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Environmental and economic effects of the Copenhagen pledges and more ambitious emission reduction targets

Interim report

by

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Glossary

ACES	American Clean Energy and Security Act
ADC	Advanced Developing Countries
AI	Annex-I countries
APA	American Power Act
BAU	Business As Usual
CDM	Clean Development Mechanism
CO_2	Carbon dioxide
COP	Conference of Parties
EC	European Commission
EU	European Union
GDP	Gross Domestic Product
GHG	Greenhouse gases
IPCC	Intergovernmental Panel on Climate Change
LDC	Least Developed Countries
LULUCF	Land Use, Land Use Change and Forestry
NAMAs	Nationally appropriate mitigation measures
NAID	Non Annex I Developed Countries
ODC	Other Developing Countries
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

Dem vierten Sachstandsbericht des Weltklimarates (IPCC 2007) zufolge 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. Der Bericht des IPCC (2007) bekräftigt darüber hinaus als Zwischenziel für 2020, dass es dazu der Minderung von Treibhausgasemissionen in Industrieländern von 25 bis 45 Prozent gegenüber 1990, sowie deutlichen Minderungen gegenüber der Referenzentwicklung in einigen Entwicklungsländern bedarf. Den Elzen und Höhne (2008) geben die nötigen Minderungen in Entwicklungsländern mit 15 bis 30 Prozent gegenüber der Referenzentwicklung an. Obwohl auf der UN-Klimakonferenz in Kopenhagen kein internationales Abkommen mit verbindlichen Zielvorgaben beschlossen wurde, hat die Mehrheit der Annex-I-Staaten im Rahmen der Kopenhagen-Vereinbarung (UNFCCC 2009) quantifizierte Emissionsreduktionsziele zugesagt. Darüber hinaus haben einige Entwicklungsländer national angemessene Emissionsminderungsmaßnahmen (NAMAs) eingereicht.

Die vorliegende Studie analysiert die ökologischen und ökonomischen Wirkungen dieser Kopenhagen-Ziele. Dabei werden zum einen Politikszenarien betrachtet, die das untere („schwach“) und das obere („ambitioniert“) Ende der Bandbreite der Kopenhagen-Ziele abbilden. Die Minderungen in den Szenarien belaufen sich auf maximal 17 % unter das Niveau von 1990 für Annex I-Staaten und maximal 13 % unter das Referenzszenario für die großen Entwicklungsländer. Damit liegen in beiden Szenarien die Emissionen oberhalb des Emissionspfads, den der IPCC zu einer Begrenzung der Erderwärmung auf 2°C für nötig hält. Zum anderen werden ergänzend zu den Kopenhagen-Szenarien zwei weitere Szenarien analysiert, die laut IPCC zu einer Erreichung des 2°-Ziels führen könnten. Darin werden als Minderungsziele für Industrieländer einmal 30 Prozent und – im ambitioniertesten aller betrachteten Szenarien – 40 Prozent bis 2020 im Vergleich zu 1990 angenommen. Gleichzeitig bleiben die CO_2-Emissionen ausgewählter großer Entwicklungs- und Schwellenländer 15 Prozent unter der Referenzentwicklung in 2020. In allen vier Politikszenarien werden für 2030 auch die Auswirkungen von Emissionspfaden simuliert, die für 2050 eine Minderung der globalen Emissionen um 50 Prozent gegenüber 1990 zum Ziel haben. Dabei wird angenommen, dass mit Ausnahme der am geringsten entwickelten Ländern (LDC) die Emissionen aller Länder nach 2020 einer Begrenzung unterliegen. Die Reduktionsziele für die Industrieländer sind dabei annahmegemäß schärfer als für die weniger entwickelten Länder. Außerdem werden in einem separaten Szenario die ökonomischen Auswirkungen eines Szenarios betrachtet, in dem die EU eine Reduktion ihrer Emissionen bis 2020 um 30 Prozent (statt 20 Prozent) gegenüber 1990 anstrebt, während die anderen Länder am unteren Ende ihrer “Kopenhagen-Ziele“ festhalten. Keine Berücksichtigung in den Berechnungen finden mögliche Finanzhilfen von Industriestaaten an Entwicklungsländer wie sie in den internationalen Klimaverhandlungen diskutiert werden und in der Kopenhagen-Vereinbarung zugesagt sind.

Die Berechnungen werden mit dem dynamischen allgemeinen Gleichgewichtsmodell DYE-CLIP durchgeführt, das die ökologischen und ökonomischen Wirkungen von Klimapolitik auf gesamtwirtschaftliche Größen wie Einkommen, Preise, Ex- und Importe, sowie auf Produktionsverlagerungen in Länder, die keinen oder nur geringen Klimaschutzauflagen unterliegen („carbon leakage"), berücksichtigt.[1]

Die wichtigsten Ergebnisse der Studie lassen sich wie folgt zusammenfassen:

- Die Einbußen im Wachstum des Bruttoinlandsprodukts (BIP) für Industrie- und Entwicklungsländer mit Kopenhagen-Zielen beträgt unter der Annahme, dass Emissionsrechte international unbegrenzt gehandelt werden können, höchstens 0,25 Prozent im Vergleich zum Niveau in der Referenzentwicklung in 2020. Für Industrieländer bleibt das Wachstum des realen BIP zwischen 2004 und 2020 im Durchschnitt bei 27 %, während es für Entwicklungsländer von einem Anstieg von 102 % minimal auf einen Anstieg von 100 % sinkt. Auch die ökonomischen Auswirkungen des ambitioniertesten betrachteten Szenarios haben nur minimale Auswirkungen auf das BIP-Wachstum (27 % Wachstum für Industrieländer und 98 % Wachstum für die großen Entwicklungsländer).
- Reduziert die EU ihre Emissionen bis 2020 gegenüber 1990 um 30 Prozent (statt um 20 Prozent), während die anderen Länder am unteren Ende ihrer "Kopenhagen-Ziele" festhalten, führt dies nur zu einer marginalen Abschwächung des BIP-Wachstums von unter 0,005 Prozent (gegenüber dem schwachen Kopenhagen-Szenario).
- In sämtlichen Politikszenarien ist die durchschnittliche prozentuale Abschwächung des BIP-Wachstums in Industrieländern mit Kopenhagen-Zielen geringer als in Entwicklungsländern. Insgesamt liegen die jährlichen BIP-Wachstumsraten in Entwicklungsländern jedoch weiterhin deutlich über denen in Annex I-Staaten.
- Der Einfluss auf das BIP ist in den Ländern besonders hoch, die stark von ihren fossilen Ressourcen abhängen. Da die Umsetzung der klimapolitischen Ziele die Nachfrage nach diesen fossilen Brennstoffen drosselt, steigen die Weltmarktpreise im Vergleich zur Referenzentwicklung weniger stark an. Daher verzeichnet z. B. Russland Einkommensverluste gegenüber dem Referenzszenario, die sich auch nicht durch Einnahmen aus dem Verkauf überschüssiger Emissionsrechte, die durch neue "heiße Luft" entstehen, kompensieren lassen.
- In einigen großen Entwicklungsländern wie China oder Indien führen strengere globale Emissionsziele zu einer größeren Abschwächung des BIP-Wachstums (im Vergleich zur Referenzentwicklung), da ihre Industrien im weltweiten Vergleich energie- und CO_2-intensiv produzieren. Ein Anstieg der CO_2-Kosten führt daher zu einem relativ hohen

1 Da DYE-CLIP nur CO_2-Emissionen beinhaltet, finden die Kopenhagen-Ziele nur auf CO_2-Emissionen Anwendung. Auch Treibhausgas-Emissionen, die sich aus Änderungen in der Land- und Waldnutzung ergeben, bleiben unberücksichtigt.

Rückgang der Produktion in diesen Sektoren. Regionen wie Japan oder die EU, deren Industrien im weltweiten Vergleich wenig energie- und CO_2-intensiv produzieren, verzeichnen hingegen bei ambitionierteren globalen Klimazielen ein etwas höheres BIP (verglichen mit dem BIP in der Referenzentwicklung). Die Ergebnisse zeigen, dass Volkswirtschaften, die frühzeitig ihre CO_2-Intensität verringern, langfristig weniger verwundbar gegenüber stringenten zukünftigen Klimazielen sind. Insbesondere energie- und außenhandelsintensive Wirtschaftszweige in Industrie- und Entwicklungsländern können von Investitionen in energie- und CO_2-arme Produktionsverfahren profitieren.

- Der durchschnittliche Rückgang des BIP-Wachstums in den Szenariorechnungen für 2030, denen wesentlich ambitioniertere Emissionsziele als im Zeitraum bis 2020 zugrunde liegen, beträgt zwischen 2 und 3 Prozent (gegenüber dem Niveau in der Referenzentwicklung). Die Wachstumseinbußen entsprechen global gesehen also in etwa dem Zuwachs des BIP von einem Jahr.
- Die Kopenhagen-Ziele führen in einigen großen Entwicklungsländern zwar zu einem geringeren BIP-Wachstum (gegenüber der Referenzentwicklung), trotzdem führen die untersuchten Politikszenarien in diesen Ländern zu Wohlfahrtsgewinnen (gemessen als Veränderung der Äquivalenten Variation). Die Wohlfahrtsgewinne in China und Indien sind insbesondere die Folge von verbesserten realen Austauschverhältnissen zwischen den exportierten und den importierten Gütern infolge des geringeren Anstieges der Öl- und Gaspreise, von Einnahmen aus dem Verkauf von Emissionsrechten sowie von ökonomischen Effizienzgewinnen, die auf die zu energieintensive Produktionsweise in diesen Ländern zurückzuführen sind. Zukünftige Regelungen zur Aufteilung von Treibhausgasemissionszielen und möglichen Kompensationszahlungen sollten diejenigen Entwicklungsländer verstärkt berücksichtigen, für die Klimapolitik mit besonders hohen Wohlfahrtsverlusten einhergeht.

Summary

Global carbon dioxide emissions need to be reduced by at least 50 to 85 % in 2050 compared to 2000 levels to limit global surface temperature increase to 2°C compared to pre-industrial levels (IPCC 2007). As an intermediate greenhouse gas emission reduction target for industrialized countries in 2020 the IPCC (2007) confirmed a range of 25 % to 40 % compared to 1990, together with a substantial deviation from baseline in some developing regions, which was quantified as reductions in the range of 15 % to 30 % below baseline (den Elzen and Höhne 2008). While the climate summit in Copenhagen (COP 15) failed to come up with an international agreement involving binding greenhouse gas emissions reduction targets, under the Copenhagen Accord (UNFCCC 2009) most Annex I countries pledged quantifiable emission reductions. Similarly, several developing countries submitted nationally appropriate mitigation actions (NAMAs).

This report explores the environmental and economic effects of the pledges submitted by industrialized and major developing countries for 2020 under the Copenhagen Accord as quantifiable emission reductions or as NAMAs. Two scenarios reflect the lower (“weak”) and upper (“ambitious”) bounds of the Copenhagen pledges leading to emission reductions of 17 % below 1990 levels for Annex I countries and 13 % below reference levels for Non-Annex I countries. Both scenarios do not reach the level of ambition indicated as necessary by science to keep temperature increase below 2°C. In addition, two scenarios in accordance with the IPCC range for reaching a 2°C target are analyzed with industrialized countries in aggregate reducing their CO_2-emissions by 30 % and – for the most ambitious policy scenario – by 40 % in 2020 compared to 1990 levels, respectively. In addition, CO_2-emissions of major developing countries remain 15 % below the expected emission levels in 2020. For all four policy scenarios the effects of emission paths leading to a global reduction target of 50 % below 1990 levels in 2050 are also simulated for 2030. In the scenarios for 2030 all but the least developed countries are assumed to take on emission targets, but emission caps are considerably less stringent for developing countries than for developed countries. In addition, a separate scenario is carried out which estimates the costs of an unconditioned EU 30 % emission reduction target, i.e. where the EU adopts a 30 % emission reduction target in 2020 (rather than a 20 % reduction target), while all other countries stick with their “weak” pledges. Not included in the calculations is possible financial support for developing countries from industrialized countries as currently discussed in the climate change negotiations and laid out in the Copenhagen Accord.

