sich vier Kernfragen:

- Entsprechen die Selbstverpflichtungen den wissenschaftlich als notwendig anerkannten Emissionsminderungen?
- Welche Kosten sind mit der Zielerreichung verbunden?
- Sind die vorgesehenen Anstrengungen der Annex-1-Staaten zur Emissionsreduktion vergleichbar?
- Wie können vergleichbare Anstrengungen unter Einbeziehung länderspezifischer sozioökonomischer Indikatoren aussehen?

Im vorliegenden Bericht werden diese Fragen untersucht und die **ökonomischen und ökologischen Auswirkungen** der im Rahmen der Kopenhagen-Vereinbarung eingegangenen Selbstverpflichtungen und NAMAs diskutiert (UNFCCC 2009). Darüber hinaus wird die **Vergleichbarkeit der Emissionsminderungsanstrengungen** von Annex-1-Staaten analysiert und anhand einer Reihe von sozioökonomischen Indikatoren, die als Grundlage einer „gerechten“ Lastenverteilung zur Erreichung eines gegebenen Ziels herangezogen werden könnten, bewertet.

Die Untersuchung erfolgt mit Hilfe des ClimStrat-Modells, das ein flexibles Analyseinstrument basierend auf Grenzvermeidungskostenkurven darstellt, sowie eines Modells zur THG-Lastenverteilung, das zur Ermittlung von Reduktionszielen für Annex-1-

Staaten entwickelt wurde und eine Reihe transparenter Indikatoren anwendet, um bei der Aufteilung notwendiger Reduktionsanstrengungen nationale Gegebenheiten abzubilden.

Die Schlüsselergebnisse bezüglich a) absoluter Emissionswerte, b) Pro-Kopf-Emissionen, c) (Grenz-)Vermeidungskosten sowie d) der auf einer Reihe sozioökonomischer Indikatoren im Vergleich zu den Selbstverpflichtungen der Kopenhagen-Vereinbarung basierten Bewertung der Vergleichbarkeit der Anstrengungen lauten:

a) Hauptergebnisse zu absoluten Emissionswerten

- Das ambitionierte Ende der unter der Kopenhagen-Vereinbarung eingegangenen Selbstverpflichtungen der Annex-1-Staaten führen zu einer Reduktion der Treibhausgase um 18 Prozent unter das Niveau von 1990 (ohne Berücksichtigung von Emissionen aus LULUCF). Die NAMAs der Nicht-Annex-I-Staaten führen zu Emissionsminderungen von 11 Prozent unter der Baseline-Entwicklung. Insgesamt geht das globale Emissionswachstum zwischen 2005 und 2020 vom vorhergesagten Anstieg (27 Prozent) auf 19 Prozent zurück. Das globale Emissionsmaximum wird jedoch in diesem Zeitraum nicht erreicht.
- Die freiwilligen Selbstverpflichtungen der Annex-1-Staaten (oberes Ende) greifen im Vergleich zur Bandbreite der IPCC-Minderungsziele (25-40 Prozent gegenüber 1990) noch um 7-22 Prozentpunkte zu kurz, um das 2°C-Ziel zu erreichen.
- Für zwei Annex-1-Staaten, Weißrussland und insbesondere Russland, liegen die Selbstverpflichtungen über den Baseline-Projektionen, d.h. sie schließen eine signifikante Menge an „heißer Luft“ ein. Diese Menge an „heißer Luft“ kann bis zu 20 Prozent der erforderlichen Emissionsminderungen aller Annex-1-Staaten im Jahr 2020 ausmachen.
- Im Hinblick auf die Nicht-Annex-1-Staaten führt das eingereichte Intensitätsziel von China zu Emissionsreduktionen, die 9 Prozent unter den Baseline-Projektionen für 2020 liegen; die Vorgabe für Indien liegt 11 Prozent unter den Baseline-Projektionen. Damit sind beide Verpflichtungen weniger ambitioniert als die NAMAs, die im Rahmen der Kopenhagen-Vereinbarung von den meisten anderen Entwicklungsländern eingereicht wurden.

b) Hauptergebnisse zu Pro-Kopf-Emissionen basierend auf den Minderungszielen

- Zwischen 2005 und 2020 gehen die jährlichen Pro-Kopf-Emissionen in fast allen Ländern deutlich zurück. Ausnahmen sind Weißrussland, Kroatien sowie Russland. Die durchschnittlichen Pro-Kopf-Emissionen der Annex-1-Staaten sinken zwischen 2005 und 2020 von 14,6 t CO_2eq/cap auf 12,1 t CO_2eq/cap.
- Einige Länder, darunter Australien, Island, Neuseeland und Norwegen, weisen zwischen 2005 und 2020 einen Rückgang der Pro-Kopf-Emissionen von 30 Prozent oder mehr auf.

c) Hauptergebnisse zu (Grenz-)Vermeidungskosten

- Unter Einbeziehung eines internationalen Emissionshandels liegen die Kosten zur Einhaltung der Zielvorgaben für alle Annex-1-Staaten im Jahr 2020 unter 0,5% des Bruttoinlandsproduktes (BIP). Die am BIP gemessenen höchsten Kosten fallen für Neuseeland und Australien an. Insgesamt liegen die Kosten für alle Länder bei unter 1/3 der durchschnittlichen jährlichen BIP-Wachstumsrate zwischen 2005 und 2020. Dies entspricht dem BIP-Wachstum von etwa 4 Monaten oder weniger.
- Russland und Weißrussland können Gewinne erzielen (für Russland 1,7 % des BIP), indem sie neue „heiße Luft“ verkaufen sowie preisgünstige Vermeidungsoptionen umsetzen und die entsprechenden Zertifikate verkaufen.
- Unter den Entwicklungsländern fallen die höchsten Grenzvermeidungskosten für Mexiko, Brasilien und Südkorea an; die Kosten zur Einhaltung der Zielvorgaben gemessen am BIP sind für Brasilien und Südafrika am höchsten (ca. 1 Prozent des BIP).
- Die Grenzvermeidungskosten in China und Indien zur Erreichung ihrer nationalen Minderungsziele liegen unter dem Preis für Offsets. Daher können China und Indien zusätzlich zu ihren nationalen Reduktionszielen weitere Emissionen vermeiden und entsprechende Zertifikate als Offsets verkaufen. Damit würden ihre Kosten zur Einhaltung der Zielvorgaben erheblich sinken.

d) Hauptergebnisse zur Vergleichbarkeit der Anstrengungen

- **Die Vergleichbarkeit der Anstrengungen** hängt im erheblichen Maße von den Kriterien zur Ermittlung des Anstrengungsgrads ab. Eine Reihe von Multi-Kriterien-Szenarien sowie die Sensitivität der einzelnen Länder gegenüber den Kriterien können als Grundlage für eine angemessene Lastenverteilung dienen.
- Die Lastverteilung hängt für die Russische Föderation sowie die Ukraine am stärksten von den verwendeten Kriterien ab. Japan und den EU27 zeigen die niedrigste Sensitivität. In den zwölf betrachteten Szenarien sind die verschiedenen Reduktionsziele der Annex-1-Staaten von erheblichen Unterschieden gekennzeichnet.
- Die Selbstverpflichtungen der Kopenhagen-Vereinbarung von Norwegen als auch der Schweiz liegen über den Emissionsreduktionszielen, die in der Szenarienanalyse berechnet wurden. Für Australien, Neuseeland, Japan und die EU27 fallen die Selbstverpflichtungen etwas in die in der Szenarienanalyse berechneten Emissionsziele. Kanada, die Russische Föderation, die Ukraine sowie die USA sind Selbstverpflichtungen eingegangen, die unter den berechneten Reduktionszielen liegen.

Executive summary

According to the IPCC fourth assessment report (2007), global carbon dioxide emissions need to be reduced by at least 50 to 85% in 2050 compared to 2000 levels if the increase in global surface temperature is to be limited to 2°C compared to pre-industrial levels. The IPCC also suggests intermediate greenhouse gas emission targets for 2020, including a range of 25% to 40% emission reductions compared to 1990 for the group of Annex I countries and a 'substantial deviation from baseline in Latin America, Middle East, East Asia and Centrally-planned Asia' (IPCC 2007, p. 776). For developing countries, a reduction range of 15 to 30% below baseline has been suggested (den Elzen and Höhne 2008).

While the climate summit in Copenhagen in December 2009 (COP 15) failed to produce an international agreement involving binding greenhouse gas emissions reduction targets, under the Copenhagen Accord (UNFCCC 2009) most Annex I countries pledged quantifiable emission reductions. In addition, several developing countries submitted nationally appropriate mitigation actions (NAMAs) listed in Appendix II of the Accord. For most countries, pledges under the Copenhagen Accord are quite similar to those made prior to COP 15.

With regard to this kind of "pledge and review" approach for determining emission reduction targets, four key questions arise:

- Do the pledges add up to the emission reductions required necessary by science?
- What are the costs associated with meeting the given targets?
- Are the proposed emission reduction efforts of Annex I parties comparable?
- What would comparable efforts look like taking country-specific socio-economic indicators into account?

In this report, we address these questions and explore the **economic and environmental implications** of the pledges and NAMAs submitted under the Copenhagen Accord (UNFCCC 2009). Furthermore, we analyze and assess the **comparability of efforts** of Annex I mitigation pledges compared to a range of socio-economic indicators that may provide a basis for a "fair" effort sharing agreement to achieve a given target.

The analysis was performed using i) the ClimStrat tool which provides a flexible, ready-to-use analytical tool based on marginal abatement cost curves resulting from a partial equilibrium framework, and ii) the GHG effort sharing tool which has been designed to allocate GHG reduction targets for the Annex I Parties and uses a transparent set of indicators to reflect national circumstances when sharing the necessary reduction effort.

The main findings regarding a) absolute emissions levels, b) per capita emissions and c) (marginal) abatement costs, and d) the assessment of the comparability of efforts based on a range of socio-economic indicators in comparison to the Copenhagen pledges include:

a) Main findings on absolute emissions levels

- The most ambitious end of the targets from Annex I countries under the Copenhagen Accord amount to a reduction of 18% below 1990 levels in 2020 (excluding LULUCF). Non-Annex I countries' NAMAs result in emission reductions of 11% below the baseline emission pathway. Overall, global emission growth slows from a projected 27% to 19% between 2005 and 2020, while a peaking of global emissions is not reached before 2020.
- Annex I emission reductions (high end) are still 7-22 percentage points short of reaching the IPCC range of 25 to 40% reduction below 1990 considered necessary to reach the 2°C target.
- For two Annex I countries, i.e. Belarus and in particular the Russian Federation, the pledges are above business-as-usual (BAU) projections, i.e. include a significant amount of new 'hot air' accounting for about 20% of required emission reductions in Annex I countries.
- With respect to non-Annex I countries, China's submitted intensity target results in emission reductions of 9% below business-as-usual in 2020; India's target is 11% below BAU. Both targets are thus relatively less ambitious than the NAMAs submitted by most other developing countries under the Copenhagen Accord.

b) Main findings with respect to per capita emissions as implied by emission targets

- Annual per capita greenhouse gas emissions decrease notably in almost all countries between 2005 and 2020 (except for Belarus, Croatia, and the Russian Federation). Annex I countries' average per capita emissions decrease from 14.6 t CO_2eq/cap in 2005 to 12.1 t CO_2eq/cap in 2020.
- Some countries (e.g. Australia, Iceland, New Zealand and Norway) show decreases in per capita emissions as high as 30% and more between 2005 and 2020.

c) Main findings on (marginal) abatement costs

- With international emissions trading, compliance costs in all Annex I countries in 2020 are below 0.5% of GDP. As a share of GDP they are highest in New Zealand and Australia. Overall, compliance costs for Annex I countries correspond to less than 1/3 of the average annual GDP growth rate. In that sense, mitigation costs would account for the annual GDP growth of about four month or less.
- Belarus and the Russian Federation can generate extra profits (1.7% of GDP in the case of Russia) from either selling new 'hot air' and/or realizing low-cost abatement options and selling the permits.
- Marginal abatement costs for developing countries are highest in Mexico, Brazil and South Korea; compliance costs in share of GDP are highest in Brazil and South Africa (around 1% of GDP).

- Marginal abatement costs for reaching their NAMAs are below offsetting prices for China and India. Therefore, in addition to meeting their NAMA reduction targets domestically, they can generate and sell offsets and thus significantly reduce their compliance costs.

d) Main findings on comparability of efforts

- Comparability of efforts is highly dependent on the criteria used to determine the effort. A set of multi-criteria scenarios can provide an indicator for an appropriate effort sharing arrangement and on the sensitivity of individual countries to the criteria used.
- The 'fair' effort sharing arrangements depends most strongly on the criteria used for the Russian Federation and the Ukraine; Japan and EU-27 show the lowest sensitivity. The Annex I Parties experienced considerable differences in their range of GHG reduction targets for the twelve scenarios analysed.
- The Copenhagen Accord pledges of both Norway and Switzerland exceed the GHG reduction targets calculated in the scenario analysis. The pledges of Australia, New Zealand, Japan and the EU-27 are more or less equal with the GHG reduction targets calculated in the scenario analysis. Canada, the Russian Federation, Ukraine and the USA have all pledged commitments that are below the GHG reduction targets calculated in the scenario analysis.

1 Introduction

To address climate change, industrialized countries and economies in transition (Annex I countries) committed in 1997 to reduce their aggregate greenhouse gas emissions by about 5.2% during the period 2008-2012 compared to 1990 emission levels in the Kyoto-Protocol to the United Nations Framework Convention (UNFCCC). A major objective of the UNFCCC climate conference in Copenhagen in December 2009 was to come up with a post-2012 climate regime, determining, among other things, long-term greenhouse gas emission targets and the future contributions of industrialized and developing countries. According to the IPCC fourth assessment report (2007), global greenhouse gas emissions need to be reduced by at least 50 to 85% in 2050 compared to 2000 levels if the increase in global surface temperature is to be limited to 2°C compared to pre-industrial levels. In 2009, the G8 Summit recognized the “2° target and the necessity to reduce global greenhouse gas emissions by at least 50% by 2050”. In its fourth assessment report, the IPCC also suggested intermediate targets for 2020, including a range of 25% to 40% emission reductions compared to 1990 for the group of Annex I countries and a “substantial deviation from baseline in Latin America, Middle East, East Asia and Centrally-planned Asia” (IPCC 2007). For developing countries, reduction ranges of 15 to 30% below baseline have been suggested in accordance with the IPCC (den Elzen and Höhne 2008). The European Commission (2009a) has also published proposals in which developed countries collectively reduce emissions by 30% in 2020 compared to 1990 and economically more advanced developing countries decrease emissions by 15 to 30% below business as usual.