The analyses are carried out with the dynamic Computable General Equilibrium Model DYE-CLIP, which accounts for economic and environmental effects resulting from changes in in-

come, prices, exports and imports, or from carbon leakage in response to climate policy.[2] The main findings are:

- Economic costs (in terms of reduced GDP compared to baseline GDP) in 2020 for industrialized and developing countries with “pledges“ are - on average - no higher than 0.25 %, assuming that these countries are allowed to trade emission certificates unrestrictedly. The average GDP growth for industrialized countries with “pledges“ remains at 27 %, while for developing countries with “pledges“ it decreases slightly from 102 % to 100 % between 2004 and 2020. Economic effects for the most ambitious scenario are also rather low: the average GDP growth remains unchanged for industrialized countries (27 % between 2004 and 2020) and decreases to 98 % growth for large developing countries.
- If the EU adopts an unconditioned 30 % emission reduction target in 2020, while all other countries stick with their “weak” pledges, the reduction in GDP growth in the EU will be rather small (less than 0.005 percentage points).
- All policy scenarios lead to relatively larger reductions in GDP growth for developing countries than for industrialized countries. In general, annual GDP growth rates in developing countries remain significantly above those for industrialized countries.
- Losses in economic growth tend to be above average in regions which depend highly on their reserves of fossil fuels, like Russia. Because climate policies result in lower global demand for these resources, their world prices fall (compared to the baseline) translating into lower incomes for the respective countries. Revenues from selling excess certificates (stemming from “new hot air“ implied by the Russian pledge) are not sufficient to compensate for these losses in economic growth.
- Some large developing countries like China and India experience larger losses in GDP growth for tighter global emission targets because their industrial sectors are more energy- and CO_2-intensive than in most other regions. Hence, increases in the cost of CO_2 emissions lead to larger reductions in the output of their energy-intensive sectors. In contrast, because these same sectors in the EU and Japan are relatively less energy- and CO_2-intensive, the EU and Japan experience slightly higher GDP. Hence, economies which reduce their CO_2-intensities earlier are less vulnerable to tight emission targets in later periods. Similarly, energy-intensive, trade-intensive industries in developed and developing countries alike may particularly benefit from investments, which reduce energy intensity and CO_2-emissions of their processes.
- Simulations for the 2030 emission targets imply a reduction in global GDP growth between 2 and 3 percentage points compared to baseline. This change corresponds roughly to the growth in global GDP for one year.

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2 Since DYE-CLIP includes CO_2-emissions only, all targets submitted under the Copenhagen Accord are applied to CO_2-emissions only. Also, the analyses abstract from LULUCF.

- While developing countries experience larger reductions in GDP growth, this does not necessarily translate into larger declines in net welfare as measured by the equivalent variation. For example, both China and India experience a gain in welfare in 2020 which is due to strong terms-of-trade improvements, revenues from selling CO_2 certificates, and gains in allocative efficiency for energy commodities due to their relatively high initial energy-intensity. Hence, changes in the burden-sharing criteria or monetary compensation should be targeted towards the developing countries with welfare losses.

1 Introduction

To address climate change, industrialized countries and economies in transition (Annex-I countries) originally committed in 1997 to reduce their aggregate greenhouse gas emissions by about 5.2 % during the period 2008-12 compared to 1990 emission levels in the Kyoto Protocol to the United Nations Framework Convention (UNFCCC). A major objective of the most recent UNFCCC climate summit in Copenhagen in December 2009 (Conference of the Parties COP 15) was to come up with a Post 2012 climate regime, determining long-term greenhouse gas emission targets and the future contributions of industrialized and developing countries. According to the IPCC fourth assessment report (2007) carbon dioxide emissions need to be reduced by 50-85 % in 2050 compared to 2000 levels and global emissions need to peak prior to 2020 if the increase in global surface temperature is to be limited to 2°C compared to pre-industrial levels ("2°C target"). In 2009, the G8 Summit recognized the "2°C target" and the necessity to reduce global greenhouse gas emissions by at least 50 % by 2050". The IPCC (2007) also suggested intermediate targets for 2020, including an indicative range of 25 % to 40 % emission reductions compared to 1990 for 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 reductions of 15-30 % below baseline have been suggested (den Elzen and Höhne 2008). The European Commission (2009a) has also published proposals where developed countries collectively reduce emissions by 30 % in 2020 compared to 1990 and economically more advanced developing countries decrease emissions by 15-30 % below business as usual.

In the wake of COP 15 most Annex I countries have pledged voluntary emission targets for 2020. In the EU climate and energy package adopted in December 2008 the 27 EU member states promised a unilateral reduction of greenhouse gas emissions by 20 % below 1990 levels by 2020 (European Commission 2009a). In case an ambitious international climate agreement is reached, the EU will meet a more ambitious reduction target of 30 %.[3] Other countries like Australia followed the EU's lead and have also pledged to reduce emissions, with tighter targets in case an international agreement will be reached. In the US, the 'American Clean Energy and Security Act (ACES) of 2009' ("Waxman-Markey") has passed the House of Representatives in June of 2009, and the Senate has yet to decide when to vote on the "American Power Act" (APA) ("Kerry-Lieberman"). Both bills set reduction targets for the covered sources for the year 2020 at 17 % below 2005 levels and envisage greenhouse gas emission reductions in 2050 of 83 % below 2005 levels.[4] In addition, prior to the Copenha-

3 Originally, the more ambitious, conditional reduction target of 30 % for the EU was adopted by the March 2007 European Council Meeting under the German EU presidency (Council of the European Union 2007).

4 However, the scope and the time path for the capped emissions differ between ACES and APA. See http://energycommerce.house.gov/Press_111/20090515/hr2454.pdf for ACES and http://kerry.senate.gov/americanpoweract/pdf/APAbill.pdffor.

gen climate summit a number of developing countries including China and India also pledged emission reduction targets for 2020.

While COP 15 failed to produce an international agreement involving binding greenhouse gas emissions reduction targets, most Annex I countries pledged quantifiable emission reductions under the Copenhagen Accord (UNFCCC 2009). In addition, several developing countries submitted nationally appropriate mitigation actions (NAMAs) listed in Appendix II of the Accord. In total, countries which submitted pledges under the Copenhagen Accord account for about 80 % of global greenhouse gas emissions. For most countries, pledges under the Copenhagen Accord are quite similar to those made prior to COP 15.[5] The EU for example, pledged to reduce greenhouse gas emissions by 20 % compared to 1990 levels. On condition that other major emitting developed and developing countries commit to do their fair share under a global climate agreement, the EU offered a more ambitious reduction target of 30 %. In the meanwhile the European Commission (2010) has analyzed the effects of moving unilaterally to an unconditioned 30 % reduction target but maintains that the conditions to do so are not met yet.

There are several studies, including den Elzen et al. (2009a,b), den Elzen et al. (2008), Rogelj et al. (2009), Ward and Grubb (2009) and Levin and Bradley (2009), analyzing the effects of the pledges announced prior to the Copenhagen summit on greenhouse gas emissions and their likely contribution towards meeting global climate targets. They all conclude that the announced pledges are not very ambitious and would involve more severe emission reductions later on if the "2°C target" is to be met with 50 % probability. For the emission targets submitted under the Copenhagen Accord Rogelj et al. (2010) calculate a 50 % chance that the increase in temperatures will exceed three degrees Celsius by 2100. Den Elzen et al. (2009b) point out that the pledge made by Russia is likely to involve "new hot air, that is, emission targets are expected to be higher than expected emissions to date.

Previous studies analyzing the economic impacts of the "pre-Copenhagen" pledges include Amann et al. (2009), Wagner and Amann (2009) and den Elzen et al. (2009a). Based on marginal abatement cost curves to calculate mitigation costs they find that overall costs in Annex I countries are below 0.04 % of GDP in 2020 (den Elzen et al. 2009a). Wagner and Amann (2009) analyze the impact of the economic crisis which started in the fall of 2008. According to their calculations, the crisis will result in 7 % lower GDP levels and 8 % lower emission levels in 2020 than calculated prior to the crisis. Hence, costs to meet the intended emission reduction targets are lower than assumed at the time when they were announced. De Bruyn et al. (2010) arrive at a similar conclusion.

So far, only Duscha et al. (2010), den Elzen et al. (2010a) and OECD (2010) have analyzed the economic effects of the pledges announced in the Copenhagen Accord. Allowing for in-

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5 Canada altered its pre-Copenhagen pledge of "20% reduction below 2006 levels" to "17% below 2005 levels" in January 2010. The new target now matches the US target.

ternational emissions trading, compliance costs for the ambitious end of the pledges in 2020 for Annex I countries are estimated to be less than 0.5% of baseline GDP in UBA (2020) and 0.2 % in den Elzen et al. (2010a). For non Annex-I countries estimated costs are around 1 % of GDP in Duscha et al. (2010) and 0.17 % of GDP in den Elzen et al. (2010a). Countries with “hot air” or low marginal abatement costs benefit from selling certificates. In particular, the GDP of Russia is estimated to increase by up to 1.7 % in Duscha et al. (2010) and 0.3 % in den Elzen et al. (2010a).

Existing estimates for the costs of the “pre Copenhagen” pledges as well as Duscha et al. (2010) and den Elzen et al. (2010a) are based on partial equilibrium models. Thus, they do not capture economic and environmental effects resulting from changes in income, prices, exports and imports, or from “carbon leakage”. Carbon leakage, i.e. an increase in emissions in regions without mitigation targets, may result from two channels (e.g. Paltsev 2001, Burnieaux and Martins 2000). First, because climate policy raises production costs in regions with climate targets, production may shift to regions without such targets and increase emissions globally (competitiveness effect).[6] Second, to the extent that climate policy translates into higher prices for fuels in countries with climate targets, demand for fuels declines and the world fuel prices fall.[7] In turn lower fuel prices lead to higher demand and higher emissions (world price effect).

To analyze economic effects of unilateral and multilateral emission reduction policies computable general equilibrium (CGE) models have recently been applied. Studies on unilateral climate policies include Böhringer et al. (2009) for the EU, Böhringer and Rutherford (2010) for Canada, and US EPA (2009) for the US. Studies on multilateral climate policies include Kemfert and Truong (2007), Kemfert and Schumacher (2005), Gurney et al. (2009) and Peterson and Klepper (2007). These studies on (hypothetical) multilateral long term targets are based on dynamic CGE models and find that global targets consistent with the “2°C target” result in GDP losses compared to the baseline of around 5 % or less in 2050. In Kemfert and Truong (2007) these losses reach 7-8 %. Peterson and Klepper (2007) find that path towards reaching a 40 % reduction of global CO_2 emissions relative to 1990 by 2050 lowers global welfare - measured in terms of equivalent variation - by 2-4 % in 2030 relative to the baseline. Böhringer and Löschel (2003) consider hypothetical multilateral intermediate targets for 2020 based on expert judgments. Those targets, however, do not match a 2°C target path but result in even lower emission reductions (10 %) than the pledges under the Copenhagen Accord and costs in terms of consumption losses are almost negligible.

In this report we apply a dynamic CGE model to explore and compare the environmental and economic effects of four multilateral emission reduction policy scenarios:

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6 See Reinaud (2008) for a recent survey of the literature on carbon leakage.

7 The decline in world prices may be dampened however, if resource owners reacted by reducing supply in order to maintain a high price for fossil fuels.

i) *"Weak Pledges"* scenario that incorporates the lower bound of the pledges as submitted by countries for 2020 under the Copenhagen Accord;
ii) *"Ambitious Pledges"* scenario that incorporates the upper bound of those pledges;[8]
iii) *"30 %-Annex-I"* scenario that assumes a 30 % emission reduction target for Annex I countries in 2020 and that advanced developing countries reduce emissions by 15 % below their baseline emissions in 2020; and
iv) *"40 %-Annex-I"* scenario that assumes a 40 % emission reduction target for Annex I countries in 2020 and that advanced developing countries reduce emissions by 15 % below their baseline emissions in 2020.

Hence, in the "30 %-Annex-I" and the "40 %-Annex-I" scenarios the contribution of the Non-Annex I countries (compared to baseline) is identical. Also, in these scenarios the burden of reducing emissions is split among Annex I countries, along the lines of the European Commission proposal (2009a). In addition, for all four policy scenarios we analyze the environmental and economic effects of emission reduction paths in 2030 that would lead to a global emission reduction target of 50 % below 1990 levels in 2050.

In addition, a separate scenario ("EU-30%") is carried out which estimates the costs of unconditioned EU 30 % emission reduction target, i.e. where the EU adopts a 30 % emission reduction target in 2020, while all other countries stick with their "weak" pledges.

In terms of environmental effects, the impact of the four policy scenarios on global CO_2 emissions is explored. Further, we calculate the effects of "new hot air" from Russia as well as carbon leakage[9]. To capture economic effects, the implications of the alternative policies on gross domestic product (GDP) and on welfare (measured via changes in the equivalent variation) are explored relative to the baseline GDP.

Similar work, but focused on the Copenhagen Accord pledges for the year 2020, has been done by the OECD (2010). Their effects on world GDP are comparable to what is found in this study. More detailed insights apart from GDP effects, however, are not provided.

The remainder of the report is organized as follows. Section 2 describes the methodology, including a description of how the targets for 2020 and 2030 are derived. In section 3 we focus on the environmental effects of the four policy scenarios, including an analysis of the effects of "new hot air" and carbon leakage. The economic effects of climate policy for the four scenarios are presented and discussed in section 4. A separate "box" presents the main findings for "EU-30 %. The concluding section 5 focuses on policy implications.

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8 Where necessary the pledges were translated into reductions below baseline in 2020.

9 Since the focus of the report is on the overall contribution of leakage rather than on the various sources for leakage we do not distinguish between "competitiveness effects" and "world price" effects.

2 Methodology

2.1 Computable General Equilibrium Model DYE-CLIP

The analyses are conducted employing a multi-country, multi-sector dynamic computable general equilibrium (CGE) model, DYE-CLIP[10,11], for 2004 to 2030. Between 2010 and 2030, the model is solved in steps of five-year periods. Rather than assuming perfect foresight over the entire horizon, the model is myopic in the sense that only information available in a particular five-year period will be used for the optimization. Households and firms are assumed to act perfectly rational, maximizing utility and profits, respectively.[12] Relative factor prices drive companies' input portfolio and output prices drive demand and supply. Prices adjust instantaneously so that all markets clear at all times. Since the model includes CO_2-emissions only, the political reduction targets specified for all greenhouse gases are applied proportionally to CO_2-emissions. Climate policies are implemented via emission quotas per region. Countries levy national CO_2-taxes on direct CO_2-emissions. Hence, a single climate policy, i.e. a CO_2-tax, is applied across all sources in a country or region. Further, the model includes transport margins as in Peterson and Lee (2008). The model has been calibrated to match the baselines taken from the EU ADAM-Project (PIK et al. 2008, Edenhofer et al. 2010, Hulme and Neufeldt 2010) using the projections for GDP growth, population/labor growth and emission growth by the POLES model (Criqui 2001, Kitous et al. 2010) on a country level, but adjusted for the current economic crisis. Technological change is autonomous, hence the model does not allow for price- or policy-induced changes in the production function. Results for all four policy scenarios in terms of environmental and economic effects are compared to the outcomes under the baseline. Hence, the baseline is identical for all policy scenarios. Table A 1 in the Annex provides specific information on the regions included in the analyses together with the region-specific baseline level of emissions and GDP, and historic emissions.

2.2 Targets and trading rules

The four policy scenarios differ by the stringency of climate policy and by the type of burden sharing across and within different country groups. In all policy scenarios, political targets are set for 2010, 2020 and 2030 with intermediate targets for 2015 and 2025 being linearly interpolated. For all periods, trading of emission permits is allowed among all countries and re-

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10 DYE-CLIP (DYnamic Equilibrium Model for CLImate Policy Analysis) is based on GTAP-E. The current version relies on the GTAP 7 database (2004 base year).

11 The sectors specifically modeled are electricity (ely), refined petroleum (p_c), chemicals, rubber and plastics products (crp), other mineral products (nmm), ferrous metals (is), paper products (ppp), other metal products (nfm), other manufacturing (oman), coal, oil, gas, transport (trans), agriculture (agr), other natural resources (onres), food, trade (trd) and services (serv).

12 Thus, the model maximizes welfare ("utility") rather than GDP.

gions with emission targets. Offsets such as credits from CDM-type projects are not modeled.[13] Also, financial support for developing countries to reach their reduction targets is not included in the analysis. Prices for CO_2-certificates (i.e. the CO_2-tax) will be equalized across countries where trading of certificates is viable. For all policy scenarios, the Kyoto-targets are implemented for 2010 for all Annex-I countries except the US. Hence, the year 2010 serves as a common starting point and differences between policy scenarios may only evolve after 2010. Rather than allowing for “hot air” in the Kyoto-Period, no emission targets are imposed on Russia and the Ukraine for 2010.[14] As a consequence, the CO_2-tax for 2010 reflects the marginal costs of achieving the Kyoto-targets for all Annex-I countries but Russia, the Ukraine, and the US. The model (implicitly) permits unlimited banking within the five-year periods, but no banking or borrowing is feasible across the five-year periods. Even though the policy scenarios considered may lead to carbon leakage and cause undesired competitiveness effects, the subsequent analyses do not include border tax adjustments or other trade measures.[15]

2.2.1 Targets for 2020

In the “Weak Pledges” and “Ambitious Pledges” scenarios, Annex-I as well as major developing countries’ targets are implemented according to their reduction targets submitted under the Copenhagen Accord[16] as of 11 March 2010[17]. For 2020, emission reduction targets are implemented for six major developing countries: Brazil, China, India, South Korea, Mexico and South Africa[18]. Where a reduction range was given, the lower (more lenient) target was associated with the “Weak pledges” scenario while the higher (more stringent) target was associated with the “Ambitious Pledges” scenario. All targets from developing countries, including the emission intensity targets submitted by China and India, have been translated into emission reductions below baseline in 2020. All reductions are assumed to exclude

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13 Given that in our analyses all regions, which currently host about 85 % of registered CDM projects (http://cdm.unfccc.int/index.html/), may engage in emissions trading from 2010 on, this assumption is unlikely to be very restrictive.

14 This assumption may be rationalized by den Elzen et al. (2009b). They argue that it may be in Russia’s best interest to refrain from banking “hot air” from the Kyoto-period into the next commitment period because revenues from selling certificates would be higher. In that sense, a weak pledge by Russia could be interpreted as compensation for renouncing banking hot air from the Kyoto-period.

15 Such measures are foreseen, for example, in the EU ETS and in the proposals for future national greenhouse gas trading systems in the US.

16 http://unfccc.int/home/items/5264.php and http://unfccc.int/home/items/5265.php See also Stern and Taylor (2010).

17 At that time, targets from Switzerland (20-30% below 1990 levels) and Belarus (5-10% below 1990 levels) were not yet announced at the UNFCCC homepage.

18 Data did not allow treating the Republic of South Africa separately. In CGE simulations, the Republic of South Africa is included in the ODC country group (pledges target is applied to RSA only, not to other ODC).

emissions from land use, land-use change and forestry (LULUCF) and reducing emissions from deforestation and degradation (REDD) or from deforestation and degradation, conservation of existing carbon stocks and enhancement of carbon stocks (REDD-Plus). For 2020, no emission targets exist for Other Developing Countries (ODCs) and for Least Developed Countries (LDCs) in the two pledges scenarios. For comparison, Table A 2 provides an overview of the Copenhagen Accord and the policy scenarios implemented in this report.[19]

For the “30 %-Annex-I” and the “40 %-Annex-I” scenarios, Annex-I countries as a group reduce emissions by either 30 % or 40 % below 1990 levels. A burden-sharing rule was specified which divided the reduction target among Annex-I countries according to a multi-criteria approach. Following the EC (2009b), equal weights were applied to the following four indicators: GDP per capita (in 2005) reflecting a country’s ability to pay, GHG per GDP (in 2005) reflecting domestic emission reduction potential, population trend (1990 to 2005) recognizing “needs” and GDP trend (1990 to 2005) recognizing domestic “early action”.[20]

For the “30 %-Annex-I” and the “40 %-Annex-I” scenarios emission reduction targets of 15 % below baseline in 2020 are implemented for the same set of major developing countries which also submitted pledges under the Copenhagen Accord. The targets for these countries correspond to the lower end of the range suggested by den Elzen and Höhne (2008) or by the European Commission (2009a). Again no emission targets are implemented for ODCs and LDCs in the two scenarios Table 1 shows the average annual growth rate of emissions as implied by the policy targets, i.e. for those countries where emissions are capped. The rates are calculated for the combined emission targets of countries with targets.[21]

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19 The targets for the major developing countries implemented in this study are very similar to those calculated in Stern and Taylor (2010), In particular the carbon intensity targets by China and India are calculated based on real GDP (base is 2004, using market exchange rate). Required reductions of CO_2emissions in “Ambitious Pledges“ scenario compared to baseline emissions in 2020 are (figures for Stern and Taylor in parentheses) are then for China 9.4 % (9 %), India 10.4 % (at least 7 %). Of course, the outcomes would be different, if the pledges for India and China were interpreted in terms of nominal rather than real GDP. In this case, the emission targets would be less stringent. In contrast, if GDP was measured in purchasing power parity rather than market exchange rates, reduction targets for India and China would likely be tighter (see den Elzen et a. 2010). Den Elzen et al. (2010) further argue that the pledges by China appear less ambitious than measures currently implemented or planned in these countries.

20 See for example, Grubb and Ward (2009) and Duscha et al. (2010) for a more detailed discussion and scenario analyses of alternative burden-sharing indicators.

21 Not the set of countries subject to emission targets differs between the two periods. To calculate the figures for emissions in 2010 in Table 1 we use the Kyoto-targets for countries which ratified the Kyoto Protocol (except for Russia and Ukraine). For all other countries (including the US, Russia and the Ukraine) we use the baseline emissions in 2010.

Table 1: Annual average growth rates of capped emissions

	Weak Pledges	Ambitious Pledges	30%-Annex I	40%-Annex-I
2010 - 2020	1.05%	0.39%	-0.29%	-0.85%
2020 - 2030	-2.69%	-2.63%	-2.56%	-2.11%

Table 1 further implies that overall emissions in 2020 are highest in the “Weak Pledges” scenario and lowest in the “40 %-Annex-I”. Tighter targets after 2020 translate into more ambitious emission reduction rates for all policy scenarios (see Table 1). Even though emission reduction rates after 2020 are highest for the “Weak Pledges” scenario, the “base effect” associated with the high emission levels in 2020 implies that target emissions are also highest in the “Weak Pledges” scenario in 2030. As in 2020 the policy scenario with the lowest emissions is the “40 %-Annex-I” scenario. By construction, the scenarios do not reflect a common probability for reaching the “2°C target“ as overall emissions differ. The probability to reach the “2°C target“ is highest in the “40 %-Annex-I” scenario as aggregate emissions are lowest.

Figure 1 shows the growth in emissions by countries/regions in the baseline and the targets in the four policy scenarios for 2020 compared to 2005 emission levels.'[22] Arguably, the most striking difference in targets across the policy scenarios refers to the targets for Russia. Similar to the 1st commitment period under the Kyoto Protocol (Kyoto-period) (but not modeled in our policy scenarios for 2010), the targets pledged by Russia for 2020 involve substantial quantities of “hot air”. The amount of hot air is reflected by the positive difference between the baseline emissions and the target emissions, corresponding to about 350 million tonnes of CO_2 in 2020 in the “Weak Pledges” scenario and to about 150 million tonnes of CO_2 in the “Ambitious Pledges” scenario. For Australia, Canada and the US the targets in the “30 %-Annex-I” scenario are also significantly more ambitious than in both “Pledges” scenarios. In contrast, for a few countries/regions, namely for the EU27 and Norway, reduction targets in the “Ambitious Pledges” scenarios are more ambitious than in the “30 %-Annex-I” scenario. Interestingly, the pledges by Korea, Mexico, Brazil, and South Africa are more ambitious than the target under the “30 %-Annex-I” and “40 %-Annex-I” scenarios, i.e. the 15 % reduction compared to baseline emissions in 2020 and hence the lower end of the range suggested by EU (2009a) and den Elzen and Höhne (2008). Table 2 summarizes the emission targets by Annex-I and Non-Annex-I countries for the policy scenarios compared to baseline for those countries with targets under the respective scenario.

22 Compared to the baseline in 2020 the “Weak Pledges“ and the “Ambitious Pledges“ scenario correspond to reductions in global CO_2 emissions of about 8.5 % and 13 % respectively. These figures are in line with findings by other studies, including Stern and Taylor (2010).

Table 2: Emission caps compared to 1990 / baseline

	2020				2030			
	Weak Pledges	Ambitious Pledges	30%-Annex-I	40%-Annex-I	Weak Pledges	Ambitious Pledges	30%-Annex-I	40%-Annex-I
All countries (% of baseline)	-10.9%	-16.6%	-22.9%	-27.2%	-40.1%	-42.8%	-46.0%	-48.1%
All countries (% of 1990)	53.1%	43.4%	32.5%	25.2%	15.4%	8.9%	1.6%	-3.2%
Annex-I (% of 1990)	-12.1%	-17.4%	-30.6%	-40.5%	-36.4%	-39.9%	-48.8%	-55.4%
Non-Annex-I (% of baseline)	-6.9%	-13.0%	-14.3%	-14.3%	-39.7%	-42.3%	-43.5%	-43.5%

Hence, industrialized countries‘ “pledges“ under the Copenhagen Accord lead to emission reductions compared to 1990 emission levels of at most 17 % and developing countries‘ “pledges“ to emission reductions compared to baseline of at most 13% in 2020 (“Ambitious Pledges” scenario). Compared to the Copenhagen “pledges” the “30 %-Annex-I scenario and, in particular, the “40 %-Annex-I” scenario attribute a significantly higher reduction (compared to 1990 levels) to Annex I countries. As den Elzen et al. (2010b) point out, pursuing ambitious climate policy targets prior to 2030 may be vital in terms of reaching the 2°C target, because it is unlikely that higher emissions from earlier years can be fully counterbalanced in future decades via a “delayed action” type strategy.