In the wake of the COP 15 climate summit in Copenhagen in December 2009, most Annex I countries, but also a number of developing countries including China, India and Brazil, pledged voluntary emission targets or actions for 2020. Most Annex I[1] and non-Annex I countries submitted the pledges made prior to the Copenhagen climate summit under the Copenhagen Accord (UNFCCC 2009). In addition to quantifiable emission reduction pledges, some developing countries submitted project proposals. However, it is difficult to quantify the emission reductions from these proposals.

With regard to this kind of “pledge and review” approach for determining emission reduction targets, four key questions arise:

- Do the pledges add up to the emission reductions required necessary by science?
- What are the costs associated with meeting the given targets?
- Are the proposed emission reduction efforts of Annex I parties comparable?
- What would comparable efforts look like taking country-specific indicators into account?

[1] Canada altered its pre-Copenhagen pledge of “20% reduction below 2006 levels” to “17% below 2005 levels” in January 2010. The new target is now nominally identical to the US target.

The various proposals for a future international climate regime have to be analysed to launch the negotiating process and enable the negotiating parties to make the right choices. Computer-aided models can be useful in this context and are routinely used for these kinds of analyses (cf. den Elzen et al. 2009a, Wagner and Amann 2009). However, time is often of the essence in the negotiation context which tends to rule out the use of full fledged models with their high demands on programming and computing time. Instead tools are needed that allow the flexible implementation of various policies at short notice with a high disaggregation of countries and sectors that capture the main environmental and economic effects of a proposal. Marginal abatement cost curves provide an important basis for such an analytical tool which enables short-term analyses.

This report presents an analysis which addresses the above mentioned key questions based on such flexible and ready-to-use computable analytical tools. The analysis was conducted, and the tools were developed, within the research project “Post-2012 climate regime: How industrial and developing nations can help to reduce emissions – assessing emission trends, reduction potentials, incentive systems and negotiation options” for the German Environment Agency (UBA)[2].

In Section 2, we analyze the pledges submitted under the Copenhagen Accord with respect to their effects on greenhouse gas emissions and associated abatement costs up to the year 2020. The Climate Strategies Tool (ClimStrat), a tool based on marginal abatement cost curves, is used to perform such quick and flexible analysis for Annex I as well as non-Annex I countries. In Section 3, we take the analysis further and assess the comparability of efforts of mitigation pledges. An effort sharing calculator tool was developed to conduct such analysis. We combine several indicators including those proposed by the European Commission (Russ et al. 2009) to calculate “fair” effort sharing proposals for Annex I countries and compare these with the pledges under the Copenhagen Accord. Section 4 concludes the report. More detailed information on the tools employed in this study is provided in the Appendix.

[2] More information on the project (FKZ 3707 41 103) can be found in the final project report available from UBA.

2 Evaluation of the pledges under the Copenhagen Accord

One main point in the Bali Action Plan was to enhance national and international action on mitigation of climate change of developed countries 'while ensuring the comparability of efforts among them, taking into account differences in their national circumstances' (UNFCCC 2007). Mitigation costs can be used as one indicator to analyse the comparability of efforts of Annex I countries. The following section presents an evaluation of the emission reduction pledges made by Annex I and non-Annex I parties under the Copenhagen Accord. In addition to costs, the analysis also includes estimations on the environmental implications of the Copenhagen Accord. Costs and emission reductions are calculated using the Climate Strategies Tool (ClimStrat) which will briefly be introduced in the following subsection.

2.1 Methodology

The Climate Strategies Tool (ClimStrat) is set within a partial equilibrium modelling framework that allows the user to perform quick and flexible analyses of GHG reduction pledges with respect to their effects on greenhouse gases and abatement costs. Targets for up to 137 countries and regions with differing target types, base years and country-specific rules for the use of offsets can be analysed with respect to their environmental and economic implications. Indicators for the economic effects include (for energy-related CO_2 emissions) the marginal abatement costs for all countries and the total mitigation costs per GDP. Furthermore, ClimStrat provides information on the amount of emissions reduced domestically, the amount of offsets and AAUs traded for all countries and regions.

The economic analyses are based on marginal abatement cost curves provided by the energy system model POLES. Two markets are modelled within ClimStrat: an international emissions trading market (IET) and a market for offsetting credits. Two main assumptions apply for the two markets: (1) Countries within one market all face the same marginal abatement costs and (2) prices in the offsetting market can never be higher than prices in the IET. In addition, it is assumed that countries within the offsetting market which face an emission reduction target must reach that target domestically before being able to generate credits for the offsetting market. This assumption implies that, in particular, countries in the offsetting market cannot buy offsetting credits from other countries to comply with their target.

A detailed description of ClimStrat, its modules and the calculation methodologies can be found in Appendix 1 (Section 6.1).

2.2 Emission reduction targets under the Copenhagen Accord

The following analysis is based on the emission reduction pledges made by Annex I and non-Annex I parties under the Copenhagen Accord. In total, 46 industrialized and developing countries provided emission reduction targets in the form of quantified economy-wide emission targets listed in Appendix I of the Accord, or nationally appropriate mitigation actions (NAMAs) listed in Appendix II of the Accord. Where countries provided a range of reduction targets, the higher pledge (resulting in fewer emissions and thus representing a rather optimistic scenario) is used for the environmental and economic analyses presented in the following sections. A number of developing countries handed in a list of actions rather than quantified reduction targets. These targets have been translated into quantified emission reductions for the purpose of this analysis. All reductions are assumed to exclude emissions from land use, land-use change and forestry (LULUCF) and reducing emissions from deforestation and degradation (REDD). In particular, a number of developing countries[3] pledged a significant amount of emission reductions in the field of REDD and REDD-plus[4] that are not taken into account in this analysis. All non-Annex I countries' targets are assumed to be met domestically. However, financial support from Annex I countries as called for by a number of non-Annex I countries, although not explicitly incorporated in the calculations, is possible. Cost and emission reductions are calculated using *Scenario_4_lowEconomicGrowth,* which accounts for the financial crisis (for more detail on the scenarios employed in the analysis, please see Appendix 6.1.6).

While most Annex I countries chose 1990 as the base year for their emission reduction pledges, a number of countries decided to use other base years. For comparability, the countries' reduction pledges are given for different base years in Table 1. Targets for the original base year are shown in italic, other targets are calculated using total greenhouse gas emissions excluding LULUCF from the national GHG inventories. So far, no emission reductions under the Copenhagen Accord have been submitted by the Ukraine.

The 4th IPCC Assessment Report (IPCC 2007) considers a range of 25 to 40% reduction below 1990 levels by Annex I countries to be necessary to stabilize the concentration of greenhouse gases in the atmosphere at 450 ppm and thus give a 50% probability of reaching the 2°C target. In addition, non-Annex I countries have to reduce their emissions by 15 to 30% below baseline (den Elzen and Höhne 2008). Table 1 shows that current reduction targets by Annex I countries are still about 7 percentage points short of reaching even the lower end of the necessary range. According to Rogelj et al. (2010) the pledges under the Copenhagen Accord correspond to a 50% chance that the increase in temperatures will exceed three degrees Celsius by 2010.

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3 In particular Brazil and Indonesia.

4 "REDD-plus" stands for "reducing emissions from deforestation and degradation, conservation of existing carbon stocks and enhancement of carbon stocks". The REDD-plus mechanism aims at providing incentives for voluntary efforts in developing countries to mitigate climate change by reducing emissions from deforestation and forest degradation and hence promote conservation of forests (as carbon stocks) and the sustainable management.

Table 1 Annex I reduction pledges (in %) for different base years excl. LULUCF

	1990	2000	2005
Australia	13/ 1/ -11	***-5/ -15/ -25***	-11/ -21/ -30
Belarus	***-5/ -10***	73/ 64	60/ 52
Canada	3	-15	***-17***
Croatia	***-5***	18	1
EU-27	***-20/ -30***	-12/ -23	-14/ -24
Iceland	***-30***	-36	-36
Japan	***-25***	-29	-30
Kazakhstan*,**	-8		22
Liechtenstein	***-20/ -30***	-28/ -37	-32/ -41
Monaco	***-30***	-37	-28
New Zealand	***-10/ -20***	-21/ -30	-28/ -36
Norway	***-30/ -40***	-35/ -44	-35/ -45
Russian Federation	***-15/ -25***	39/ 22	33/ 17
Switzerland	***-20/ -30***	-18/ -29	-21/ -31
USA	-4	-16	***-17***
Annex I (excl. Ukraine*)**	**-18**	**-13**	**-16**

Notes: * Targets for Kazakhstan, Liechtenstein and Monaco were not incorporated in the analysis as these countries are not included in ClimStrat.

** The target for Kazakhstan is given as 15% reduction below 1992.

*** The Ukraine so far has not submitted an emission reduction target under the Copenhagen Accord.

NAMAs given by non-Annex I countries vary greatly among countries. While some countries (Brazil, Indonesia, Israel, Marshall Islands, Mexico, Republic of Korea, Republic of Moldova, Singapore and South Africa) pledged non-binding, absolute emission reductions below a certain baseline or a business-as-usual (BAU) emission development, others like China and India gave non-binding relative targets based on economic development and still others provided a list of intended actions in a number of sectors.

For calculations with ClimStrat, all submitted NAMAs had to be translated into quantified emission targets. For those countries that provided an absolute or relative emission reduction target, ClimStrat was used to translate the targets into quantified emission targets applying a baseline scenario with low economic growth (compare Appendix B, Section 6.1.6). The quantified emission reductions of those non-Annex I countries that submitted targets are listed in Table 2. For countries that provided a list of activities, the emission reductions which are possible in those sectors for up to 5/10/20€ in 2020 were calculated. Thus, the analyses implicitly assume that the cheapest measures will be realized and that no measures will be realized at costs exceeding 20 €/t CO_2eq. The figures are given in Table 3. Quantification of activities was possible for 13 countries resulting in 7.5 Mt CO_2eq reductions up to 24 Mt CO_2eq reductions in 2020. Not included in ClimStrat and therefore neglected in the calculations are the sectoral NAMAs proposed by Madagascar, Mauritania and Sierra Leone, whose CO_2 emissions in 2006 added up to 0.02% of global total CO_2 emissions.

A complete list of all non-Annex I NAMAs can be found at the UNFCCC website[5]. Overall, global emission growth slows from the projected 27% to 19% between 2005 and 2020 under the Copenhagen Accord, while peaking of global emissions occurs after 2020.

Table 2 Quantified NAMAs by non-Annex I countries under the Copenhagen Accord

	NAMAs
Bhutan	carbon neutral by 2020
Brazil	36.1-38.9% below BAU by 2020
China	40-45% reduction of CO_2 emissions/GDP below 2005 levels by 2020
Costa Rica	carbon neutral
India	20-25% reduction of CO_2 emissions/GDP below 2005 levels by 2020
Indonesia	26% below BAU by 2020
Israel	20% below BAU by 2020
Maldives	carbon neutral by 2020
Marshall Islands	40% below 1990 levels by 2020
Mexico	30% below BAU by 2020
Papua New Guinea	carbon neutral by 2050
Republic of Korea	30% below BAU by 2020
Republic of Moldova	at least 25% below 1990 levels by 2020
Singapore	16% below BAU by 2020
South Africa	34% below BAU by 2020

5 http://unfccc.int/home/items/5265.php

Table 3 Quantification of NAMAs by non-Annex I countries under the Copenhagen Accord [MtCO_2eq] to different abatement cost levels

	5 €/tCO_2	10 €/tCO_2	20 €/tCO_2
Armenia	0.37	0.65	1.06
Benin	0.02	0.04	0.08
Botswana	0.48	0.94	1.51
Congo	0.01	0.03	0.04
Côte d'Ivoire	0.57	1.11	1.78
Ethiopia	0.08	0.16	0.26
Gabon	0.28	0.53	0.89
Ghana	1.00	1.98	3.32
Jordan	1.04	1.97	3.46
Macedonia	1.12	1.99	3.16
Mongolia	0.93	1.70	3.06
Morocco	1.56	2.99	5.47
Togo	0.05	0.09	0.17
Total	7.50	14.18	24.26

2.3 Analysis of Annex I countries' targets

2.3.1 Absolute GHG emissions

The pledges submitted under the Copenhagen Accord as shown in Section 2.2 were translated with the help of ClimStrat into absolute emissions levels for Annex I countries' 2020 targets as well as in i) absolute emission reductions below 1990 and ii) below BAU necessary to reach those targets (compare Table 4). Where countries provided a range of reduction targets, the higher pledge (resulting in fewer emissions and thus representing a rather optimistic scenario) is used. To reach a 25% reduction below 1990, another 1.15 Gt CO_2eq reduction of emissions in 2020 is necessary in addition to the targets submitted under the Copenhagen Accord. As even with the more ambitious target for the Russian Federation of 25% reduction below 1990 is above the 2020 baseline, about 0.6 Gt CO_2eq reductions could be achieved by ruling out countries to choose emission targets above their baseline and thus preventing new "hot air" from entering the system.[6] "Hot air" from the first commitment period is not considered in these calculations[7]. To reach the high end of 40% reduction by 2020, an additional reduction of about 4 Gt CO_2eq is necessary.

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[6] According to the figures in Table 4, the new hot air from the Russian Federation in 2020 corresponds to about 50% of the required emission reductions in the EU-27 and almost 20% of the required reductions in Annex I countries (without the Russian Federation).