2.2.2 Targets for 2030

For the periods between 2020 and 2030, all countries except for LDCs face emission targets in all policy scenarios. These targets are derived from a linear reduction path between 2020 and 2050 assuming that each Annex-I country reduces its emissions by 85 % below 1990 levels by 2050. For Annex-I countries and the six major developing countries, emission targets for 2020 were used as the starting point for the linear reduction path. By definition, emissions in the Annex-I countries in 2020 differ among the four policy scenarios: the “40 %-Annex-I” scenario corresponds to the lowest overall Annex-I emission level and the “Weak Pledges” scenario corresponds to the highest overall Annex-I emission level. Since the base of the linear reduction path from 2020 to 2050 differs across the policy scenarios, the targets for 2030 also differ. As a consequence, the “40 %-Annex-I” scenario results in the lowest overall Annex-I emission level of all policy scenarios while the “Weak Pledges” scenario implies the highest overall Annex-I emission level in 2030.[23] Annual reduction rates between 2020 and 2030 in Annex-I countries, in contrast, are highest in the “Weak Pledges” scenario and lowest in the “40 %-Annex-I” scenario.

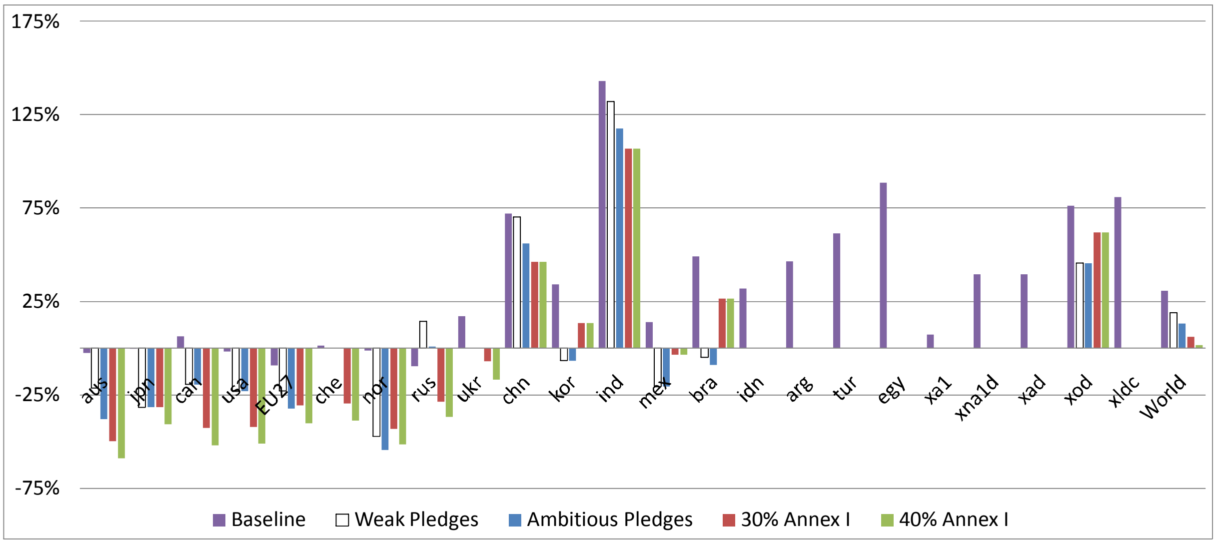
23 In 2050 targets would converge for all policy scenarios.

For Non Annex-I Developed Countries (NAID), for Advanced Developing Countries (ADC) and for Other Developing Countries (ODC)[24] reduction targets for 2030 are determined based on a global emission reduction target of 50 % below 1990 levels in 2050. Annex-I countries will reduce emissions by 85 % below 1990 levels in 2050. Non-Annex-I countries except LDCs will contribute the remainder to reach the 50 % global reduction target in 2050. Assuming a linear reduction path for all Non-Annex-I countries, NAID and ADCs will reduce emissions at twice the rate of ODCs. By choice, Non-Annex-I targets differ between the "Weak Pledges" and the "Ambitious Pledges" and the "30 %-Annex-I" and "40 %-Annex-I" scenarios for Brazil, China and India.

Figure 2 shows the growth in emissions by countries/regions in the baseline and the targets in all policy scenarios for 2030 compared to 2005 emission levels. Overall targets are significantly more ambitious in 2030 than they were in 2020, in particular for Non-Annex-I countries (see also Table 2). For the period 2020 to 2030 average emission targets relative to baseline emissions for Non-Annex-I countries are still below those of Annex-I countries, but the gap has become smaller.

In addition, Figure 3 shows the growth in emissions in baseline and target emissions for all four policy scenarios for 2020 and 2030 for Annex I countries compared to 1990 emission levels.

Figure 1: Growth in baseline and target emissions for the policy scenarios in 2020 compared to 2005 (in %)



24 See Table A 1 in the Annex for the grouping of regions.

Figure 2: Growth in baseline and target emissions for the policy scenarios in 2030 compared to 2005 (in %)

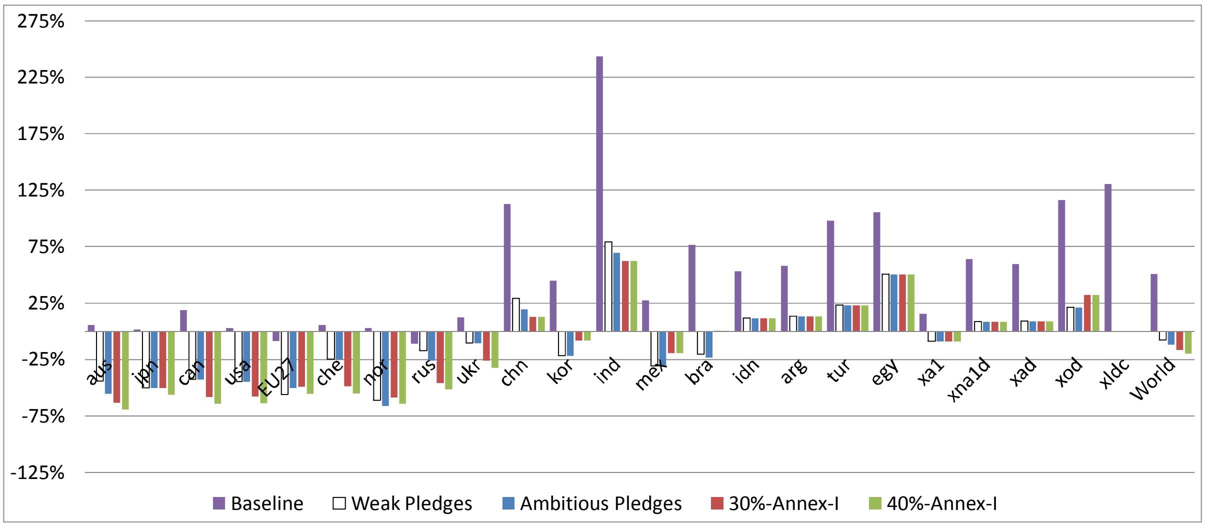
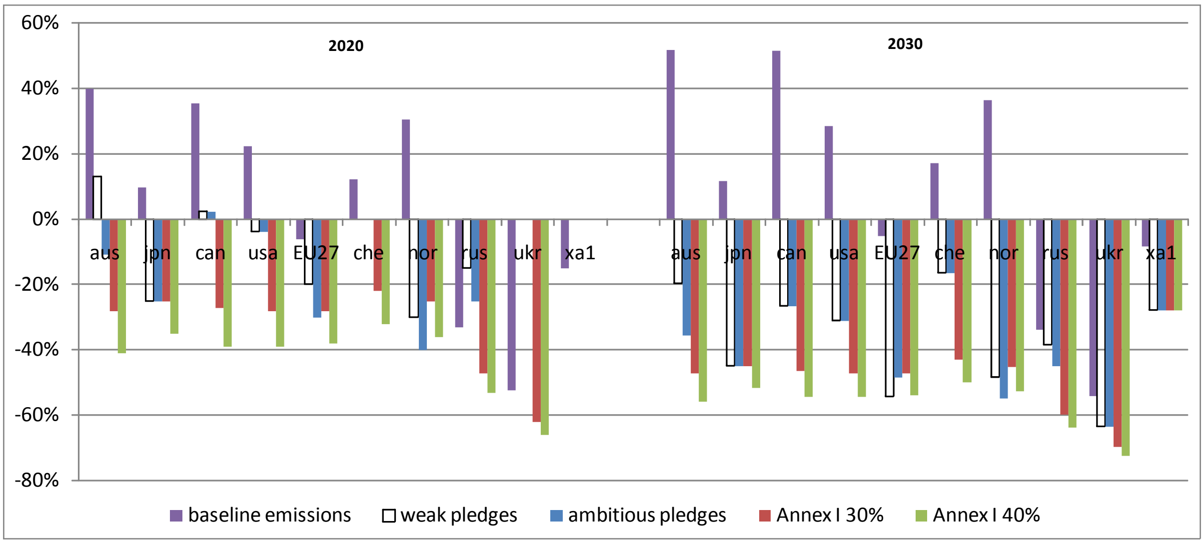


Figure 3: Growth in baseline and target emissions of Annex I countries for the policy scenarios in 2020 and 2030 compared to 1990 (in %)



3 Results of policy scenarios

For all four policy scenarios the findings in terms of environmental and economic effects are compared to the outcomes of the baseline simulations.

3.1 Certificate prices

Prices for CO_2-certificates (in real 2004 US$ per ton of CO_2) for the trading regions in the respective periods appear in Table 3 for all four policy scenarios. In 2020 certificate prices, which reflect the marginal abatement costs of trading regions, range from 10$/tonne of CO_2 in the “Weak Pledges” scenario to about 27$/tonne of CO_2 in the “30 %-Annex-I” scenario and 35$/tonne of CO_2 in the “40 %-Annex-I” scenario. Compared to the targets for the Kyoto-period, only the “30 %-Annex-I” and the “40 %-Annex-I” scenarios result in higher prices in 2020 than in 2010. The “Ambitious Pledges” scenario leads to the same tax rate in 2020 as in 2010.

To meet the 2030 targets, marginal abatement costs rise substantially in all four policy scenarios. On average certificate prices increase by 23 % per year between 2020 and 2030 in the “Weak Pledges” scenario, 19 % in the “Ambitious Pledges” scenario, 15 % in the “30 %-Annex-I” scenario and 13 % in the “40 %-Annex-I” scenario. Since the “40 %-Annex-I” scenario leads to the lowest emissions (in all periods), increasing marginal abatement costs imply that the prices for CO_2-certificates are the highest among all policy scenarios (for all periods). By the same token, the “Weak Pledges” scenario leads to the lowest prices for CO_2-certificates of all policy scenarios.

Table 3: CO_2-certificate prices in the policy scenarios (in 2005 $/tonne)

Year	Weak Pledges	Ambitious Pledges	30%-Annex-I	40%-Annex-I
2010	17	17	17	17
2015	5.5	8.5	12.8	16.6
2020	10.2	17	26.9	34.9
2025	39.1	47.8	59.8	68.8
2030	83.2	94.9	110.5	122.1

3.2 Emissions trading, hot air and leakage

In all four policy scenarios countries with targets are allowed to trade emission certificates. Figure 4 and Figure 5 show the traded volumes of certificates for the different countries and regions in 2020 and 2030 respectively. Traded volumes are endogenously determined and depend on a country’s emission target (compared to baseline emissions) and on its marginal abatement costs. Optimal trading and abatement strategies imply that countries facing tight targets and high abatement costs will purchase certificates from countries with excess certificates resulting from lenient targets and/or low marginal abatement costs.

Results for 2020

Figure 4 shows that - except for the “Ambitious Pledges” scenario - the US will be the major buyer of certificates in absolute terms in all policy scenarios in 2020. In the “Ambitious Pledges” scenario, the EU 27 will be the most important buyer of certificates. China, India, South Africa (part of xod in Figure 4) will be the main sellers of certificates for all policy scenarios; together with Russia these countries will also be the main sellers for the two “pledges” scenarios.