[7] Refraining from banking may actually be in the Russian Federation's best interest in terms of maximizing revenues from selling certificates. In that sense, a weak pledge by the Russian

Table 4 Absolute emission targets and reductions

	Emissions [$MtCO_2eq$]			Target [$MtCO_2eq$]		
	1990	2005	2020 BAU	2020 Target	Reduction to 1990	Reduction to BAU
Australia[(a)]	416	530	639	371	-45	-267
Belarus*	127	76	104	115	-13	11
Canada	592	734	867	610	17	-258
Croatia	33	31	36	31	-2	-5
EU-27	5 572	5 154	5 173	3 900	-1 672	-1 272
Iceland	3	4	4	2	-1	-1
Japan	1 272	1 358	1 451	954	-318	-497
New Zealand	62	77	93	50	-12	-44
Norway	50	54	56	30	-20	-26
Russian Federation*	3 326	2 123	1 869	2 495	-832	626
Switzerland	53	54	56	37	-16	-19
Ukraine**	922	426	585	585	-337	0
USA	6 135	7 107	6 946	5 899	-237	-1 048
Annex I countries	18 572	17 726	17 878	15 078	-3 492	-2 801
Annex I -25%	18 572	17 726	17 878	13 929	-4 643	-3 949
Annex I -30%	18 572	17 726	17 878	13 001	-5 572	-4 878
Annex I -40%	18 572	17 726	17 878	11 143	-7 429	-6 735

Notes: * Target above 2020 baseline levels which would bring new “hot air” into the system.

** The Ukraine did not submit a reduction target under the Copenhagen Accord, therefore baseline figures are given here.

[(a)] Emission figures exclude emissions from LULUCF. For Australia an additional 72 MtCO2e came from the LULUCF sector in 2005.

2.3.2 Per capita emissions

The analysis is taken further to consider the effects in terms of per capita emissions. Table 5 shows per capita emissions in 1990, 2005 and projections for 2020 based on the reduction targets. Furthermore, trends in per capita emissions between 1990 and 2020 and between 2005 and 2020 are shown. All pledges result in a negative per capita emissions trend between 1990 and 2020 except in Croatia, where the per capita emissions remain constant. The negative trend is particularly high for Iceland, Norway and New Zealand. With the submitted targets, all Annex I countries would decrease their per capita emissions below 20 t/cap. Still, extreme differences remain between

Federation could be interpreted as compensation for renouncing banking hot air from the Kyoto-period. Of course, if the Russian Federation was assumed to transfer “hot air” from the Kyoto phase and the pledges remained the same, certificate prices would be substantially lower than calculated above.

countries: annual per capita emissions are well below 10 t/cap in 6 countries, around 10 t/cap in 2 countries, and well above 10 t/cap in 4 countries. Average per capita emissions in 2020 are 12.1 t/cap. Countries with the highest per capita emissions in 2020 continue to be the Russian Federation, the USA, Australia and Canada. Per capita emissions in the EU-27 remain to be below the Annex I average and reach 7.8 t/cap in 2020. This is comparable with per capita emissions in Japan and way below per capita emissions in Australia, Canada, the USA or the Russian Federation.

Table 5 Per capita emissions and trends for Annex I countries with reduction targets

	Per capita emissions			**Per capita emissions trend**		
	1990	2005	2020	1990-2020	1990-2005	2005-2020
Australia	24.4	26.0	15.4	-37%	7%	-41%
Belarus	12.5	7.7	10.7	-15%	-38%	38%
Canada	21.3	22.7	16.8	-21%	7%	-26%
Croatia	6.9	7.0	7.0	1%	1%	0%
EU-27	11.8	10.5	7.8	-34%	-11%	-26%
Iceland	13.4	12.5	6.2	-53%	-7%	-50%
Japan	10.3	10.6	7.5	-27%	3%	-29%
New Zealand	20.3	18.8	10.3	-49%	-7%	-45%
Norway	11.8	11.7	6.0	-49%	-1%	-49%
Russian Federation	22.4	14.8	18.7	-16%	-34%	26%
Switzerland	7.9	7.3	4.6	-42%	-8%	-37%
USA	24.6	24.0	17.5	-29%	-2%	-27%
Annex I	16.4	14.6	12.1	-27%	-11%	-17%

2.3.3 Abatement and compliance costs

The following analyses focus on the costs associated with the pledges. The analyses are based on calculations with the ClimStrat tool, choosing a baseline scenario that is adapted to the financial crisis (Scenario 4, see Appendix 6.1.6).

Domestic action only

Table 6 shows the marginal abatement costs and total abatement costs which result in 2020 if countries had to achieve their pledged targets with domestic action only, i.e. countries are not allowed to buy IET allowances or offsetting credits to comply with their reduction target. For Iceland, Norway and Switzerland, the targets are outside the range of the abatement cost considered in the analysis, i.e. marginal abatement costs higher than 126 €/t CO_2eq in 2020 would be necessary to reach the target. Abatement costs are zero in countries in which target emissions exceed baseline emissions like Belarus and the Russian Federation.

Excluding the countries whose targets are higher than their baseline emissions, the marginal abatement costs are lowest in Croatia and the USA. These countries also face the lowest total abatement costs (below 0.1% of GDP) in 2020. Except for Australia and New Zealand with abatement costs rising to 1.23% and 1.87% of GDP, respectively, abatement costs remain well below 1% of GDP in all the countries. Marginal abatement costs in the EU-27 are higher than in Canada, Croatia and the US but below the level of abatement costs in countries like Australia or Japan. Total abatement costs in share of GDP in the EU-27 are also above the costs in Croatia and the US, but below costs in countries like Australia, Japan or Canada. For all countries abatement costs are also below the average per-annum GDP growth rate between 2005 and 2020 except New Zealand where abatement costs add up to 98% of the average p.a. GDP growth rate. In Australia costs are still more than 50% of average annual GDP growth.

Table 6 Abatement costs in 2020 without international emissions trading

	No international emissions trading		
	Marginal abatement costs 2020 [€/tCO_2]	Abatement costs 2020 [% of GDP]	Abatement costs/ Average GDP growth
Australia[(a)]	73.36	1.23	0.65
Belarus	0.00	0.00	0.00
Canada	36.56	0.38	0.22
Croatia	6.65	0.07	0.02
EU-27	46.09	0.22	0.14
Iceland*	>126.00	>0.52	0.4
Japan	79.64	0.30	0.31
New Zealand	95.61	1.87	0.98
Norway*	>126.00	>0.43	0.33
Russian Federation	0.00	0.00	0.00
Switzerland*	>126.00	>0.30	0.23
USA	12.35	0.05	0.03

Notes: * 126 €/tCO2eq is the upper price limit of the marginal abatement cost curves; actual costs necessary to reach the target are higher than the figures given here.

(a) Emission figures exclude emissions from LULUCF. Inclusion of LULUCF could alter the results for Australia significantly.

Use of international emissions trading and offsets

For this analysis, the amount of offsets allowed in a country was assumed to be 50%[8] of overall emission reductions below the baseline for each country except for those countries not facing a target or having submitted a target involving new "hot air". Compliance costs include abatement costs derived from the marginal abatement cost curves and the net costs for buying and selling offsets or assigned amount units (AAUs). Transaction costs, which may be quite significant in particular for smaller offset projects, are not included in the analyses.

Allowing countries to trade allowances and to use offsets from non-Annex I countries lowers the overall compliance costs in the system. The price of AAUs is 10.45 €/tCO_2 in 2020 and thus well below most countries' marginal abatement costs in 2020 in the case of no trade. The exceptions are Belarus and the Russian Federation, which did not face any costs from target setting, and Croatia. The price of offsets is also 10.45 €/tCO_2, indicating that the limits on offsets are not strict enough to impact the market.

Comparing abatement costs in the no trading case and compliance costs in the trading case, we find that - as theory would suggest – the total costs are lower in the trading case. More specifically, costs are now below 0.5% of GDP for all countries. Belarus and the Russian Federation benefit from the "hot air" they can sell on the market and generate profits of up to 1.7% of GDP in the case of the Russian Federation. Croatia can also sell a number of allowances in the trading case, although significantly fewer than the 'hot air' countries. This allows Croatia to compensate the costs incurred for reaching its emission reduction target to some extent, but not to generate any profit from selling allowances. Compliance costs in the EU-27 in case of international emissions trading are above the level of the US and Japan, but below the level of Australia and Canada. For all countries costs are significantly below the average annual GDP growth between 2005 and 2020. Highest are again New Zealand and Australia who have to spend about ¼ of their GDP growth equivalent to about 3 month of GDP growth. For the EU-27 costs add up to 6% of the annual GDP growth. Russia, on the other hand, can add another 50% to its annual GDP growth from selling emission allowances to other Annex I countries.

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8 This limit reflects that the use of flexible mechanisms under the Kyoto Protocol should be supplemental to domestic action. There is no agreed definition of 'supplemental' and it is not clear whether such a requirement will be part of a post-2012 agreement. The analysis shows, however, that the limit is not binding, i.e. countries are limited by the price of offsetting credits rather than by the quantitative limit applied.

Table 7 Abatement costs in 2020 with the use of international emissions trading and offsets

	International emissions trading			
	Price AAUs 2020 [€/tCO_2eq]	Price Offsets 2020 [€/tCO_2eq]	Compliance Costs 2020 [% of GDP]	Compliance costs/ average GDP growth
Australia	10.45	10.45	0.41	0.22
Belarus	10.45	10.45	-0.74	-0.15
Canada	10.45	10.45	0.21	0.12
Croatia	10.45	10.45	0.06	0.02
EU-27	10.45	10.45	0.10	0.06
Iceland	10.45	10.45	0.12	0.09
Japan	10.45	10.45	0.09	0.09
New Zealand	10.45	10.45	0.51	0.27
Norway	10.45	10.45	0.12	0.09
Russian Federation	10.45	10.45	-1.74	-0.53
Switzerland	10.45	10.45	0.06	0.05
USA	10.45	10.45	0.05	0.03

2.4 Mitigation action in non-Annex I countries

The varying NAMAs submitted by developing countries under the Copenhagen Accord are listed and, where necessary, quantified in Table 2 and Table 3. Table 8 shows the emission reductions implied by the given countries' NAMAs. For those countries that submitted a list of projects rather than a quantified reduction target, the quantifications from Table 3 were used. It was assumed that mitigation actions up to costs of 5 €/t mitigated CO_2eq will be realised in the sectors mentioned in the submissions. Overall reductions in non-Annex I countries are calculated to add up to 2.9 GtCO_2eq in 2020. The main reductions in terms of percentage below BAU come from Brazil, Mexico, South Korea and South Africa. The main reductions in terms of absolute tons of CO_2eq occur in China, Brazil and India which are also the countries with the highest projected GHG emissions in 2020.

Table 8 Emission reductions from NAMAs in developing countries

	BAU 2020 [$MtCO_2eq$]	Target 2020 [$MtCO_2eq$]	Reduction to BAU [$MtCO_2e$]	Reduction to BAU [%]
Brazil[(a)]	1 394	850	-544	-39
China	11 292	10 275	-1 016	-9
India	3 917	3 486	-431	-11
Indonesia[(a)]	757	560	-197	-26
Israel	107	86	-21	-20
Mexico	683	478	-205	-30
Moldova	17	29	12	72
Republic of Korea	684	479	-205	-30
Singapore	64	54	-10	-16
South Africa	840	554	-286	-34
Other countries‘ NAMAs	370	362	-8	-2
Other non-Annex I countries	7 112	7 112	0	0
Total non-Annex I countries	27 237	24 327	-2 910	-11

Notes: [(a)] Emission figures do not include emissions from REDD or REDD-plus. Inclusion of emissions from REDD and REDD-plus could change results for Brazil and Indonesia significantly.

In total, emission reductions in non-Annex I countries are about 11% below the business-as-usual emissions path. This is about 4 percentage points short of the lower end of the 15-30% reduction range below business-as-usual (den Elzen and Höhne 2008).

Table 9 shows the marginal abatement costs necessary to reach developing countries' NAMAs as well as the total abatement costs and the compliance costs in percent of GDP in 2020. As developing countries' targets under the Copenhagen Accord are non-binding, it is assumed that countries have to reach their targets domestically without the use of international emissions trading or offsets. Financial aid from industrialized countries, however, might be an option although this is not explicitly included in the analysis. Countries as well as sectors for which no targets are defined under the Copenhagen Accord are able to produce offsets to sell to Annex I countries. Where a NAMA is defined, however, offsets can be generated only after achievement of the NAMA related target.

Similar to the Russian Federation and the Belarusian targets, the Moldovan target also results in emissions higher than the projected business-as-usual path. Therefore, abatement costs for Moldova are zero. Compliance costs, which, in addition to abatement costs also include costs or profits from credit purchases or sales, are negative because Moldova can profit from selling offsets to Annex I countries which is not banned although the target is higher than the projected business-as-usual path. Mexico, Brazil and the Republic of Korea face the highest marginal abatement costs as well as abatement costs in percent of GDP in 2020. Total abatement costs are also high in Indonesia and particularly in South Africa due to the comparatively low GDP in those countries.

The marginal abatement costs in China and India in 2020 are below the price for international offsets allowing these countries to sell offsets to Annex I countries and thus to reduce their compliance costs.