Since projected emissions by Russia are below its target in both “pledges” scenarios, some of the traded certificates are actually “hot air”. For example, in the “Weak Pledges” scenario, gross of “hot air,” total required emission reductions by all regions with targets compared to baseline emissions are about 3.2 billion tonnes of CO_2 in 2020. Since baseline emissions in Russia are about 0.35 billion tonnes of CO_2 below its “Weak Pledges” target,[25] required emission reductions net of “hot air” are about 3.35 billion tonnes CO_2. The total share of “new hot air” in 2020 is about 9.7 % in the “Weak Pledges” Scenario.[26] Similarly, the share of “new hot air” for the “Ambitious Pledges” scenario is approximately 3 %. In contrast, the “30 %-Annex-I” scenario does not result in new “hot air” for Russia. In fact, Russia becomes a net buyer of certificates in the “30 %-Annex-I” and the “40 %-Annex-I” scenario.

The implied reduction targets in all policy scenarios affect the group of large developing countries quite differently. In all scenarios, China and India sell large amounts of certificates. Conversely, Brazil[27], Mexico, South Korea and – apart from the “Weak Pledges” scenario – also South Africa have to purchase certificates to meet their emission targets.

Across all policy scenarios, a substantial share of required reductions in emissions for regions with targets is achieved via emissions trading (see also Table 4). In 2020 this share ranges between 75 % in the “Weak Pledges” scenario and about 43 % in the “30 %-Annex-I” scenario.

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25 For comparison, den Elzen et al. (2009b) estimate the magnitude of hot air from Russia in 2020 at 0.42 Gt.

26 Clearly, if Russia was assumed to transfer “hot air” from the Kyoto phase and the pledges remained the same, certificate prices would be substantially lower than 10$/tonne or 17$/tonne in 2020 in the “Weak Pledges” and the “Ambitious Pledges” scenarios, respectively.

27 Brazil’s position, however, would likely be different, if REDD and REDD-plus were included in the analysis, since these measures have a high potential and are relatively cheap.

Table 4: Overview of emission reductions, role of certificate trading, and leakage

	2020				2030			
	Weak Pledges	**Ambitious Pledges**	**30%-Annex-I**	**40%-Annex-I**	**Weak Pledges**	**Ambitious Pledges**	**30%-Annex-I**	**40%-Annex-I**
Global emissions (in % of 2005 emissions)	19.5%	13.8%	7.2%	2.9%	-7.2%	-11.2%	-15.7%	-18.7%
Share of certificate trading in reductions	75.9%	56.2%	42.7%	44.8%	17.6%	16.0%	16.5%	18.1%
Leakage rate in % of baseline emission	0.3%	0.6%	0.8%	1.0%	0.4%	0.4%	0.4%	0.5%
Leakage rate	4.3%	4.4%	4.6%	4.8%	1.0%	1.0%	1.1%	1.1%

In terms of environmental effectiveness, neither policy scenario will reduce global CO_2-emissions in 2020 compared to 2005 emission levels. Global CO_2-emissions in the “Weak Pledges” and in the “Ambitious Pledges” scenarios will increase by about 20 % and 14 %, respectively. While the voluntary “pledges” scenarios limit global emission growth to about half the growth in the baseline (29 % in 2020 compared to 2005) at best, they are unlikely to be compatible with an emission path allowing to achieve the “2°C target” (Ecofys and PIK 2009, Stern and Taylor 2010).[28] Global emissions also rise in the “30 %-Annex-I” and the “40 %-Annex-I” scenarios, but the growth rates of 11 % and 6.5 % are significantly lower. Hence, no policy scenario considered is likely to be consistent with the intermediate target proposed by the IPCC (2007).

To some extent, emission reductions in the policy scenarios (compared to baseline) are offset by emission increases in regions which do not take on mitigation action (“carbon leakage”). Ceteris paribus, these additional emissions rise with higher prices of CO_2-certificates. If leakage is measured relative to the reductions in countries with targets (as in IPCC 2007), the leakage rate in 2020 ranges between 4.3 %[29] in the “Weak pledges” scenario and 4.8 % in the “40 %-Annex-I” scenario (Table 4). If leakage is measured as a share of global baseline CO_2-emissions in (and hence based on the same “denominator”) across all policy scenarios, leakage increases from 0.35 % in the “Weak Pledges” scenario to 1.03 % in the

28 According to PIK (2010), the pledges under the Copenhagen Accord would lead to a temperature increase of around 3.5°C.

29 This means, that 4.3 % of the respective reductions in Annex-I countries and in the six major developing countries with capped emissions are offset with emissions in LDCs and other regions without emission targets.

"40 %-Annex-I" scenario (see Table 4). In general, though, the reported leakage rates are rather small.[30]

Results for 2030

Targets for 2030 are significantly more ambitious than for 2020. For example, 2030 global emissions are approximately 4 % less than 2004 emissions in the "Weak Pledges" scenario and about 16 % lower in the "40 %-Annex-I" scenario. Compared to baseline emissions, the reductions range between around 39 % in the "Weak Pledges" scenario and 46 % in the "40 %-Annex-I" scenario. As was the case for 2020, the US is the largest buyer of certificates in all but the "Ambitious Pledges" policy scenario (see Figure 5). Certificates are mostly sold by China, with India, with other developing countries (ODC) supplying much lower levels. Compared to 2020, developed countries engage more heavily in "domestic" emission reductions. Certificate trading accounts for about 17 % of the total required emission reductions, significantly less than 2020. Hence, for more ambitious targets, domestic abatement becomes relatively more cost-efficient. In absolute terms, though, the (minimum) traded volume increases in all policy scenarios, the most in the "30 %-Annex-I" scenario by about 10 %.

Unlike in the policy scenarios for 2020, in the simulations for 2030 all regions (except for LDCs) are assumed to commit to limit their emission. Consequently, the leakage rate in the policy scenarios for 2030 is substantially smaller than in the scenarios for 2020 even though certificate prices are much higher in 2030.

30 When leakage rates are compared to findings from other studies, the level of aggregation needs to be taken into account. If leakage rates are measured at the sectoral level (including sectoral targets), rather than at the country level, the calculated leakage rates are higher (e.g. Bernard and Vielle 2009).

Figure 4: Volume of certificate sales (+) and purchases (-) in 2020 (in million tonnes)[31]

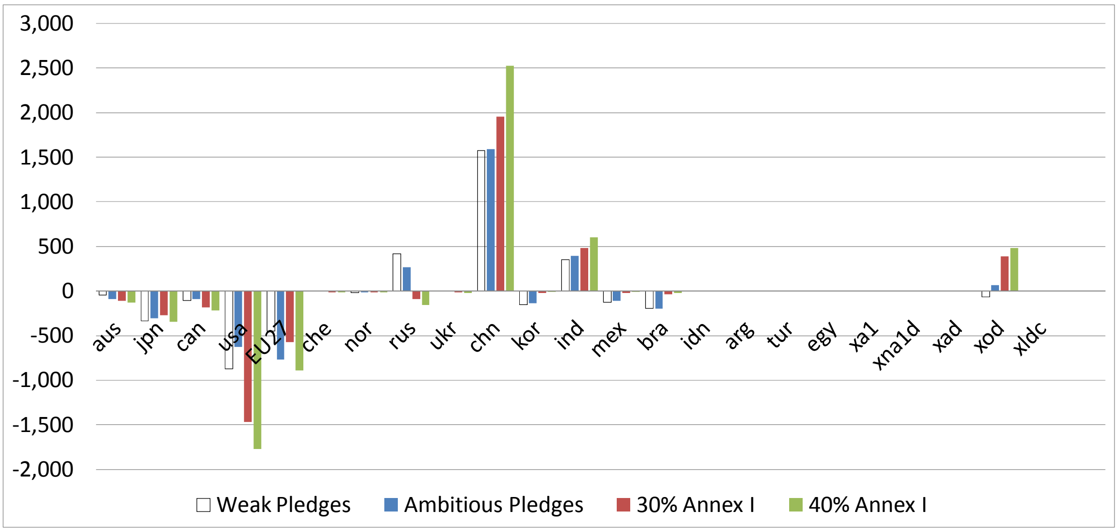
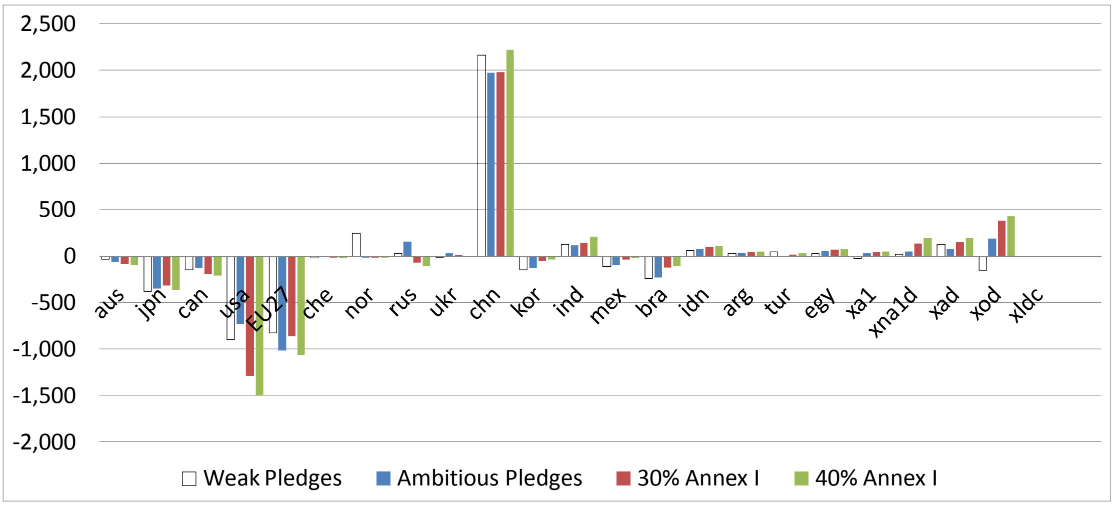


Figure 5: Volume of certificate sales (+) and purchases (-) in 2030 (in million tonnes)



31 Note that results for South Africa are included in the xod region in Figure 4 and Figure 5.

3.3 Gross domestic product

Unlike bottom-up engineering or partial equilibrium models, where GDP is typically given exogenously, a CGE model allows GDP, input and output prices, production levels, and trade flows to change endogenously in response to climate policy. Figure 6 and Figure 7 show for 2020 and 2030 the level of GDP for the four policy scenarios and the baseline (normalized at 2004 levels) at the country and regional level. Results for "EU-30 %" are presented and discussed in Box 1.

Relative to GDP in the baseline, the reductions in global GDP growth in 2020 amount to around 0.2 percentage points for the "Weak Pledges" scenario, 0.3 percentage points for the "Ambitious Pledges" scenario, 0.5 percentage points for the "30 %-Annex-I" scenario, and 0.7 percentage points for the "30 %-Annex-I" scenario. Overall, global GDP growth decreases by 1 percentage point from 43 % between 2004 and 2020 in the baseline scenario to 42 % in the "Ambitious Pledges" scenario. In Annex I countries, changes in average GDP growth between 2004 and 2020 due to emission reduction targets are negligible (27 % in all scenarios). Reductions in GDP growth compared to baseline for Annex I countries (with targets[32]) are fairly modest, averaging under 0.1 percentage point in the "Weak Pledges", 0.1 percentage point in the "Ambitious Pledges" scenario, 0.2 percentage points in the "30 %-Annex-I" scenario, and 0.3 percentage points in the "40 %-Annex-I" scenario. For Russia, while GDP growth remains above the average Annex I GDP growth (58 % between 2004 and 2020), reductions in GDP growth in the policy scenarios relative to baseline are above average, ranging from 0.9 percentage points to about 3 percentage points in the "40 %-Annex-I" scenario. The lower growth in GDP for Russia compared to the baseline mainly results from a smaller increase in private consumption due to lower growth in factor income (e.g. wages and returns on capital). All policy scenarios lead to a decline in the output of fossil fuels (coal, oil, gas) commodities (relative to the baseline) because of lower domestic and export demand. Because climate policies result in lower global demand for fossil fuels, their world prices fall (compared to the baseline).[33] Given the size of these sectors in Russia, this leads to a strong decline in the demand for labor and capital and to a decrease in the price of those factors (relative to baseline). Results for Russia for the "Pledges" scenarios also imply that the profits from selling "new hot air" are (by far) not sufficient to compensate the loss in factor income.[34]

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32 Note that in this report not all Annex-I countries are associated with targets under the Copenhagen Accord (notably Switzerland and the Ukraine).

33 This finding is typical for climate policy analyses based on CGE models.

34 Qualitatively similar findings for Russia can be found, among others, in Böhringer and Vogt (2003), for the impact of the Kyoto Protocol, which also involves substantial amounts of hot air for Russia.