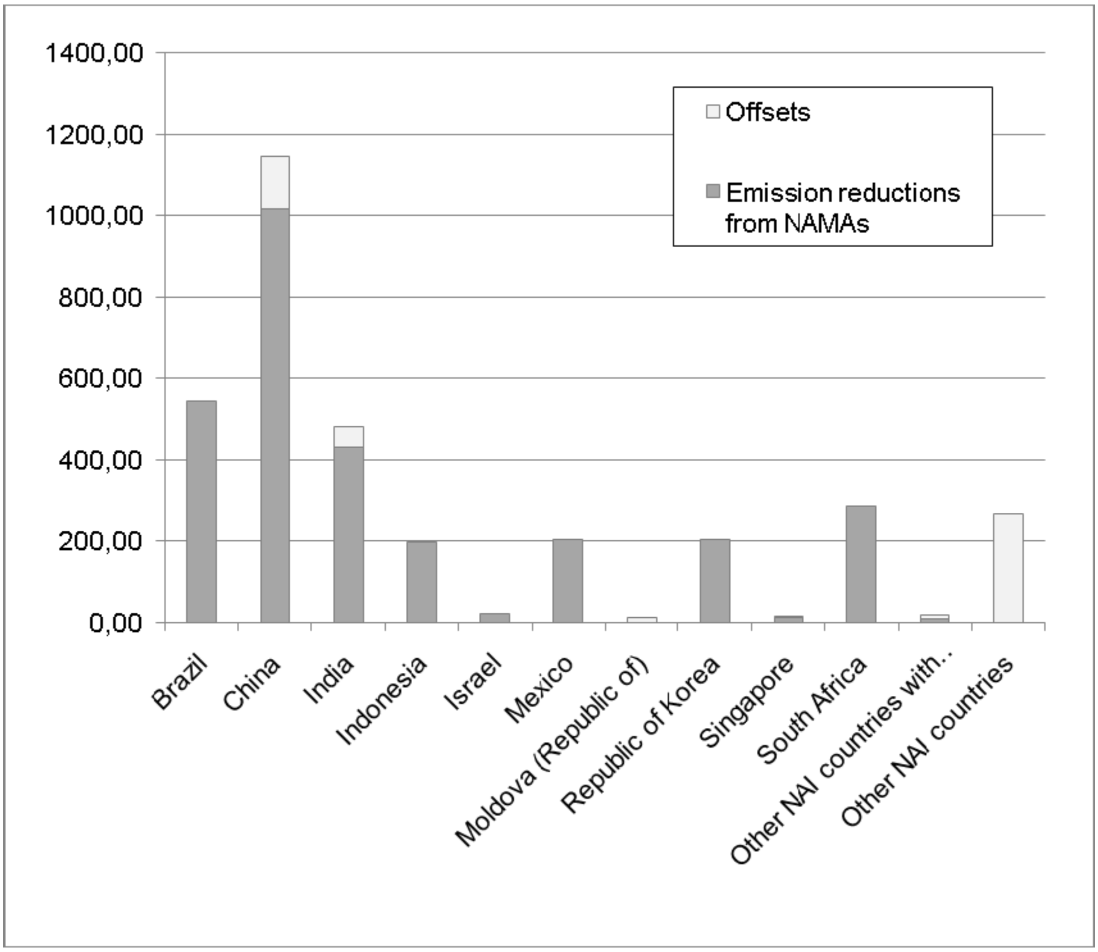
Table 9 Domestic abatement costs for non-Annex I countries' NAMAs in 2020

	Marginal abatement costs 2020 [€/tCO_2eq]	**Abatement costs 2020 [% of GDP]**	**Compliance costs 2020 [% of GDP]**	**Compliance costs/ average GDP growth**
Brazil[(a)]	69.40	1.26	1.26	0.39
China	5.43	0.08	0.06	0.01
India	5.15	0.10	0.07	0.01
Indonesia[(a)]	29.10	0.70	0.70	0.19
Israel	25.55	0.10	0.10	0.02
Mexico	85.38	0.72	0.72	0.27
Moldova	0.00	0.00	-0.13	-0.03
Republic of Korea	64.81	0.62	0.62	0.23
Singapore	12.22	0.03	0.03	0.01
South Africa	19.68	0.91	0.91	0.23

Notes: [(a)] Emission figures do not include emissions from REDD or REDD-plus. Inclusion of emissions from REDD and REDD-plus could change results for Brazil and Indonesia significantly.

Figure 1 shows the amount of emission reductions from NAMAs and for the creation of offsets. While most countries that submitted NAMAs cannot create offsets in addition to their reduction targets, China and India can use about one sixth of their emission reductions to create offsets. Overall, emission reductions from NAMAs are significantly higher than emission reductions for the creation of offsets.

Figure 1 Emission reductions from NAMAs and offsets



3 Sharing the effort of meeting the 2° C target

According to the IPCC (2007), the Annex I Parties will be required to collectively reduce their GHG emissions by 25-40% below 1990 levels by 2020 in order to achieve the 2°C target. Following the UNFCCC principle of 'common but differentiated responsibilities' (Article 3.1) it was envisaged that the overall GHG reduction target for the Annex I Group would be distributed amongst the Parties in a fair and equitable manner. However, a GHG mitigation gap emerged at the COP 15 with the GHG reduction targets pledged by the Annex I Parties in the Copenhagen Accord being lower on aggregate (18% below 1990 levels, compare Table 1) than the range recommended by the IPCC. Given this GHG mitigation gap, it is necessary to further assess effort sharing arrangements to equitably allocate GHG reduction targets amongst the Annex I Parties in order to lower the risk of exceeding the 2°C threshold of global temperature increase.

The concept of 'comparable efforts' was often applied by the Annex I Parties to determine their individual GHG reduction pledge at the COP 15. According to den Elzen et al. (2009b), two issues need further exploration to define the concept of comparable efforts:

- Comparability of different types of commitment
- Differentiation between efforts by countries with different national circumstances

Given that the Annex I Parties can express their GHG commitment pledges in a multitude of ways (i.e. referring to emission reductions in either absolute or relative terms / the setting of a particular base year for emission reductions / in- or excluding certain sectors such as LULUCF) the concept of comparable efforts can refer to the difficult task of comparing the different types of commitment, in order to understand the relative level of effort of each Annex I Party. Secondly, the concept of comparable efforts can refer to the task of differentiating between efforts by countries with different national circumstances. In this context 'the concept of comparability of efforts can incorporate the notion of equal treatment of Parties in similar circumstances. Countries at a similar level of socio-economic development (measured with appropriate indicators) should make similar contributions to climate change mitigation' (den Elzen et al. 2009b). In order to achieve a 'comparable level of effort' amongst the Annex I Parties, several effort sharing approaches have been applied to determine the allocation of GHG reduction targets. These effort sharing approaches can be categorised into two frameworks:

- Equal effort: Compares countries to their (relative) state in time.
- Equal endpoint: Compares countries to an equal (absolute) future state.

Effort sharing approaches within the equal effort framework (i.e. equal percentage reduction below BAU / equal marginal abatement costs) define the problem as future mitigation effort that needs to be distributed equitably amongst the Annex I Parties. These effort sharing approaches need a BAU scenario to define the mitigation effort required, which would then subsequently be allocated to the Annex I Parties according to their national circumstances. Effort sharing approaches within the alternative equal endpoint framework (i.e. converging per capita emissions / triptych approach) focuses on the level of effort needed by each country to reach the same state, at a certain time in the future. In contrast, these effort sharing approaches do not require equal future effort from all countries as early mitigation action is acknowledged.

Given the varying national circumstances of the Annex I Parties, the application of any effort sharing arrangement often disproportionately favours a particular country. Therefore the extent to which the allocation of GHG reduction targets represents 'comparable efforts' can be a contentious issue amongst negotiators. For example, the triptych and converging per capita emissions approaches under the equal endpoint framework show relatively stringent reductions for the USA and Canada and relatively less stringent reductions for the EU and Japan (only Triptych) as these approaches acknowledge past actions. Alternatively, the equal marginal costs approach under the equal effort framework assigns stringent reductions to the emission-intensive (but less wealthy) regions, such as the Ukraine and the Russian Federation, while assigning less stringent reductions to the EU and Japan.

Clearly the UNFCCC negotiations are multi-dimensional in nature and no single factor governs the concerns of all the Parties involved, thus making the task of reaching a political consensus on a fair approach to GHG effort sharing extremely difficult. In light of this difficulty, the use of a multi-criteria methodology has been advanced as a means of resolving the potential limitations associated with single variable approaches to GHG effort sharing. In the context of the UNFCCC negotiations, a multi criteria approach involves the differentiation of emission reduction targets for individual countries based upon a multi criteria rule containing indicators that reflect important underlying principles. The multi criteria approach has most recently been applied by the EU Commission (European Commission 2009b) to allocate the overall Annex I reduction target of 30% below 1990 across the individual Parties based upon a combination of four indicators reflecting different principles underlying a GHG effort sharing arrangement:

- **GDP per capita:** reflecting the capability to pay for domestic emission reductions and to purchase emission reduction credits;
- **GHG emissions per unit of GDP:** indicating the domestic GHG emission reduction potential;
- **Trend in GHG emissions between 1990 and 2005:** recognising domestic early action;
- **Population trend 1990 to 2005:** taking into account the link between population and emissions

The *GHG Effort Sharing Tool* developed by Öko-Institut/ISI-Fraunhofer has been designed to allocate GHG reduction targets for the Annex I Parties. It is based on the European Commission Communication (European Commission 2009b) and uses the same multi criteria approach. It uses a transparent set of indicators that can be used to reflect national circumstances when sharing the necessary reduction effort. The indicators encompass both the equal effort as well as the equal endpoint approach (i.e. capability to pay, historic responsibility and mitigation potential). The objective of the GHG Effort Sharing Tool is to assist the negotiation process with the provision of transparent data on the socio-economic circumstances of each AI Party.

3.1 Methodology

The function of the GHG Effort Sharing Tool is to allocate GHG reduction targets to Annex I Parties in accordance with their performance compared to other Annex I Parties in a range of indicators. The indicators used in the GHG Effort Sharing Tool include the following (indicators used by the European Commission are marked with an asterisk):

- GDP per Capita (2005)*
- GHG Intensity (2005)*
- GHG Trend (1990-2005)*
- Population Trend (1990-2005)*
- Average Mitigation Cost (2020)
- Total Mitigation Cost (2020)
- GHG per Capita (2005)
- GDP Trend (2005)
- Total Primary Energy Supply (2002)

It is important to note that where possible historical data is preferred to calculate these indicator values (i.e. to reduce the level of uncertainty associated with the projections in 2020). Table 14 (see Appendix 6.2.2) provides a more detailed description of how each indicator value is calculated. The GHG Effort Sharing Tool enables the user to select several inputs in order to determine how the overall GHG reduction target for the Annex I Group should be distributed amongst the Parties. The GHG Effort Sharing Tool enables the user to select, weight and scale the indicators. Ambitious and less ambitious GHG reduction targets can then be inputted for the selected indicator providing an upper and lower limit of GHG reduction targets. The Annex I Party with the worst indicator performance will be attributed the maximum GHG reduction target, whilst the country with the best indicator value will be attributed the minimum GHG reduction target. The GHG reduction values for the remaining countries will subsequently be proportional to their indicator score within the range of GHG reductions that have been specified. In order to determine the total GHG reduction required by each Annex I Party the weighting of each indicator is multiplied by the corresponding GHG reduction target. The GHG reduction targets for each indicator are then added together to calculate the total GHG reduction target for the Annex I Parties (refer to Appendix 6.2.1 for further information).

3.2 Scenario Analysis

The GHG Effort Sharing Tool is used to design twelve scenarios to analyse the performance of the Annex I Parties according to different combinations of indicators (refer to Table 15 and Table 16 in Appendix 6.2.3). The twelve scenarios are based on the four indicators applied by the EU Commission plus total and average mitigation cost indicators that are derived from the POLES marginal abatement costs curve (Scenario 1: No CCS, see Appendix 6.1.6) of each Annex I Party in the ClimStrat tool. Every scenario delivers an aggregate Annex I Group GHG reduction of 30% below 2005 emission levels;[9] GHG reduction targets of all individual indicators are within a boundary range of 0-50%. The scenarios analysis involved three steps.

Firstly, the performance of each Annex I Party for six single indicator and six multiple indicator scenarios is calculated. The following scenarios are created using the GHG Effort Sharing Tool:

Single indicator scenarios:

A) GDP per Capita (2005)

B) GHG/GDP (2005)

C) GHG Trend (1990-2005)

D) Population Trend (1990-2005)

E) Average Mitigation Cost (2020)

F) Total Mitigation Cost (2020)

Multiple indicator scenarios:

G) GHG Trend (1990-2005) / Population Trend (1990-2005)

H) GDP/Cap (2005) / GHG Trend (1990-2005)

I) GHG/GDP (2005) / Population Trend (1990-2005)

J) GHG/GDP (2005 / Total Mitigation Cost (2020)

K) GHG Trend (1990-2005) / Average Mitigation Cost (2020)

L) Population Trend (1990-2005) / Total Mitigation Cost (2020)

The combination of indicators in the multiple indicator scenarios are deliberately chosen so that the indicators were independent of one another (i.e. that a multiple indicator scenario does not contain indicators that were calculated using the same raw data). For example, the GDP per Capita (2005) and GHG/GDP (2005) indicators are not selected as a multiple indicator scenario because both indicators are derived from GDP data.

Secondly, the GHG Effort Sharing Tool is used to calculate the average GHG reduction target of each Annex I Party based upon their performance in all twelve of the scenar-

[9] Given that the total average GHG emissions for the Annex I Group have experienced limited change over the last 15 years, the 2005 base year was selected on account of its more accurate emissions data. The 30% reduction below 2005 emission levels translates to a 33% reduction below 1990 emission levels and lies in the middle of the 25-40% range recommended by the IPCC (2007).

ios. The standard deviation of the GHG reductions for the twelve scenarios is also calculated for each Annex I Party. The GHG reduction target and the standard deviation (which is initially relative to 2005 levels) are then converted to 1990 emission levels to demonstrate the differences in GHG mitigation effort between 1990 and 2005. Thirdly, the average GHG reduction targets for each Annex I Party are then compared to the EU Commission's Effort Sharing Proposal (European Commission 2009a) and the Copenhagen Accord pledge of each Annex I Party.

The scenario analysis demonstrates the different levels of sensitivity of the Annex I Parties to scenarios that are based upon single and multiple indicators and the following classifications have been defined:

- **High sensitivity**: A country is defined as highly sensitive to a particular indicator if its performance receives a GHG reduction target that deviates by ten percentage points or more from the 30% average.
- **Medium sensitivity:** A country is defined as moderately sensitive to a particular indicator if its performance receives a GHG reduction target that deviates between five percentage points and ten percentage points from the 30% average.
- **Low sensitivity**: A country is defined as having a low sensitivity to a particular indicator if its performance receives a GHG reduction target that deviates by five percentage points or less from the 30% average.

It is evident from Figure 2 below that countries within the Annex I Group have different levels of sensitivity to the twelve scenarios in the analysis. The **Ukraine** and the **Russian Federation** have been classified as highly sensitive to eight scenarios (A, B, C, D, E, F, H, I) and both countries experience a higher level of variation in their GHG reduction targets for each of the twelve scenarios than the other Annex I Parties. The higher level of sensitivity of the Ukraine and the Russian Federation in the scenario analysis reflects the socio-economic changes that have occurred in these countries following the collapse of the Soviet Union. For example, the Ukraine and the Russian Federation have experienced a 54% and 36% reduction in its GHG emissions between 1990 and 2005. This is primarily due to a significant decline in their industrial productivity (i.e. Ukraine's and the Russian Federation's GDP declined by 37% and 9% respectively between 1990-2005) and not necessarily due to GHG mitigation actions. Interestingly Table 10 shows that the Ukraine and the Russian Federation were less sensitive to scenarios that included multiple indicators as the impact of extreme single indicators could be reduced.

Table 10 Distribution of countries' scenario sensitivity: 2005

	Scenario Sensitivity					
	High		Medium		Low	
	Quantity	Scenario	Quantity	Scenario	Quantity	Scenario
AUS	5	B,C,D,H,K	2	E,L	5	A,F,G,I,J
CAN	5	C,D,E,H,K	3	A,B,L	4	F,G,I,J
JAP	2	B,E	2	C,K	8	A,D,F,G,H,I,J,L
NZ	4	B,C,D,K	4	E,F,H,L	4	A,G,I,J,
NOR	4	A,B,E,H	4	C,I,J,K	4	D,F,G,L
RUS	8	A,B,C,D,E,F,H,I	0		4	G,J,K,L
SWI	5	A,B,E,I,K	2	H,J	5	C,D,F,G,L
UKR	8	A,B,C,D,E,F,H,I	4	G,J,K,L	0	
USA	4	A,C,D,H	3	I,K,L	5	B,E,F,G,J
EU-27	1	E	2	B,K	9	A,C,D,F,G,H,I,J,L

The majority of the Annex I Parties (AUS, CAN, NZ, NOR, SWI, USA) have a high sensitivity to either four or five of the scenarios in the analysis. **Australia** is classified as highly sensitive to five scenarios (B, C, D, H, K). Given that the country has experienced a 27% increase in their GHG emissions between 1990 and 2005 it is to be expected that Australia is highly sensitive to the scenarios B, C, H and K, which have all been derived from GHG emissions data. Australia receives a GHG reduction target of 34% below 2005 levels in the scenario analysis that is higher than the Annex I Group average reflecting the country's increasing 1990-2005 GHG trend. **Canada** is also classified as highly sensitive to five scenarios (C, D, E, H, K) and the country's performance in the twelve scenarios is very similar to that of Australia (i.e. Canada's GHG emissions have increased by 24% between 1990 and 2005) resulting in an identical GHG reduction target of 34% below 2005.

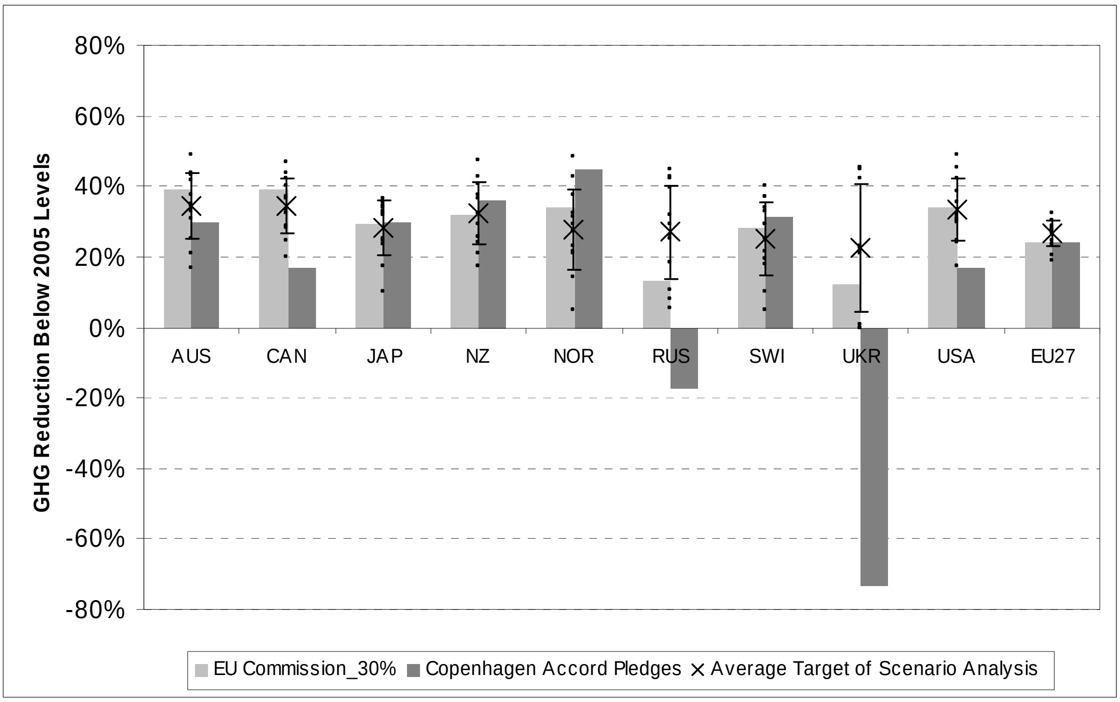
Norway is classified as highly sensitive to four scenarios (A, B, E, H). The country has experienced a GDP growth of 60% between 1990-2005 and has the highest GDP/Cap of all the Annex I Parties. The increase in GHG emissions associated with this GDP growth has been limited to 9% between 1990-2005 due to the Norwegian economy being highly efficient and its high renewable energy share. Given the efficiency of the country's economic output and its expensive mitigation potential (indicating early mitigation effort), Norway receives a GHG reduction target in the scenario analysis of 28% below 2005 levels, which is below the Annex I Group average. It is important to acknowledge that Norway experiences the highest level of variation in its GHG reduction targets in the scenario analysis after the Ukraine and the Russian Federation. **Switzerland** is classified as highly sensitive to five scenarios (A, B, E, I, K) and shares similar characteristics to Norway with regards to its performance in the scenario analysis. Switzerland receives a lower GHG reduction target than Norway (25% below 2005 levels) primarily due to its lower GDP/Cap.

The **USA** is classified as highly sensitive to four scenarios (A, C, D, H). The sensitivity of the USA to these indicators can be explained by the fact that the country has experienced GDP growth of 57% between 1990 and 2005, which has been accompanied with a 16% increase in GHG emissions. As a consequence the USA receives a GHG reduction target (33% below 2005 levels) in the scenario analysis above the Annex I Group average. **New Zealand** is classified as highly sensitive to four scenarios (B, C, D, K) and unlike the USA, the country is highly sensitive to the GHG/GDP scenario. However, despite this important difference New Zealand receives a similar GHG reduction target to the USA in the scenario analysis of 32% below 2005 levels. New Zealand and the USA also have the same level of variation in their GHG reduction targets.

The only indicator that is classified as highly sensitive for the **EU-27**'s GHG reduction target is scenario E (Average mitigation costs 2020). Therefore the EU-27 is least affected by the selection of a scenario to determine the GHG effort sharing arrangement. The EU-27 experienced a low variability in its GHG reduction targets with a low standard deviation, which reflects the fact that the EU-27 is classified as having a low sensitivity in nine scenarios (A, C, D, F, G, H, I, J, L). Although individual Member States are highly sensitive to some or many scenarios the 27 countries average each other out leading to an overall low sensitivity of the union. The EU-27 receives an average GHG reduction target of 27% below 2005 emission levels. **Japan** is only highly sensitive to two scenarios (B, E) and also experiences low variability in its GHG reduction targets. As Japan is rewarded for its performance in the two scenarios classified as highly sensitive, the country receives a lower than average GHG reduction target of 28% below 2005 emission levels.

Figure 2 shows the average GHG reduction targets (below 2005 emission levels) that have been calculated from the twelve scenarios in the GHG Effort Sharing Tool and for comparison the EU Commission Effort Sharing Proposal and the Copenhagen Accord pledges (whereby the maximum pledge of each Annex I Party is assumed) are also included. Assuming that the effort sharing scenarios from the EU Commission and the scenario analysis represent a fair distribution of effort amongst the Annex I Parties it is clear that two countries (NOR, SWI) have submitted GHG reduction pledges in the Copenhagen Accord that exceed the outcome of the GHG Effort Sharing Tool. Four countries (AUS, NZ, JAP, EU-27) have pledged GHG reduction commitments that are more or less equal with the output of the scenario analysis. However, it can be argued that numerous countries (CAN, RUS, UKR, USA) will need to commit to mitigation action that is considerably more ambitious than their current pledges in the Copenhagen Accord if the Annex I Group is to reduce its GHG emissions by 25-40% below 1990 levels by 2020. The Ukraine has the largest disparity between its Copenhagen Accord pledge and the GHG reduction target expected by both the EU Commission and the scenario analysis. When the Copenhagen Accord pledge of the Ukraine is converted to the 2005 base year, it represents a 73% increase in GHG emissions which may not be acceptable to many of the negotiating Annex I Parties.

Figure 2 Range of the GHG reduction targets below 2005 for the Annex I Parties



Note: Each dot represents the GHG reduction target of an Annex I Party for a particular scenario (i.e. GDP/Cap). Each bar illustrates the standard deviation in the GHG reduction targets of the Annex I Parties for the twelve scenarios.

The results of the scenario analysis look different if the GHG reduction targets are converted to 1990 levels (compare Table 11). The conversion of the Annex I Group's GHG reduction target of 30% below 2005 is equivalent to a 33% GHG reduction below 1990. Although the overall target for the Annex I Group is similar for both base years it is evident that sensitivity to the selection of the base year can differ amongst the Annex I Parties. For example, the Ukraine and the Russian Federation both have a high level of sensitivity to all twelve scenarios (A, B, C, D, E, F, G, H, I, J, K, L) when the GHG reduction targets are converted to 1990 emission levels. This higher level of sensitivity to the twelve scenarios results in both countries experiencing a lower variation in their GHG reduction targets (due to their negative 1990-2005 GHG trend) when the 1990 base year is adopted.[10] In contrast, several countries (AUS, CAN, NZ, NOR, USA) have a higher level of variability in their GHG reduction targets when they are converted to 1990 emission levels, which reflects an increase in their 1990-2005 GHG trends. Japan, Switzerland and the EU-27 do not experience a change in the variability

[10] The reason for the lower variability is that the same reduction target (Z Mt of CO_2 in 2020) is divided by higher base year emissions (X Mt in 1990 compared to Y Mt in 2005 with X>Y). Vice versa, if 2005 emissions are higher than 1990 emissions the sensitivity increases if the targets are converted from a 2005 base year to 1990 base year.

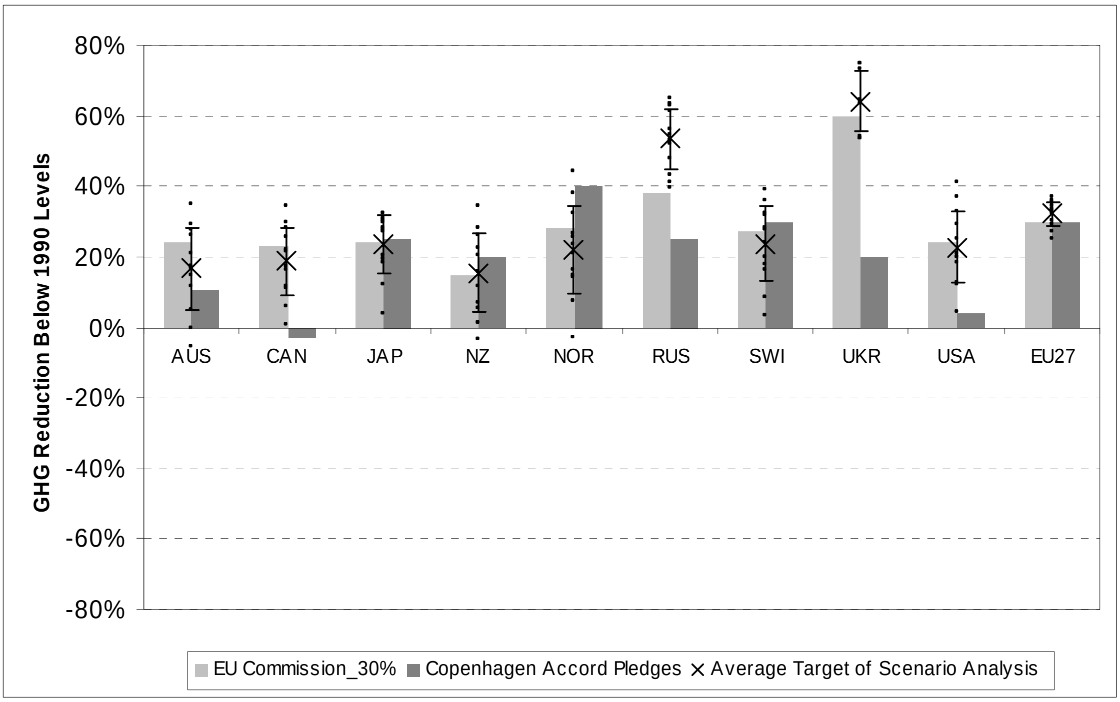
of their GHG reduction targets. This is due to the relatively stable GHG trend between 1990-2005.