For most large developing countries, the reductions in GDP growth in 2020 compared to the baseline are well below 2 percentage points in both "Pledges" scenarios, and generally higher in the "30 %-Annex-I" and "40 %-Annex-I" scenarios. The average reduction in GDP relative to GDP in the baseline in Non-Annex I countries with emission targets are much higher in all scenarios than the average reduction in GDP relative to the baseline in Annex I countries with emission targets[35]. In contrast, GDP growth rates in large developing countries are significantly higher than for Annex I countries leading to a doubling of average real GDP between 2004 and 2020 in the baseline as well as the four policy scenarios. Even though GDP reductions are higher for developing countries, their GDP growth remains significantly above Annex I countries' GDP growth. The countries facing the highest reductions in GDP growth compared to baseline, India and China, are also the countries with by far highest GDP growth between 2004 and 2020. Reductions in GDP growth slow down economic growth in those countries only slightly. In particular, real GDP in China and India between 2004 and 2020 increases by a factor of 2.6 and 2.7, respectively, rather than a factor 2.7 and 2.8 in the most ambitious "40 %-Annex-I" scenario.[36]

Interestingly, tighter emission targets lead to larger reductions in GDP for some large developing countries like China and India, while some Annex-I countries, notably the EU and Japan[37] experience an increase in GDP. The larger reductions occur for China and India, because their industrial sectors are more energy- and CO_2-intensive than most other regions, so increases in the cost of CO_2 emissions leads to larger reductions in the output of their energy-intensive sectors. In contrast, because these same sectors in the EU and Japan are relatively less energy- and CO_2-intensive than most other regions, a higher cost of CO_2 emissions will have less affect on the prices and make EU and Japanese firms more competitive, leading to increases in output. Table 5 exemplifies this for selected sectors for the "Ambitious Pledges" scenario.

35 If REDD and REDD-plus measures were included, the reduction in GDP for Brazil would probably be much smaller compared to baseline in all policy scenarios. Brazil could even become a net seller (rather than buyer) of certificates and GDP may increase.

36 Even though growth will be larger in developing countries, per capita GDP in developing countries will still be substantially below per capita GDP in industrialized countries.

37 Peterson and Klepper (2007) find qualitatively similar results for Japan, but do not offer further insights.

Table 5: Difference in output in selected industry sectors in the “Ambitious Pledges” scenario compared to the baseline in 2020 (in % of baseline)

Sector	Japan	EU15	China	India
other manufacturing	0.16%	0.16%	-2.36%	-2.75%
paper	0.04%	-0.01%	-2.65%	-3.60%
chemicals, rubber, plastics	0.03%	0.34%	-4.23%	-3.38%
other mineral	0.49%	0.43%	-2.95%	-2.28%
iron and steel	0.54%	0.68%	-2.82%	-4.29%
other metals	0.43%	-0.16%	-3.35%	-10.20%

For example, steel production in China and India in 2020 is still more than twice as CO_2-intensive as in the EU. Hence, CO_2-intensive production sectors are much more vulnerable to higher certificate prices in several major developing countries such as China or India than in Japan or the EU. Besides costs for direct emissions, higher CO_2-prices also affect the costs of intermediaries, in particular of electricity. Thus, higher CO_2-prices may significantly increase production costs for electricity-intensive sectors like chemicals, rubber and plastic products or other metals such as aluminum. Because coal is the main fuel used to generate electricity in China and India, electricity prices rise more in both regions than in other regions (compared to baseline). These price increases are larger for tighter emission targets.[38] For example, the electricity price increase in China is twice as high for the “30 %-Annex-I” scenario compared with the “Ambitious Pledges” scenario and about three times as high compared with the “Weak Pledges“ scenario in 2020. In this respect, it should be noted that the dynamic nature of the model allows capturing “early action” effects in the sense that it recognizes the effects of climate policy on CO_2-intensity of the economy in past periods.

To sum up, tighter targets for Annex-I countries render sectors in regions with emission targets and which produce relatively energy-intensively less competitive. As a consequence energy- and trade-intensive sectors in these regions lose market shares (relative to baseline) to regions where production is less energy intensive.

Countries and regions without climate targets, like LDCs, Argentina or Turkey, generally experience small GDP gains in all policy scenarios compared to the baseline. However, countries like Indonesia and Egypt, i.e., economies that rely heavily on domestic energy sectors, suffer from lower world prices for their products (compared to baseline).

38 Of course, these analyses implicitly assume that carbon (opportunity) costs will be passed on to electricity consumers.

Results on the effects of the policy scenarios on the growth of real GDP in 2030 are displayed in Figure 7. In 2030 the reduction in global GDP growth equals 1.7 percentage points for the “Weak Pledges” scenario, 2.0 percentage points for the “Ambitious Pledges” scenario, 2.3 percentage points for the “30 %-Annex-I” scenario, and 2.5 percentage points for the “40 %-Annex-I” scenario. For regions which faced emission targets in 2020, the economic effects for 2030 follow the pattern described for 2020 but they are more pronounced because targets are significantly tighter and certificate prices substantially higher. The EU, Japan and Switzerland experience an increase in GDP as targets become tighter. All other regions with targets in 2030 experience a reduction in GDP, while LDCs benefit from carbon-leakage effects. On average, the reductions in GDP growth are relatively higher for Non-Annex-I countries than for Annex-I countries.

Figure 6: Increase in GDP in baseline and policy scenarios in 2020 (relative to 2004)

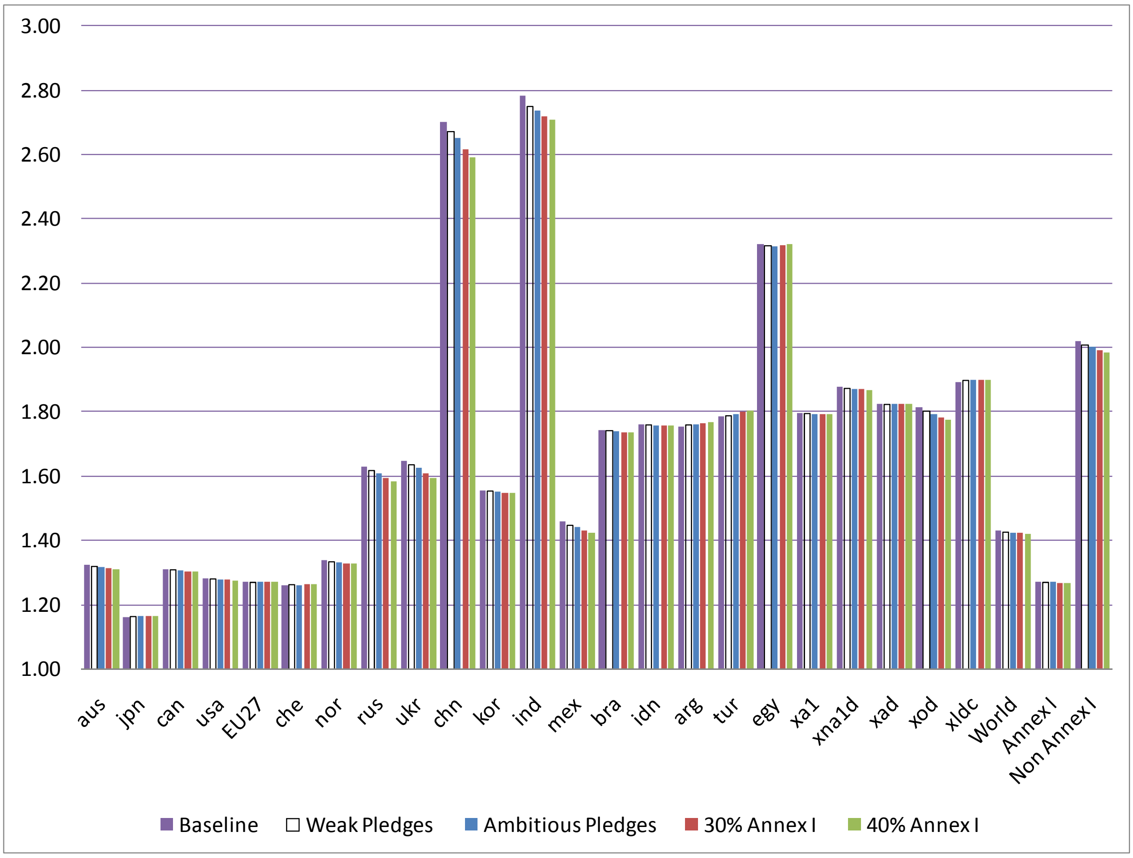
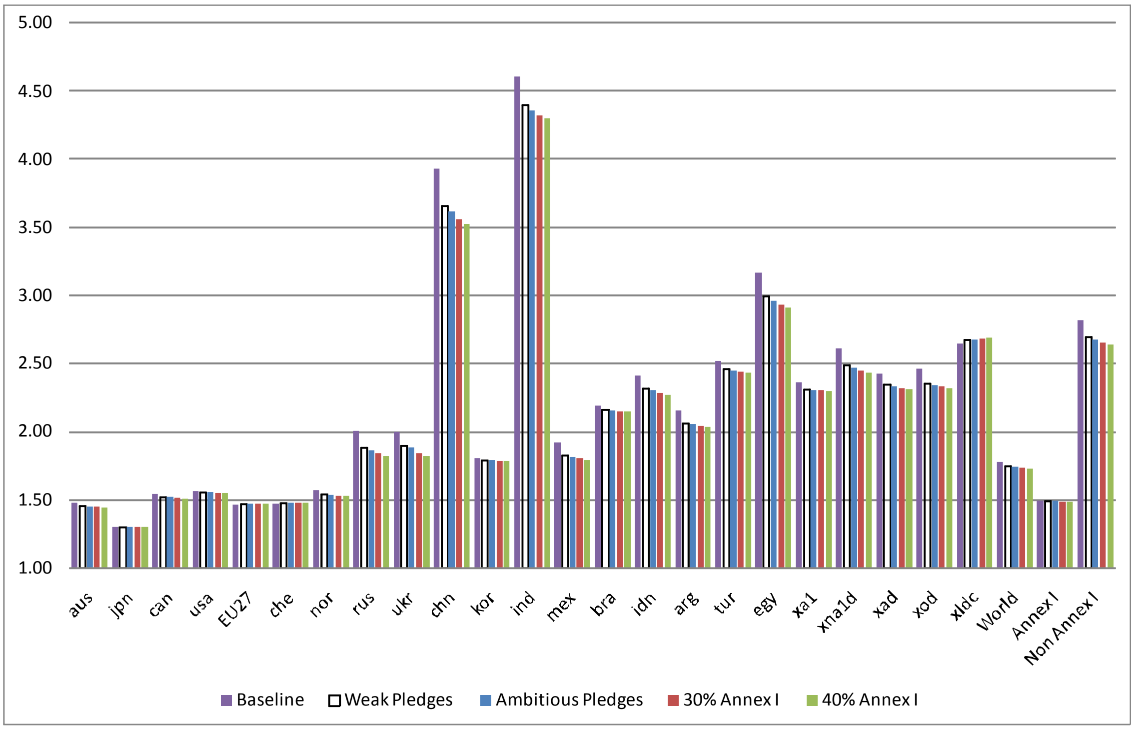


Figure 7: Increase in GDP in baseline and policy scenarios in 2030 (relative to 2004)



Box 1: Findings for unconditioned EU 30 % target

This box presents findings for changes in GDP in the "EU-30 %" scenario compared to "Weak Pledges". In the "EU-30 %" scenario the EU is assumed to adopt a 30 % emission reduction target in 2020 compared to 1990 levels as in "Ambitious Pledges" scenario, while all other countries adopt the same emission targets as in the "Weak Pledges" scenario.

The results imply that the price of certificates increases by approximately 10 % to 11 €/tonne of CO_2. compared to the "Weak Pledges" scenario. Hence, the environmental and economic effects of the "EU-30 % scenario will be very similar to the "Weak Pledges" scenario. The EU achieves the additional emission reductions primarily via purchasing certificates from other countries. Approximately 95 % of the extra reductions will be met via purchasing certificates from abroad. In particular, China and to a lesser extent also India expand certificate sales in response to the increase in certificate prices. Our calculations indicate that the net effect of an unconditional EU 30 % emission reduction target compared to the "Weak Pledges" scenario involves a small reduction in GDP of less than 0.005 % for the EU.

In general, these findings are in line with the results of a similar analysis carried out on behalf of the European Commission (2010), even though under somewhat different assumptions.[39] Accordingly, additional total costs for the EU to go from a 20 % to a 30 % target are approximately 0.2 % of GDP in 2020.

3.4 Welfare Effects

While the changes in GDP provide insight into the change in overall economic activity from implementation of emission targets, it is not necessarily a good indicator of how emission targets affect the well-being (or welfare) of individuals in a given region. The change in economic welfare from the implementation of emission targets will depend on how this policy affects the efficient use of resources (e.g., labor and capital) in a region's economy (allocative efficiency), the level of resources available to that economy, whether it will affect that

39 For example, unlike in this report, the CGE-based calculations in EU (2010) assume that the amount of certificates from abroad that can be used for compliance is limited. More specifically, countries cannot use more than 1/3 of the distance between the emission targets and the baseline emissions. Assuming that these certificates can be used without restrictions – as in this report – tends to dampen the effects of a tighter emission target in the EU on GDP in the EU. At the same time though, the more ambitious targets in the EU, which accounts for about ¼ of all required emission reductions in 2020, also raise the costs of CO_2 in China and elsewhere.

region's terms-of-trade with other regions,[40] and whether that region buys or sells CO_2 certificates. In this report, Equivalent Variation (EV) is used to measure the economic welfare of a representative consumer in a given region. EV is defined as the amount that the representative consumer would need to be paid to be as well off after the implementation of emission targets as it would be if no climate policy was implemented (using baseline prices).

In the DYE-CLIP model, EV is decomposed into its constituent components of allocative efficiency, terms-of-trade, factor endowments, and revenues from CO_2 certificate trading. In determining the change in allocative efficiency for the energy commodities, we take into consideration that climate policy is being implemented to address a negative (global) externality from CO_2 emissions associated with the use of fossil fuels. Without implementing climate policies and assuming perfectly competitive energy markets, the price of the energy commodities is equal to their marginal production costs. However, CO_2 emissions from the use of energy commodities cause economic and environmental damages (e.g., social costs). Thus, the market price of energy commodities is less than the total social cost (marginal production costs plus marginal social cost of the CO_2 emissions), implying that a larger quantity of energy commodities is consumed relative to what is socially optimal. However, when part or all of the marginal social cost is "internalized" through the use of carbon taxes (e.g., price of CO_2 certificates), the use of energy commodities will be reduced which will lead to an increase in allocative efficiency. Because increases in atmospheric CO_2 levels from higher CO_2 emissions will affect all regions, the externality is assumed to exist in all regions in the model.

One limitation to accounting for the externality in the use of energy commodities is that the marginal social cost of CO_2 emissions is not known with certainty. As noted, among others, by Tol (2009), there is a large range of estimates of the social cost of climate change. One reason for large divergence in estimates is the use of different pure rates of time preference (e.g., discount rates). If more of the costs associated with climate change will occur in the future, then using a larger rate of time preference will more heavily discount those costs, leading to a lower present value of the social cost of CO_2 emissions. In order to take into consideration the costs of climate change on future generations, a 0 % pure rate of time preference is assumed in this study. This is the same assumption made by Stern (2007, p. 344), who estimated an $85/tonne social cost of CO_2 emissions, in 2000 $. Because all values in the model data base are in 2004 $, the Stern estimate is adjusted to 2004 dollars ($94.65/tonne of CO_2) using the GDP deflator for the United States.[41]

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40 A region's terms-of-trade is determined by the prices they receive for its exports compared to the prices it must pay for its imports. If a region must pay more for its imports relative to what it receives for its exports, then that region experiences a decline in its terms-of-trade and a reduction in welfare.

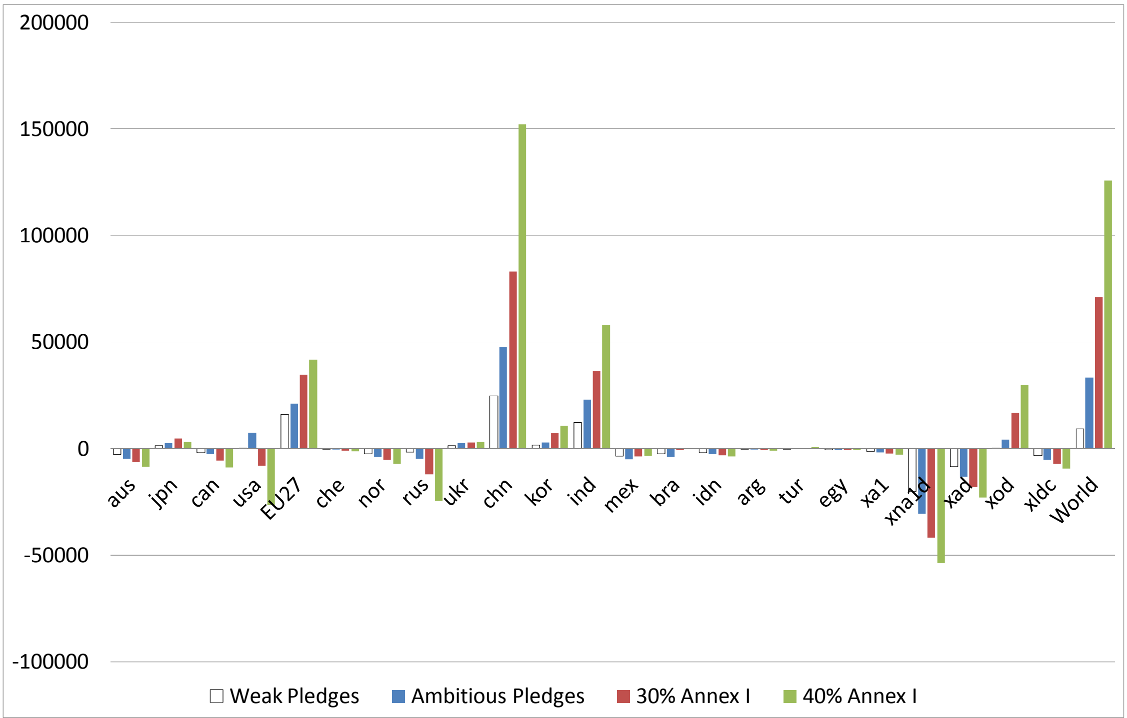
41 The Stern (2007) estimate is approximately $17/tonne CO_2 higher than the unweighted sample mean for a 0 % pure rate of time preference reported in Table 2 of Tol (2009) after adjusting to 2004 $. Assuming a higher pure rate of time preference will lower the social cost of carbon and lead to reduced gains in allocative efficiency from climate policy.

If the price of CO_2 certificates exceeds the marginal social cost of CO_2 emissions, then the difference represents a decrease in allocative efficiency (even compared to the social optimum). This occurs in 2030 for both, the “30 %-Annex-I” and the “40 %-Annex-I” scenarios. Thus, the gain in allocative efficiency from internalizing the negative externality is partially offset by the loss in allocative efficiency from price of CO_2 certificates exceeding the marginal social cost.[42]

Finally, it should be noted that while the gains in allocative efficiency from internalizing the externality associated with CO_2 emissions is included in the estimate of EV for each region, we do not include any other benefits from a reduction in CO_2 emissions. For example, these benefits could include other benefits from local pollution control.

Figure 8 shows the change in welfare (EV) in 2020 for the four alternative scenarios. In absolute terms, the EV from implementing climate change policies is relatively small for most regions, with values less than \$10 billion across the four scenarios.

Figure 8: Change in welfare in 2020 (in million 2004\$)



The exceptions are the United States and Korea for the “40 %-Annex-I” scenario; Russia and Rest of developing countries (xod) for the “30 %-” and “40 %-Annex-I” scenarios; and the

42 By using the same social costs across all regions to calculate EV as well as its component allocative efficiency, we implicitly assume all representative consumers realize the global nature of the externality and care about the global costs, not just the costs incurred in their region. Hence, results for EV analyses would differ if regions‘ representative consumers only cared about the damages in their regions.

EU27, China, India, Rest of non-Annex-I developing countries (xna1d), and Rest of advanced developing countries (xad) for all scenarios. The regions with the largest gain in EV are the EU27, China, India, and the xod. For China and India, the sources of gain are the allocative efficiency for energy commodities, the sale of CO_2 certificates, and their terms-of-trade improvement, mainly from a lower price of oil imports.[43] For the EU27, the sources of welfare gain are allocative efficiency for both energy and non-energy commodities, and their terms-of-trade, again mainly from lower oil prices. For the xod, the gain in EV is from allocative efficiency gains for energy commodities returns to capital, and from selling CO_2 certificates in the “Ambitious Pledges”, and “30 %-Annex-I”, and “40 %-Annex-I” scenarios. The regions with the largest loss in EV are xna1d, xad, and Russia. All three of these regions are major exporters of energy commodities (e.g., oil and gas) and experience large declines in their term-of-trade as well as decreases in the returns to capital owned by these regions.[44] That is, these countries receive lower prices for their exports of fossil fuels in relation to the prices of their imported goods. Even the sale of CO_2 certificates by Russia could not offset the decline in their terms-of-trade. For the United States, as the emission targets become stricter across the scenarios, it purchases an increasing amount of CO_2 certificates from abroad (see also Figure 4 and Figure 5). In the “Ambitious Pledges” scenario, the value of CO_2 certificates purchased is less than the gain in allocative efficiency for energy commodities and the terms-of-trade, leading to a small gain in EV for the United States.

However, in both the “30 %-Annex-I” and “40 %-Annex-I” scenarios, the increased purchases of CO_2 certificates more than offsets any gain in allocative efficiency and terms-of-trade for the United States. The global EV, obtained by summing EV across regions, is positive across all four scenarios in 2020, indicating the regions that gain could compensate the regions that lose welfare.

Because of differences in income levels across the regions, it is also instructive to consider the change in welfare relative to baseline GDP in 2020. As shown in Figure 9, for most regions, the EV from implementing the climate policies in our four scenarios is less than 0.1 % of 2020 baseline GDP[45]. The exceptions are China, India, and the Ukraine, whose welfare gain exceeds 0.1 % of 2020 baseline GDP, and Norway, Russia, xna1d, xad, and the Rest of least developed countries (xldc), whose welfare loss equals or exceed 0.1 % of 2020 baseline GDP. It is interesting to note that while the absolute value of EV for Norway, Ukraine, and xldc is less than $1 billion annually, given the relative size of these regions’ economy, the welfare change is relatively large. Because Norway is a net exporter of energy commodities (e.g., oil), it experiences a relatively large decline in its terms-of-trade, leading to the de-

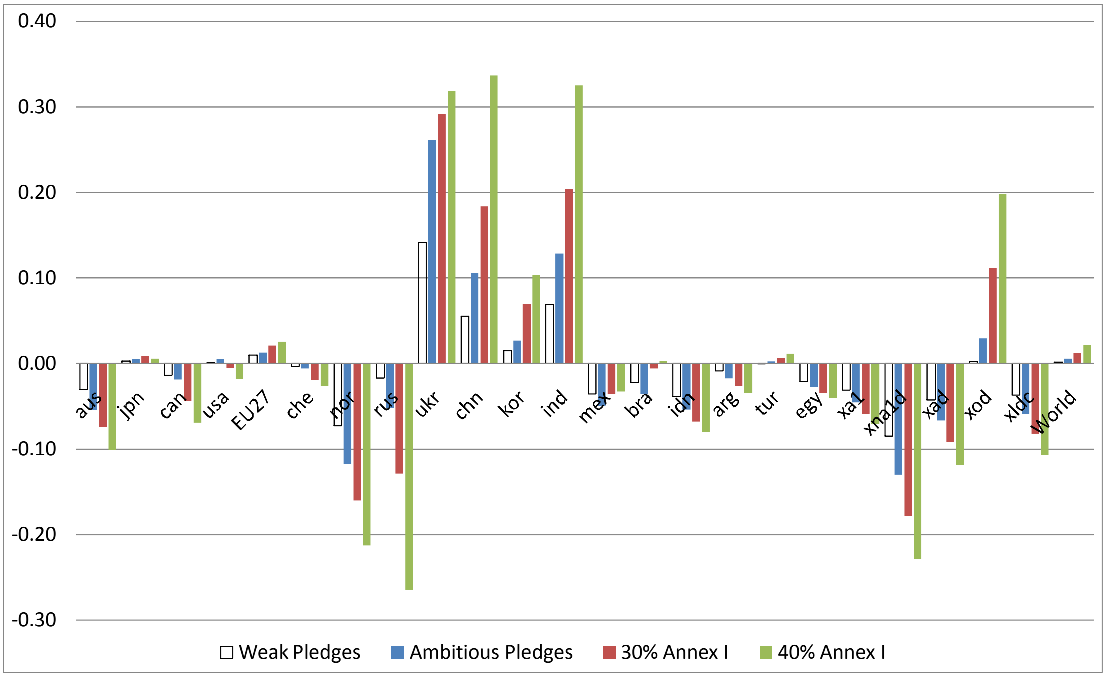
43 The EV value for each region and scenario for 2020 are listed in Table A.3.

44 The xna1d region includes the Middle Eastern oil producing countries while xad includes Venezuela.

45 Because EV is a cumulative value from 2010 to 2020 and the baseline GDP is for a single year, the value of EV is divided by 10 to convert it to an average annual basis.

crease in EV. Similarly, because the xldc region includes Nigeria, a major oil exporting country, it also experiences a relatively large decline in its terms-of-trade. For the Ukraine, the relative large gain in EV is mainly due to an improvement in its term-of-trade in oil, chemicals, rubber and plastics products (crp), and ferrous metals (is). Also note that while the United States and the EU27 had relatively large absolute changes in EV, given the size of their economies, these changes are relatively small as a percentage of 2020 baseline GDP.