Table 11 Distribution of countries' scenario sensitivity: 1990

	Scenario Sensitivity					
	High		Medium		Low	
	Quantity	Scenario	Quantity	Scenario	Quantity	Scenario
AUS	7	A,D,F,G,I,J,L	1	E	4	B,C,H,K
CAN	6	D,F,G,I,J,L	2	A,B	4	C,E,H,K
JAP	5	B,E,I,J,K	1	L	6	A,C,D,F,G,H
NZ	7	A,D,F,G,I,J,L	2	E,H	3	B,C,K
NOR	6	A,B,E,I,J,K	3	D,H,L	3	C,F,G
RUS	12	A,B,C,D,E,F,G,H,I ,J,K,L	0		0	F,G,L
SWI	5	B,E,I,J,K	3	A,D,H	4	C,F,G,L
UKR	12	A,B,C,D,E,F,G,H,I ,J,K,L	0		0	
USA	7	A,B,D,G,I,J,L	2	F,H	3	C,E,K
EU-27	0		2	D,L	10	A,B,C,E,F,G,H, I,J,K

Figure 3 shows the average GHG reduction targets (below 1990 emission levels) that have been calculated from the twelve scenarios in the GHG Effort Sharing Tool and for comparison the EU Commission Effort Sharing Proposal and the Copenhagen Accord pledges (whereby the maximum pledge of each Annex I Party is assumed) are also included. Assuming that the effort sharing scenarios from the EU Commission and the scenario analysis represent a fair distribution of effort amongst the Annex I Parties it is evident that when the GHG reduction targets of the scenario analysis are converted to 1990 emission levels the same countries either exceed the outcome of the GHG Effort Sharing Tool (NOR, SWI), are more or less in line with the output of the scenario analysis (AUS, NZ, JAP, EU-27) or will be required to increase their GHG mitigation efforts (CAN, RUS, UKR, USA). The conversion of Canada's Copenhagen Accord pledge reveals a considerable GHG mitigation gap between the country's commitment and the GHG target derived from the scenario analysis. For example, Canada's pledge of a 17% GHG reduction below 2005 emission levels in the Copenhagen Accord represents a 3% increase in GHG emissions from 1990 levels and this results in a mitigation gap of 22 percentage points between what has been pledged and what the scenario analysis indicates as a fair share of the GHG mitigation effort for Canada.

Figure 3 Range of the GHG reduction targets below 1990 for the Annex I Parties



Note: Each dot represents the GHG reduction target of an Annex I Party for a particular scenario (i.e. GDP/Cap). Each bar illustrates the standard deviation in the GHG reduction targets of the Annex I Parties for the twelve scenarios.

3.3 Results of the Effort Sharing Analysis

An effort sharing agreement on GHG reductions based upon a range of socio-economic indicators will never produce an entirely satisfactory outcome for all of the Annex I Parties. This analysis clearly demonstrates the socio-economic diversity that exists within the Annex I Group, which means that the use of indicators in the 12 scenarios analysed in this study will always benefit certain countries at the expense of others. Negotiations at the COP level have too often descended into long discussions about which indicators best represent ‘comparable efforts’ amongst the Annex I Parties and which base year is most appropriate to use. This demonstrates the limitation of the effort sharing approach based upon socio-economic indicators for it can delay negotiators from reaching an agreement on GHG reductions. Although the GHG Effort Sharing Tool may provide a clear indication of the effort required by countries with a small range of reduction targets (i.e. EU-27), ultimately strong political decision making will be required to reach agreement on the mitigation efforts of countries with a larger range of reduction targets (i.e. UKR / RUS).

The pledges of the Annex I Parties at the COP 15 in Copenhagen collectively represent a GHG emission reduction of 18% below 1990 levels, which is less than the 25-40% reduction recommended by the IPCC. Assuming that the average GHG reduction targets derived from the scenario analysis represent a fair effort sharing arrangement, it is evident from Figure 2 and Figure 3 that several of the Annex I Parties will be required to increase their GHG mitigation efforts in the near future. For example, the Copenhagen Accord pledge of the USA is currently substantially lower than the range of GHG reduction targets calculated in the scenario analysis. The pledge of the USA in the Copenhagen Accord could be regarded as 'comparable' if the population trend (1990-2005) was the only scenario considered. However, the GHG reduction targets derived from the remaining eleven scenarios in the analysis are considerably greater than the USA commitment at the COP 15 (see Table 15 in annex 6.2.3). Given that effort sharing arrangements need to consider a range of indicators to acknowledge the different national circumstances of all the Annex I Parties, the GHG mitigation effort of the USA is currently insufficient for the Annex I Group to equitably reduce its GHG emissions by 25-40% below 1990 by 2020.

However, it is important to acknowledge that a difference of opinion concerning the necessary time horizon for GHG reductions may explain the disparity between the USA pledge in the Copenhagen Accord and the GHG reduction target derived from the scenario analysis. According to the chief US climate negotiator Todd Stern (2009), the IPCC recommendation is unrealistic (i.e. would require the US to make significantly deeper GHG reductions than the EU by 2020) and ultimately unnecessary (i.e. the pathway to 2050 is more important). The US position demonstrates the conflict between scientific aspiration and political reality, and ultimately a compromise may be required to enable all of the Annex I Parties to reach a consensus on an equal effort sharing arrangement which reduces the risk of exceeding the 2C threshold to an acceptable level. Nevertheless, it is vital that climate policy continues to be led by the science and that Annex I Parties re-define what is now regarded as 'politically acceptable' to acknowledge the impact of climate change in the near future. Therefore any political compromise (i.e. broadening the time horizon for GHG reductions) needs to be scientifically credible.

The Copenhagen Accord pledges by both the Ukraine and the Russian Federation are below the GHG reduction targets calculated for all twelve of the scenarios considered in this analysis, which implies (assuming the GHG reduction targets from the scenario analysis are equitable) that further GHG mitigation effort will be required from these countries before 2020. This study has demonstrated that the Ukraine and the Russian Federation are highly sensitive to the selection of a scenario, reflecting the fact that their performance in this analysis is considerably more extreme than the other Annex I Parties. Given that the negative GHG trend between 1990-2005 of the Ukraine and the Russian Federation is not necessarily due to GHG mitigation action there is a reluctance to reward these countries based upon this indicator. The EU Commission Annex I 30% Effort Sharing Proposal (European Commission, 2009a) clearly supports such a view and imposes limits upon the more extreme values of both the Ukraine and the Russian Federation. In addition, the Russian Federation's Copenhagen Accord pledge is contingent upon an 'appropriate allowance' for the Russian Forests to contribute to their mitigation action. Therefore an agreement on changes to LULUCF accounting rules will also determine whether or not the mitigation action of the Russian

Federation can be considered to be ‘real’. It is important that the GHG reduction commitments of both the Ukraine and the Russian Federation represent real mitigation action (beyond their existing commitments that actually exceed BAU 2020 projections) in order to be acceptable to the other Annex I Parties.

The Copenhagen Accord pledges of Norway and Switzerland in particular have increased the pressure on the EU-27 to shift its GHG reduction target from 20 to 30% below 1990 levels by 2020. The impact of the economic recession has further strengthened the argument that the EU-27’s 30% target could now be met at considerably lower cost than previously anticipated (de Bruyn et al. 2010). Figure 2 and Figure 3 illustrate that the EU-27 needs to increase its GHG reduction target to at least 30% to be ‘comparable’ with the efforts of Norway and Switzerland, which have both pledged commitments that are higher than the GHG reduction targets derived from the scenario analysis. Although this analysis has demonstrated that the EU-27 is the least sensitive Annex I Party to the selection of different scenarios, it is important to acknowledge that internally the EU-27 remains diverse and the level of sensitivity to particular indicators will vary amongst the individual member states. For example, EU-27 states that have recently entered the union (i.e. Poland, Romania) have more GHG intensive industries than their more developed counterparts and have internally argued strongly for a fair distribution of effort within the bloc that does not disadvantage their development. Indeed such internal difficulties may have hindered the ability of the EU-27 to influence the outcome of the COP 15 and need to be resolved before the COP 16 in Mexico.

4 Conclusion

The climate summit in Copenhagen (COP 15) in December 2009 did not lead to a legally binding agreement that could serve as a successor to the Kyoto Protocol. Instead, it resulted in an agreement, which was recognized but not adopted by the COP. Our analyses suggest that the targets proposed under the Copenhagen Accord are not sufficiently ambitious to meet the emission reductions necessary to reach the 2°C target. For some countries (e.g. the Russia Federation and Belarus), the targets submitted under the Copenhagen Accord do not translate into any emission reductions by 2020 at all, but create new ‘hot air’ instead. Likewise, mitigation costs to reach those targets are rather low, especially if flexible mechanisms like emissions trading or offsets are allowed. The emission targets by Annex I countries and NAMAs as specified in the Copenhagen Accord, are, on average, cheaper for Annex I countries than for developing countries (measured as mitigation costs in relation to GDP in 2020). In this respect, the findings rationalize compensation payments from industrialized to developing countries for their mitigation (and adaptation) efforts. Also, even though mitigation costs (as share of GDP) for the targets under the Copenhagen Accord are rather low, they vary substantially across regions.

These findings suggest that the pledges under the Copenhagen Accord may have to be reconsidered to become both environmentally more ambitious and politically more acceptable. For example, GHG reduction commitments of all countries may need to represent real mitigation action (beyond their existing commitments that actually exceed BAU 2020 projections) in order to be acceptable to the other Annex I Parties.[11] Likewise, emission targets by Annex I countries may need to become more ambitious before they are perceived acceptable by developing countries. More ambitious overall targets in 2020 would also help achieve the 2°C target with a higher probability.

The pledges of the Annex I Parties in the Copenhagen Accord were also compared to possible ‘fair’ effort-sharing arrangements based upon various socio-economic indicators. Assuming that the outcome of the scenario analysis represented a ‘fair’ effort sharing arrangement it was evident that several of the Annex I Parties will need to increase their level of commitment if the GHG mitigation gap is to be addressed to enable the Annex I Group to fulfil the recommendations of the IPCC (2007). However, it is important to acknowledge that the outcome of an effort sharing arrangement derived from socio-economic indicators will never produce an entirely satisfactory outcome for all of the Annex I Parties. This reflects the diversity that exists within the Annex I Group and demonstrates the difficulty of reaching consensus on what constitutes a ‘fair’ effort sharing arrangement.

[11] It should be noted though that analyses including similar targets as the analyses in this report, but allowing for general economic effects (like change in prices for oil and gas) may find the Russian Federation worse off even though it can sell a large amount of „hot air“.

The conference in Copenhagen made it clear that climate protection is only one of a number of political objectives worldwide and cannot be discussed separately from other global political issues. Although at the moment it may seem unrealistic that the world will see a climate change agreement in the near future that is based on a top-down approach, the analysis presented in this study can help to indicate the road forward.

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6 Appendix

6.1 Appendix 1: The Climate Strategies Tool (ClimStrat)

The Climate Strategies Tool (ClimStrat) is a partial equilibrium modelling framework that allows the user to perform quick and flexible analyses of international climate agreement proposals with respect to their effects on greenhouse gases and abatement costs. Targets for up to 137 countries and regions with differing target types, base years and country-specific rules for the use of offsets can be analysed with respect to their environmental and economic implications. Indicators for the economic effects include (for energy-related CO_2 emissions) the marginal abatement costs for all countries and the total mitigation costs per GDP. Furthermore, ClimStrat provides information on the amount of emissions reduced domestically, the amount of offsets and AAUs traded for all countries and regions. The environmental and economic analyses may be based on historical emissions and socio-economic data as well as the data projections and marginal abatement cost curves provided by the energy system model POLES.

6.1.1 General outline

The main area of application for ClimStrat is the analysis of GHG reduction pledges of parties. Two main priorities during the program's development were therefore to include as many countries as possible and a wide variety of target types. 137 countries and regions were able to be included based on the available historical data. In addition to absolute targets with varying base years, per capita targets as well as no-lose and dual targets for developing countries can be applied. In addition, sectoral targets can be specified for 4 main sectors (cement, iron & steel, electricity and aviation).

ClimStrat also contains a database with historical data on emissions, population and economic development starting from the year 1990. The analyses of future climate regimes may be performed up to the year 2020. For cost calculations, annual marginal abatement cost curves are available for the years 2006/2008 to 2020/2030. At present, target setting is only available for the year 2020. Calculations are based on specific targets for 2020 that provide the CO_2 price necessary to reach that target. Based on the CO_2 price for the year 2020, the pathway starting in 2006/2008 is endogenously given by the model based on a linearly increasing CO_2 price path between 2005/2008 and 2020. Path dependencies for technology development are accounted for by remaining within the linearly increasing CO_2 price path for the years 2005/2008 to 2020. However, banking and borrowing of emission allowances or credits as well as analyses of trading periods are not possible with ClimStrat.

Two markets are modelled within ClimStrat: An international emission trading market (IET) and a market for offsetting credits. Targets can be defined for countries in both markets. However, countries within the offsetting market facing a reduction target can only create credits after they have met the reduction target domestically.

6.1.2 Basic modelling structure

The ClimStrat analysis tool consists of two parts. The main item is a sizeable database containing more than 600,000 records including historical and projected emissions and production data as well as abatement cost information and scenario specifications. For convenient handling, the database is separated from the main program and saved in a separate file labelled *climstratdb*. The latest version of the database is automatically uploaded at each program start. When closing the program, changes to data sets are automatically saved in the database for the next session.

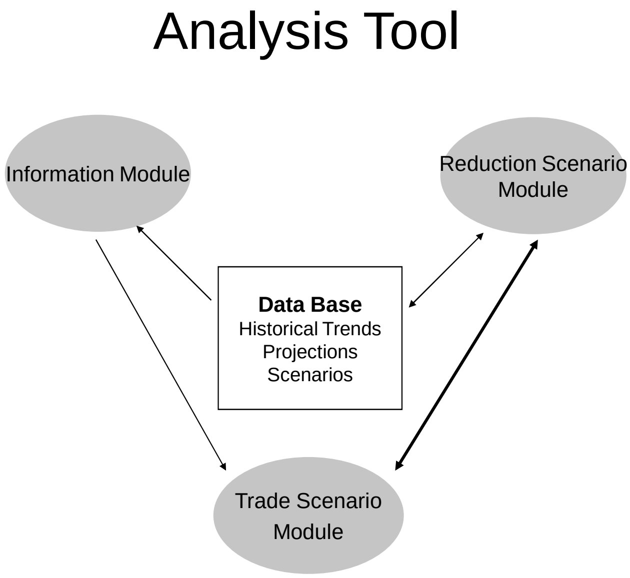
The actual program code and the user interface forms are contained in the main file labelled *climstrat*. ClimStrat consists of three different sections that allow the user to retrieve information and to specify and analyse reduction scenarios.