Figure 9: Change in welfare in 2020 (in % of baseline GDP)



Stricter emission targets in 2030 lead to higher carbon taxes and, on average, also to larger welfare changes compared to 2020. Otherwise the relative results are quite similar to the results for 2020 and are not reported here.

4 Conclusions

Several policy implications emerge from the analyses presented in the previous sections on the environmental and economic effects of various climate policies. In particular, the "pledges" announced by several industrialized and large developing countries are neither ambitious in terms of global emission reductions required to stay on an emissions path towards the 2°C target, nor costly in terms of average global GDP losses or average changes in welfare (EV) – but significant differences exists across countries and regions. Compared to cost estimates for the Copenhagen pledges which are based on partial equilibrium models, the costs in this report, which are calculated with a CGE model, are generally higher. Environmental effectiveness is also tarnished by new hot air from Russia, but revenues from selling hot air cannot compensate for economic losses in Russia. Somewhat more ambitious 30 % and even 40 % reduction targets for Annex-I countries along with the 15 % below baseline target for major developing countries in 2020, also imply only moderate average reductions in GDP and changes in EV.

The reduction in GDP in 2020, relative to the baseline, is not evenly distributed across regions. Although in all policy scenarios and in particular in the "30 %-Annex-I" and "40 %-Annex-I" scenarios, major developing countries (with emission targets) have relatively larger reductions in GDP compared with Annex-I countries, the effects on the growth of real GDP are relatively small leading to a decrease in the growth of GDP in developing countries from 102 % in the baseline to 98 % in the "40 %-Annex-I" scenario between 2004 and 2020. Since major developing countries tend to produce relatively energy-intensively, they lose market shares to regions where production is less energy intensive.

Consequently, some Annex-I countries like the EU or Japan experience even small GDP gains which increase with tighter emission targets. Hence, economies which commit to climate targets earlier and reduce their CO_2-intensities sooner are less vulnerable to tight emission targets in later periods. Similarly, energy-intensive, trade-intensive industries in developed and developing countries alike may particularly benefit from investments leading to lower energy intensity and CO_2-emissions of their production processes. Considering a scenario where the EU unilaterally moves from a 20 % to a 30 % emission reduction target, while all other countries stick with their "weak" pledges, the calculations show that additional costs for the EU are negligible (0.005 % compared to the "weak" pledges scenario).

While in all policy scenarios many developing countries (with emission targets) experience larger reductions in GDP than developed countries, this does not necessarily translate into larger declines in net welfare (EV) as well. For example, both China and India experience a gain in welfare in 2020. This is due to strong terms-of-trade effects, the sale of CO_2 certificates, and gains in allocative efficiency for energy commodities by 2020 compared to their relatively high initial energy-intensity to date.

The policy scenarios involve substantially more ambitious emission targets for 2030, including all regions but LDCs. Qualitatively, the effects are similar to those found for 2020, but more pronounced since the tighter emission targets imply higher CO_2-prices. On average, the reduction in global GDP growth is below 3.0 percentage points while global EV remains virtually unchanged even for the most ambitious scenario considered.

Given the differential effects on the reduction in GDP and net welfare across regions, particularly among developing countries, the chosen emission burden-sharing criteria may have to be reconsidered in order to better address the situation of many developing countries and the possibility of options to compensate their financial burden due to their mitigation efforts. However, because some developing countries enjoy a gain in welfare, any changes in the burden-sharing criteria or monetary compensation should be targeted towards the developing countries with welfare losses.

In terms of carbon-leakage, the findings suggest that the environmental effectiveness of the sub-global climate agreements considered in this report is hardly challenged by higher emissions in regions which are not committed to climate targets. Carbon leakage effects would be more severe if targets were tighter or if less countries committed to limit their emissions.

When interpreting the results, some caveats apply. In particular, quantitative effects on emissions and costs would differ from the findings presented in this report, if other greenhouse gases, LULUCF and the corresponding mitigation measures and financial support from industrialized countries for developing countries were also included. These differences would vary across regions, depending on the significance of other greenhouse gas emission sources in terms of mitigation potential and costs and the extent to which they are included in countries' emission reduction targets. It should also be kept in mind that the analyses presented assume unlimited certificate trading across countries with emission targets. While this implies that tighter targets in some regions translate into higher CO_2-costs in all regions with emission targets, unrestricted emission trading contributes to achieving climate targets at lowest global costs. Similarly, the analyses presented do not allow for offsets generated in non-trading countries. While this option is expected to also reduce overall mitigation costs, this cost-containment effect vanishes once more countries take on binding emission targets. Similarly, if banking was allowed, reduction costs over time would be lower since countries may choose to reduce more emissions than required in early periods and transfer unused certificates in future periods. Unless the time path of targets takes into account cost differences over time (and hence does not require banking or borrowing to achieve the intertemporal optimum), an optimizing strategy would require that future targets are known to investors well in advance. At last, technological change is modeled as being exogenous. That is, the rate of technological progress is not affected by policies. Allowing for price-induced technological progress would lower mitigation costs.

Finally, the four policy scenarios represent very different emission paths and hence imply different probabilities of achieving the "2 degree target". Thus, they should not be interpreted as alternative ways of reaching the same target.

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6 Annex

Table A 1: Overview of country groups and baseline CO_2 emission and GDP

	Acronym	country group	Emissions [Mt CO_2]	Baseline			
				Average growth rate of emissions		Average growth rate of GDP	
			2005	2005-2020	2020-2030	2005-2020	2020-2030
Australia***	aus	AI	373	0.02%	0.83%	1.88%	1.11%
Japan***	jpn	AI	1130	0.19%	0.19%	1.01%	1.10%
Canada***	can	AI	542	0.16%	1.13%	1.82%	1.64%
USA***	usa	AI	6011	-0.12%	0.49%	1.66%	2.03%
EU15***	EU15	AI	3410	-0.59%	0.16%	1.55%	1.37%
EU12***	EU12	AI	751	-0.57%	-0.21%	2.50%	2.03%
EU27***	EU27	AI	4161	-0.59%	0.09%	1.60%	1.41%
Switzerland***	che	AI	45	0.43%	0.43%	1.55%	1.54%
Norway***	nor	AI	37	0.32%	0.43%	1.96%	1.60%
Russia***	rus	AI	1379	-0.43%	-0.12%	3.31%	2.09%
Ukraine*	ukr	AI	284	0.01%	-0.40%	3.38%	1.96%
China**	chn	ADC	5259	4.31%	2.15%	6.85%	3.83%
Korea**	kor	NAID	447	2.15%	0.80%	2.99%	1.51%
India**	ind	ODC	1108	6.38%	3.52%	7.06%	5.18%
Mexico**	mex	ADC	413	1.04%	1.13%	2.55%	2.77%
Brazil**	bra	ADC	382	2.96%	1.72%	3.77%	2.31%
Indonesia*	idn	ODC	412	2.16%	1.53%	3.85%	3.17%
Argentina*	arg	NAID	152	3.03%	0.77%	3.82%	2.06%
Turkey*	tur	NAID	246	3.65%	2.08%	3.94%	3.51%
Egypt*	egy	ODC	166	4.53%	0.86%	5.77%	3.16%
Rest AI*	xa1	AI	257	0.88%	0.77%	3.98%	2.78%
Rest Non AI developing*[46]	xna1d	ADC	1350	2.63%	1.65%	4.30%	3.35%
Rest of ADC (incl. RSA)**[47]	xad	ADC	1267	2.61%	1.35%	4.09%	2.90%
Rest of ODC	xod	ODC	1055	4.12%	2.08%	4.06%	3.08%
LDC*	xldc	LDC	493	4.41%	2.45%	4.35%	3.40%
World	world		26967	2.03%	1.47%	2.41%	2.19%

* Business as usual (BAU) target for 2020
** Reduction target of 15% in 2020
*** Individual reduction target in 2020

46 Includes, for example, Israel, Chile, Singapore, Taiwan, or Serbia and Montenegro.

47 Includes, for example, Malaysia, Iran, Colombia, or Venezuela.

Table A 2: Overview of Copenhagen Accord and policy scenarios

	Copenhagen Accord			Scenarios			
	Target	*Base year*	*Reduction below 1990/ BAU*	*Weak Pledges*	*Ambitious Pledges*	*30%-Annex I*	*40%-Annex I*
Annex I countries							
Australia	-5% up to -15% or -25%	2000	13%/ 1%/ -11%	13.0%	-11.0%	-28.0%	-41.0%
Canada	-17%	2005	3%	3.0%	3.0%	-27.0%	-39.0%
EU 27	-20%/ -30%	1990	-20%/ -30%	-20.0%	-30.0%	-28.0%	-38.0%
Japan	-25%	1990	-25%	-25.0%	-25.0%	-25.0%	-35.0%
Norway	-30%/ -40%	1990	-30%/ -40%	-30.0%	-40.0%	-25.0%	-36.0%
Federation	-15%/-25%	1990	-15%/ -25%	-15.0%	-25.0%	-47.0%	-53.0%
Switzerland**	-20%/ -30%	1990	-20%/ -30%	BAU	BAU	-22.0%	-32.0%
Ukraine				BAU	BAU	-62.0%	-66.0%
USA	-17%	2005	-4%	-4.0%	-4.0%	-28.0%	-39.0%
Rest AI				BAU	BAU	BAU	BAU
Non-Annex I countries							
Brazil	It is anticipated that these actions will lead to an expected reduction of 36.1% to 38.9% of the projected emissions of Brazil by 2020			-36.1%	-38.9%	-15.0%	-15.0%
China	Lower CO2-emissions per unit of GDP by 40-45% by 2020 compared to the 2005, increase the share of non-fossil fuels in primary energy consumption to around 15% by 2020 and increase forest coverage by 40 million ha and forest stock volume by 1.3 billion m3 by 2020 from the 2005 level.			-1.1%	-9.3%	-15.0%	-15.0%
India	Reduce the emissions intensity of its GOP by 20-25% by 2020 in comparison to the 2005 level. The emissions from agriculture sector will not form part of the assessment of emissions intensity.			-4.6%	-10.5%	-15.0%	-15.0%
Mexico	Mexico aims at reducing its GHG emissions up to 30% with respect to the business as usual scenario by 2020, provided the provision of adequate financial and technological support from developed countries as part of a global agreement.			-30.0%	-30.0%	-15.0%	-15.0%
South Africa	South Africa reiterates that it will take nationally appropriate mitigation action to enable a 34% deviation below the 'Business As Usual' emissions growth trajectory by 2020.			-34.0%	-34.0%	-15.0%	-15.0%
South Korea	Reduce national greenhouse gas emissions by 30 % from the BAU emissions by 2020			-30.0%	-30.0%	-15.0%	-15.0%

** Countries are modelled as one group (Rest of Annex I)*

*** As of 11 March 2010 targets for Switzerland and Belarus were not yet announced at the UNFCCC homepage and are therefore not included in this analysis*

Table A 3: Equivalent Variation in 2020 (in millions 2004$)

	Pledges		Annex-I	
Region	Weak	Ambitious	30%	40%
Australia	-2572.6	-4575.1	-6282.2	-8542.7
Japan	1469.6	2689.1	4860.1	3238.1
Canada	-1779.8	-2416.4	-5594.9	-8892.7
USA	397.4	7447.0	-8019.1	-26551.5
EU27	16191.0	21029.5	34854.1	41862.9
Switzerland	-165.5	-254.6	-878.0	-1174.5
Norway	-2438.0	-3910.1	-5363.5	-7109.0
Russia	-1580.1	-4812.3	-11945.3	-24580.8
Ukraine	1420.1	2622.6	2927.6	3199.9
China	24930.0	47874.1	83153.3	152146.1
Korea	1603.6	2845.2	7323.4	10900.8
India	12323.3	22973.3	36457.1	58036.4
Mexico	-3552.0	-4954.5	-3555.6	-3242.6
Brazil	-2356.6	-3871.1	-607.5	331.7
Indonesia	-1728.0	-2422.2	-3039.5	-3601.2
Argentina	-232.1	-462.2	-701.0	-911.3
Turkey	-9.8	141.0	338.9	622.3
Egypt	-368.9	-494.4	-611.8	-722.4
Rest AI	-1179.2	-1738.0	-2239.9	-2682.9
Rest Non AI	-19943.3	-30568.7	-41732.2	-53737.1
Rest of ODC	-8321.4	-12990.9	-17884.4	-23011.0
Rest of LDC	321.4	4372.2	16834.2	29742.4
Global	-3214.8	-5167.7	-7197.6	-9397.4