- The **information module** provides data on emissions, production or socio-economic indicators for single countries or regions from different data sources.
- The **reduction scenario module** allows the user to create and analyse climate agreement scenarios with respect to their global environmental effectiveness.
- The **trade scenario module** allows the user to analyse the costs of realizing these targets based on scenario- and country-specific assumptions about emissions trading and the use of offsets.

ClimStrat's main function, the analysis of emission reduction scenarios, uses the reduction and the trade scenario modules. In the reduction scenario, all the country-specific information about target type, level of ambition, base year and use of offsets can be specified. The definition of the reduction scenario is sufficient for an analysis of the environmental implications. To permit the economic analysis of a proposal, parameters regarding the trade of emission allowances and credits have to be defined in the trade scenario module. The trade scenario module allows the user to specify which countries participate in the international emissions trading market, which countries are only allowed to participate via an offsetting market and which countries are not included in the trading at all. After the different trading groups have been specified, marginal abatement cost curves are used to determine the amount of domestic reduction, the amount of emission allowances and credits traded as well as the marginal and total abatement costs. A detailed description is given in the following subsections.

ClimStrat is implemented using Microsoft Access, a standard Microsoft application. The output is generated in Microsoft Excel. Solution time for a scenario is 1 to 2 minutes on a standard Pentium PC.

Figure 4 Design of ClimStrat



6.1.3 Information Module

ClimStrat provides broad information to give the user a better understanding of the situation in different countries or sectors. This includes historical data on CO_2 and non-CO_2 greenhouse gas emissions, production and socio-economic indicators from various sources. Data projections contained within ClimStrat are taken from different scenario-runs conducted with the energy system model POLES (Criqui 2001). In addition, it provides scenarios calculated from a historical database and projected growth rates taken from POLES.

Major sources for historical data are the UNFCCC greenhouse gas inventories and IEA emission data, PRODCOM and the world development indicators provided by the World Bank. Projected data are mainly provided by the energy system model POLES. POLES provides emissions and cost data for 48 countries and regions. To disaggregate the POLES regions, historical data for the year 2005 were used to calculate a country's share in a region. The following algorithm specifies the calculation of the data series based on historical 2005 emissions and projected growth rates taken from POLES.

$x_{k,2005}$: historical emissions in country k in the year 2005

For all $x_{k,2005+t}$, $t = 1$:

$x_{k,2005+1} = x_{k,2005} =$ $x_{k,}$[illegible]

if $x_{k,2005}$ historically not available

For all $x_{k,2005+t}$, $t > 1$:

$$x_{k,2005+t} = x_{k,2005+t-1} * \alpha_{K,2005+t-1,2005+t}$$

where:

$\alpha_{K,2005+t-1,2005+t}$: growth rate of projected emissions from period 2005+t-1 to 2005+t in region K, where country $k \in$ region K

$\alpha_{K,2005+t-1,2005+t}$: growth rate of projected emissions from period 2005+t-1 to 2005+t in region K, where country $k \in$ region K

Disaggregating the POLES data was able to be done for 137 countries and regions. For a country to be included, data for 1990 had to be available from at least one major data source (UNFCCC greenhouse gas inventories or IEA).

Data for about 50 sectors and subsectors are available in ClimStrat. Categories are taken from the UNFCCC GHG inventories, including *Total GHG emissions including/ excluding LULUCF*. Depending on data availability, subsectors from other data sources have been included in the database in addition to the UNFCCC ones, creating a high level of detail in some areas (e.g. electricity from coal, gas, nuclear, hydro power, solar, wind). The output differentiated by data source is shown in the form of a table or a graph and can be exported to Excel.

6.1.4 Reduction Scenario Module

The target module provides an interface to calculate global emission reductions based on country-specific national and sectoral targets. The type of target which can be set for a particular country depends on its level of economic development, i.e. for Annex I countries, the user can choose between an absolute target and a per capita target. For non-Annex I, no-lose and dual targets are added for both target types. Sectoral targets are currently implemented for four main sectors: iron & steel, cement, electricity and aviation. Table 12 provides an overview of the different types of national and sectoral targets that are available for Annex I and non-Annex I countries.

Table 12 Target types available in ClimStrat

Sector	Annex I	Non-Annex I
National Target	absolute (% of base year) per capita (t per capita)	absolute (% of base year) absolute no-lose (% of base year) absolute dual (% of base year) per capita (t per capita) per capita no-lose (t per capita) per capita dual (t per capita)
Iron&Steel/ Cement	absolute (% of base year) per t product	absolute (% of base year) absolute no-lose (% of base year) absolute dual (% of base year) per t product per t product no-lose per t product dual
Electricity	absolute (% of base year) per MWh electricity	absolute (% of base year) absolute no-lose (% of base year) absolute dual (% of base year) per MWh electricity per MWh electricity no-lose per MWh electricity dual
Aviation	absolute (% of base year)	absolute (% of base year) absolute no-lose (% of base year) absolute dual (% of base year)

Where necessary a base year can be chosen between 1990 and 2020 (business-as-usual). In addition, the amount of offsetting credits able to be used can be specified for each country. This is given as a percentage of the difference between the 2020 business-as-usual emissions and the specified target, i.e.

$$x \cdot \frac{e_{2020}^{BAU} - e_{2020}^{target}}{100}.$$

Country-specific discount rates for offsets can also be specified.

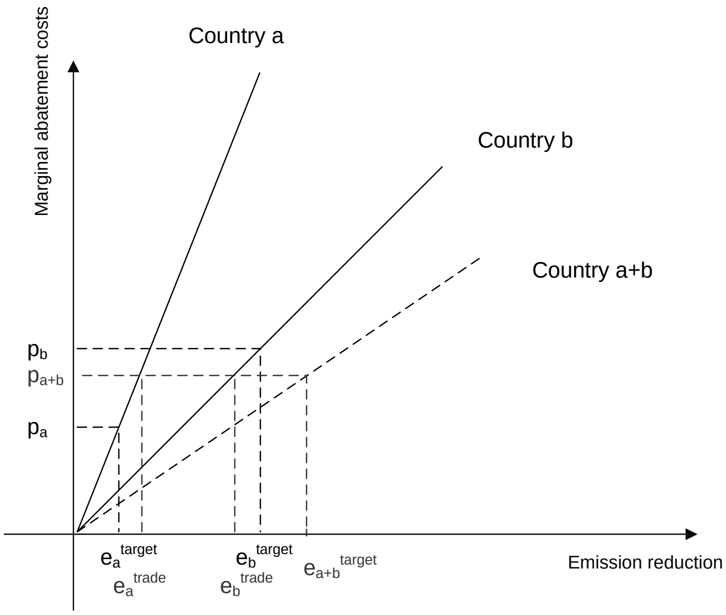
Standard algorithms and necessary data from the database are used to calculate the global emission reductions defined in the reduction scenarios. The results of the scenario calculations are shown in an Excel spreadsheet and contain the national per capita emissions, sector-specific emissions, Annex I, non-Annex I and worldwide emissions in 2020 among others. The use of Excel means there are multiple options for saving and further processing these results. For example, it allows the user to plot emission paths and thus provides good ways to compare different scenarios.

6.1.5 Trade Scenario Module

Additional assumptions about the carbon market have to be made for the economic analysis of a reduction scenario. The trade scenario module interface allows the user to define the carbon and the offsetting markets. For sensitivity analyses, different cost scenarios are provided for the calculations.

Cost calculations are based on marginal abatement cost curves for the year 2020. The underlying assumption for calculating the costs and allowances/credits traded is that within an efficient emissions market all the countries allowed to unrestrictedly trade certificates face the same marginal abatement costs. Figure 5 shows the assumed mode of operation in a two-country case. With the given targets e_a^{target} and e_b^{target} for countries a and b, respectively, and in the absence of offsetting, the equilibrium price for emission allowances can be calculated from the aggregated marginal abatement cost curve for countries a and b. In this case, the equilibrium price p_{a+b} is lower than the price for country b before emissions trading p_b, allowing country b to emit more than in the no-trading case and buy the missing emission allowances in the order of $e_b^{trade} - e_b^{target}$ from country a. Country a, on the other hand, faces a higher international allowance price under the emissions trading scenario. Therefore, emission reductions are higher and country a can sell its excess allowances in the order of $e_a^{target} - e_a^{trade} = e_b^{trade} - e_b^{target}$ to country b. In the multi-country case, the price and emission allowances and credits traded can be similarly calculated by aggregating the countries' cost curves.

Figure 5 Emissions trading in a two-country case with linear marginal abatement cost curves[12]



In addition to the international emissions trading market, a market for offsetting credits is modelled in ClimStrat. Within the offsetting market, the same assumptions apply as within the international emissions market, i.e. all countries within the offsetting market abate emissions up to the same marginal abatement costs.

The main difference between the offsetting market and the international emissions market is that not the entire emission reduction potential in a country can be used for offsetting purposes. The amount available for creating offsets is assumed to be limited to 20% of the total (economically and technically feasible) emission reduction potential at the prevailing price for CO_2 emissions in order to reflect the economic, institutional and methodological constraints for CDM/offsetting projects. To reflect this, the marginal abatement cost curve for countries within the offsetting market is adjusted by the factor 1/5.

It is assumed that countries within the offsetting market which have an emission reduction target must reach that target domestically before being able to generate credits for the offsetting market. The marginal abatement cost curve is set to zero for all prices up to the level needed to meet the reduction target domestically. In this case, the marginal

[12] Unlike this figure, the marginal abatement cost curves within ClimStrat are not linear. The best approximation is given by a polynomial of degree 3.

abatement cost curve is only adjusted after the national reduction target has been met domestically. An exception to this occurs if a country within the offsetting market faces a reduction target that results in higher marginal abatement costs than the equilibrium costs. In this case, the country is still assumed to meet its target domestically, but it cannot generate credits to sell on the market.

The interaction between the international emissions trading market and the market for offsetting credits is modelled in two ways. If the amount of offsetting credits is not limited at all, or if the limit is not exceeded, the international emissions market and the offsetting market are modelled as one market applying the same rules as previously described for the international emissions trading market. However, the emission reduction potential for countries in the offsetting market remains limited to 20%. The target for the aggregated market is given by:

$$\sum_{i \in IET} e_{i,2020}^{target} + \sum_{\substack{j \in offsetting\ market \\ j\ no\ target}} e_{j,2020}^{BAU} + \sum_{\substack{j \in offsetting\ market \\ j\ with\ target}} e_{j,2020}^{target}.$$

Modelling the two markets as one yields a common price for emission allowances and offsetting credits which is the same as the equilibrium marginal abatement costs for the joint market.

If the limit on offsetting credits is binding and would be exceeded if the two markets are modelled as one, then each market has to be modelled separately. The target for the offsetting market is then given by:

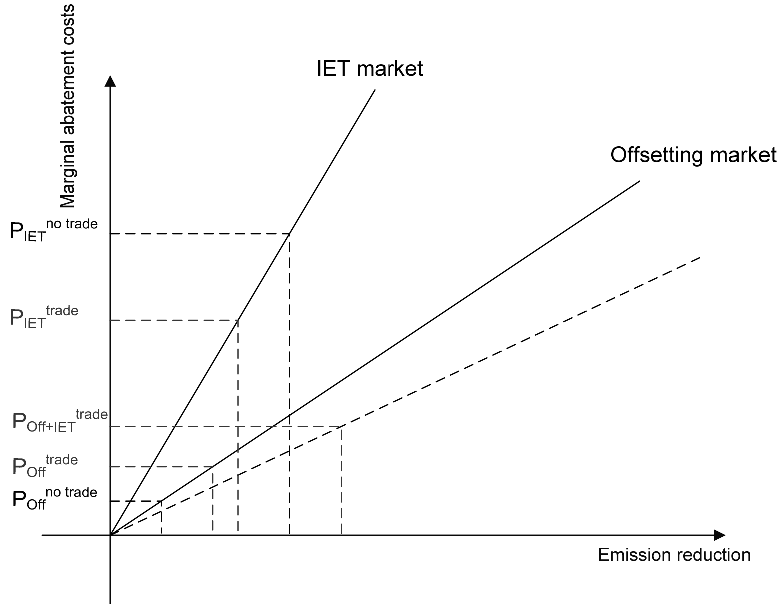
$$\sum_{i \in offsetting\ market} \left(e_{i,2020}^{BAU} - e_{i,2020}^{target}\right) - \sum_{j \in IET} e_{j,2020}^{offsets}.$$

The target for the international emissions trading market is given by:

$$\sum_{i \in IET} e_{i,2020}^{target} + \sum_{i \in IET} e_{i,2020}^{offsets}.$$

If the markets are modelled separately, different prices result on the international emissions trading market and the offsetting market. Due to the modelling logic, the price for offsets can never exceed the price for emission allowances on the international emissions trading market. Due to the limit on offsetting credits, the offsets can help to bring down the price for emission allowances in the international emissions market, but cannot bring them up to a similar price level in both markets (see Figure 6).

Figure 6 Interaction between the IET and the offsetting markets with limited use of offsetting credits



The results provided by the economic analysis performed with the settings from the reduction and the trade scenario modules include the marginal abatement costs with trade and under the assumption that the target has to be reached by domestic action. They also include the total compliance costs including abatement costs and costs/profits from buying/selling emission allowances and/or offsetting credits as a percentage of GDP. Not included in the calculations are transaction costs. All costs are given in 2005 € prices.

6.1.6 POLES scenarios

6 baseline scenarios are available for analyses in ClimStrat. They were provided by the energy system model POLES and adjusted using the most recent emissions data. They differ by assumptions about future economic growth and the diffusion of Carbon Capture and Storage (CCS) and renewable electricity technologies. The main specifications for the 6 scenarios are given below.

- **Poles-Scenario1_noCCS**: Baseline scenario with no CCS before the year 2021; data available up to the year 2020
- **Poles-Scenario2_earlyCCS**: Scenario with CCS starting in 2006 already; data available up to the year 2020
- **Poles-Scenario3_mediumCCS**: scenario with CCS starting in 2018; data available up to the year 2020

- **Poles-Scenario4_lowEconomicGrowth:** Scenario with a lower economic growth rate than in the baseline scenario Poles-Scenario1_noCCS; other assumptions are as in Poles-Scenario1_noCCS; data available up to the year 2030

- **Poles-Scenario5_highRenewables:** Scenario with a higher growth in renewable energy than in the baseline scenario; other assumptions are as in Poles-Scenario1_noCCS; data available up to the year 2030

- **Poles-Scenario6_highOilPrice:** Scenario with a higher oil (and gas) price than in the baseline scenario; other assumptions are as in Poles-Scenario1_noCCS; data available up to the year 2030

6.2 Appendix 2: The GHG Effort Sharing Tool

The function of the GHG Effort Sharing Tool is to allocate GHG reduction targets to Annex I Parties in accordance with their performance in a range of socio-economic indicators – relative to the indicator scores achieved by other Annex I Parties. The GHG Effort Sharing Tool has been designed in Microsoft Excel and consists of three main sheets (i.e. User Interface, Indicator and Data sheets).

6.2.1 Description of the GHG Effort Sharing Tool

The User Interface Sheet of the GHG Effort Sharing Tool enables the user to select several inputs in order to determine how the overall GHG reduction target for the Annex I Group should be distributed amongst the Annex I Parties. The User Interface Sheet consists of two main tables. Firstly, the Indicator Value Table (Figure 7) displays the set of indicators that can be used to determine a 'comparable level of effort' amongst the Annex I Parties. The screenshot provides an overview of each indicator value that has been attributed to each Annex I Party – and it should be referred to when deciding how to select, weight and scale the indicators to determine the distribution of GHG effort sharing.

Figure 7 Indicator Value Table

INDICATOR VALUES

	EU Commission Indicators				Cost Indicators		Additional Indicators		
Country	GDP/Cap (2005)	GHG/GDP (2005)	GHG Trend 1990-2005	Population Trend 1990-2005	Average Mitigation Cost in 2020	Total Mitigation Cost in 2020	GHG/Cap (2005)	GDP Trend 1990-2005	Energy Intensity
	[1000 US$]	[kg of CO2 per US$]	[%]	[%]	[US$ per tCO2e]	[% of GDP]	[Tonnes of CO2e]	[%]	[kJ per GDP US$]
Australia	28.3	0.92	27%	19%	8.32	0.17%	26.05	40%	8.98
Canada	29.7	0.77	24%	16%	7.65	0.12%	22.74	34%	11.79
Japan	27.8	0.38	7%	3%	16.54	0.08%	10.63	18%	6.50
New Zealand	22.2	0.85	25%	19%	8.32	0.18%	18.87	36%	9.05
Norway	36.8	0.32	8%	9%	18.09	0.08%	11.64	37%	6.95
Russian Federation	9.6	1.54	-36%	-3%	4.02	0.27%	14.84	-10%	34.53
Switzerland	31.7	0.23	2%	11%	18.09	0.06%	7.23	14%	5.00
Ukraine	6.1	1.48	-54%	-9%	3.89	0.51%	9.04	-59%	24.01
United States of America	37.3	0.64	16%	19%	9.02	0.08%	23.98	36%	9.59
EU27	23.6	0.45	-8%	4%	13.93	0.12%	10.52	26%	5.70

The Result Table (Figure 8) enables the user to select, weight and scale the set of available indicators. An indicator can be selected by assigning a weighting to the preferred criteria in the orange coloured cells. Ambitious and Less Ambitious GHG reduction targets can then be inputted into the yellow coloured cells for the selected indicators providing an upper and lower limit for GHG emission reduction. The country with the worst indicator score will be attributed the maximum GHG reduction target, whilst the country with the best value will be attributed the minimum GHG reduction target. The GHG reduction values for the remaining countries will subsequently be proportional to their indicator score within the range of GHG reductions that have been specified. In order to determine the total GHG reduction required by each Annex I Party – the weighting of each indicator is multiplied by the GHG reduction target calculated for each specific indicator selected. The GHG reduction values for each selected indicator are then added together to calculate the total GHG reduction commitment.

Figure 8 Result Table

RESULT	Scenario Setting		EU Commission Proposal_30%		Reference Year					2005
Country	GDP/Cap (2005)	GHG/GDP (2005)	GHG Trend 1990-2005	Population Trend 1990-2005	Reductions from 1990		Reductions from 2005		Reductions from 2020 BAU	
	[%]	[%]	[%]	[%]	[%]	[Mt	[%]	[Mt	[%]	[Mt
Weighting	1.00	1.00	1.00	1.00						
Less Ambitious Reduction [%]	5	4	5	-10						
Ambitious Reduction [%]	20	18	20	0						
Limit for RUS/UKR	--	20.00	-8.00	--						
Australia	16%	18%	20%	-10%	28%	118	44%	231	59%	422
Canada	16%	15%	19%	-9%	27%	158	41%	300	52%	462
Japan	15%	7%	11%	-4%	25%	313	29%	399	39%	613
New Zealand	13%	17%	19%	-10%	23%	14	38%	30	55%	58
Norway	20%	6%	12%	-6%	25%	13	31%	17	39%	24
Russian Federation	7%	20%	-8%	-2%	47%	1 557	17%	354	11%	215
Switzerland	17%	4%	9%	-7%	22%	12	23%	13	32%	20
Ukraine	5%	20%	-8%	0%	62%	569	17%	72	40%	231
United States of America	20%	12%	15%	-10%	28%	1 705	38%	2 677	38%	2 737
EU27	13%	8%	5%	-5%	28%	1 571	22%	1 153	29%	1 596
Total	14%	12%	9%	-5%	33%	6 047	30%	5 263	34%	6 396

All of the GHG reduction targets are then automatically illustrated in the form of a bar chart and there is the option to select a different reference year for the allocated GHG reductions for the Annex I Parties. The User Interface Sheet has been designed to be easy to use by policy makers and thus includes the option to select automated scenarios that represent different levels of Annex I ambition and use different combinations of indicators to distribute the overall Annex I target amongst the Annex I Parties. To further enhance the usability of the GHG Effort Sharing Tool, a macro function was included to automatically reset the spreadsheet to a default setting. The Indicator Sheet uses the data inputs from the User Interface, along with the raw data provided by the Data Sheet to calculate the GHG reduction targets for the Annex I Parties based upon their level of performance for a specific indicator. The following set of indicator values was calculated in the Indicator Sheet to reflect the varying capacity, responsibility, mitigation potential and national circumstances of the Annex I Parties.

- GDP per Capita (2005)
- GHG Intensity (2005)
- GHG Trend (1990-2005)
- Population Trend (1990-2005)
- Average Mitigation Cost (2020)
- Total Mitigation Cost (2020)
- GHG per Capita (2005)
- GDP Trend (2005)
- Total Primary Energy Supply (2002)

It is important to note that where possible historical data was preferred to calculate these indicator values (i.e. to reduce the level of uncertainty associated with the socio-economic projections in 2020). For certain indicators, the ambitious and less ambitious value for the GHG reduction threshold is reversed to inverse the GHG reduction commitments. For example, the Population Trend (1990-2005) and Average Mitigation Cost (2020) attribute the highest GHG reduction target to the Annex I Party with the lowest indicator score to acknowledge the varying national circumstances of the Annex I Group. All of the data necessary for the calculations performed in the GHG Effort Sharing Tool is derived from the information provided in the Data Sheet and the original source of this information is summarised in Table 13.

Table 13 Data Sources

	Data Categories				
	Population	**GDP**	**GHG Emissions (Excl. LULUCF)**	**Mitigation Costs**	**Total Primary Energy Supply**
Indicator 1990 -2005	World Development Indicators		Historic, UNFCCC Data	n/a	IEA Data
Indicator 2006-2020	Poles Scenario1_noCCS				n/a

6.2.2 Indicators in the GHG Effort Sharing Tool

The following table provides a description of each indicator used in the GHG Effort Sharing Tool and is accompanied by further information on how each indicator is calculated.

Table 14 Description of the GHG Effort Sharing Tool indicators

Indicator	Calculation
GDP per Capita: The ability of a country to pay for GHG reductions, whilst also considering the national circumstances of each country with regards to their population size.	GDP 2005 / Population 2005
GHG Intensity: The efficiency of each country's economy to produce low carbon goods and services. This indicator demonstrates the mitigation potential for GHG reductions amongst the Annex I Parties.	GHG 2005 / GDP 2005
GHG Trend: The responsibility of each country to anthropogenic climate change based upon their GHG trend between 1990-2005.	((GHG 2005/GHG 1990)*100)-100
Population Trend: The national circumstances of each country with regards to their population trend between 1990-2005.	((Population 2005/ Population 1990)*100)-100
Average Mitigation Cost: Average Abatement Cost of the Annex I Parties achieving the same level of GHG reduction in 2020 measured in $ per tCO2e.	Derived from Climstrat model
Total Mitigation Cost: The total cost of mitigation (measured as a % of GDP) of the Annex I Parties achieving the same level of GHG reduction in 2020.	Derived from Climstrat model
GHG per Capita: The GHG emissions emitted per person of an Annex Party.	GHG 2005 / Population 2005
GDP Trend: The GDP Trend of the Annex I Parties between 1990-2005.	((GDP 2005/GDP 1990)*100)-100
Total Primary Energy Supply: The total primary energy supply (as measured in 2002) for each of the Annex I Parties.	Total Primary Energy Supply 2002 / GDP PPP 2002

6.2.3 Scenario Analysis Results

The following tables show the results of the scenario analysis.

Table 15 Results of the 12 Scenarios for the 2005 base year

	GDP/Cap (2005)	GHG/GDP (2005)	GHG Trend (1990-2005)	Population Trend (1990-2005)	Average Mitigation Cost (2020)	Total Mitigation Cost (2020)	GHG Trend_Pop Trend	GDP/Cap_GHG Trend	GHG/GDP_Pop Trend	GHG/GDP_Total Mitigation	GHG Trend_Average Cost	Pop Trend_Total Mitigation
AUS	35%	44%	49%	17%	38%	25%	33%	42%	31%	35%	43%	21%
CAN	37%	36%	47%	20%	40%	29%	33%	42%	28%	33%	44%	24%
JAP	34%	18%	37%	33%	10%	32%	35%	35%	25%	25%	23%	32%
NZ	25%	40%	48%	17%	38%	24%	32%	36%	29%	32%	43%	21%
NOR	48%	14%	38%	27%	5%	31%	32%	43%	21%	23%	21%	29%
RUS	6%	45%	11%	40%	42%	18%	25%	8%	43%	32%	26%	29%
SW	40%	10%	34%	25%	5%	33%	29%	37%	18%	22%	19%	29%
UKR	0%	45%	0%	45%	42%	1%	23%	0%	45%	23%	21%	23%
USA	49%	30%	42%	17%	35%	32%	30%	46%	24%	31%	39%	24%
EU27	28%	21%	28%	32%	19%	29%	30%	28%	27%	25%	23%	31%

Note: The results of the twelve scenarios for the 2005 base year are shown for each Annex I Party in the table above. The GHG reduction targets for each scenario reflect the performances of the Annex I Parties in the scenario analysis. Depending upon the deviation of an Annex I Party's GHG reduction target from the Annex I Group 30% average, each Annex I Party is classified as having either a high, medium or low level of sensitivity for each of the twelve scenarios.

High	equal or >10 percentage points	(dark grey)
Medium	<5->10 percentage points	(light grey)
Low	equal or <5 percentage points	(white)

Table 16 Results of the 12 Scenarios for the 1990 base year

	GDP/Cap (2005)	GHG/GDP (2005)	GHG Trend (1990-2005)	Population Trend (1990-2005)	Average Mitigation Cost (2020)	Total Mitigation Cost (2020)	GHG Trend_Pop Trend	GDP/Cap_GHG Trend	GHG/GDP_Pop Trend	GHG/GDP_Total Mitigation	GHG Trend_Average Cost	Pop Trend_Total Mitigation
AUS	17%	29%	35%	-6%	21%	5%	15%	26%	12%	17%	28%	0%
CAN	22%	22%	34%	1%	26%	12%	18%	28%	11%	16%	30%	6%
JAP	30%	12%	32%	28%	4%	27%	30%	31%	20%	20%	18%	28%
NZ	7%	26%	35%	-3%	22%	5%	16%	21%	11%	16%	28%	1%
NOR	44%	8%	32%	21%	-3%	26%	27%	38%	14%	16%	15%	23%
RUS	40%	65%	43%	61%	63%	48%	52%	41%	63%	56%	53%	55%
SWI	39%	9%	32%	24%	3%	32%	28%	36%	16%	20%	18%	28%
UKR	54%	75%	54%	75%	73%	54%	64%	54%	75%	64%	64%	65%
USA	41%	20%	33%	4%	25%	21%	19%	37%	12%	20%	29%	13%
EU27	33%	27%	33%	37%	25%	34%	35%	33%	32%	30%	29%	36%

Note: The results of the twelve scenarios for the 1990 base year are shown for each Annex I Party in the table above. The GHG reduction targets for each scenario reflect the performances of the Annex I Parties in the scenario analysis. Depending upon the deviation of an Annex I Party's GHG reduction target from the Annex I Group 30% average, each Annex I Party is classified as having either a high, medium or low level of sensitivity for each of the twelve scenarios.

High	equal or >10 percentage points	(dark grey)
Medium	<5->10 percentage points	(light grey)
Low	equal or <5 percentage points	(white)