GREENHOUSE GAS–AIR POLLUTION INTERACTIONS AND SYNERGIES

GAINS

ANALYSIS OF THE PROPOSALS FOR GHG REDUCTIONS in 2020 MADE BY UNFCCC ANNEX I COUNTRIES BY MID-AUGUST 2009

Fabian Wagner, Markus Amann

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INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
A-2361 LAXENBURG, AUSTRIA http://gains.iiasa.ac.at

This report analyzes the implications of the August 2009 negotiation offers (pledges) of UNFCCC parties for the Copenhagen negotiations on a post-2012 climate agreement.

The following additional information sources are available at http://gains.iiasa.ac.at/Annex1.html :

- An interactive GAINS GHG mitigation efforts calculator that allows online-comparison of mitigation efforts across Annex I Parties. Free access is provided at http://gains.iiasa.ac.at/MEC.
- Access to all input data employed for the calculations for all countries via the on-line version of the GAINS model at http://gains.iiasa.ac.at/Annex1.html.

The following reports document specific methodology details:

- GHG mitigation potentials and costs from energy use and industrial sources in Annex I countries. J. Cofala, P. Purohit, P.Rafaj. Z. Klimont, 2008
- GHG mitigation potentials and costs in the transport sector of Annex I countries. J. Borken-Kleefeld *et al.,* 2008
- GHG mitigation potentials and costs from land-use, land-use changes and forestry (LULUCF) in Annex I countries. H. Böttcher *et al*., 2008
- Potentials and costs for mitigation of non-CO_2 greenhouse gases in Annex I countries. L. Höglund-Isaksson et al., 2008

Further information:

Markus Amann
Atmospheric Pollution and Economic Development Programme
International Institute for
Applied Systems Analysis (IIASA)
Schlossplatz 1
A-2361 Laxenburg
Austria

Tel: +43 2236 807 432
Email: amann@iiasa.ac.at
Web: http://gains.iiasa.ac.at

Executive summary

This paper analyzes the implications of the August 2009 negotiation offers (pledges) of UNFCCC parties for the Copenhagen negotiations on a post-2012 climate agreement. The analysis shows that the greenhouse gas (GHG) emission reductions currently proposed by industrialized countries fall short of the pathway to reaching a 2 degree target that has been set out by the Intergovernmental Panel on Climate Change, despite the fact that the cost of meeting these pledges is much lower than anticipated. Depending on the conditions associated with the pledges, by 2020 total GHG emissions of industrialized (Annex I) countries would decline by between 5% and 17%, relative to 1990. The aggregate proposal falls short of the 25-40% range that has been referred to by the UNFCCC Kyoto Protocol negotiating group in 2007. In particular, a reduction by only 5% would merely carry forward the Kyoto Protocol targets to the next decade.

The analysis, conducted using IIASA's GAINS (Greenhouse Gas and Air Pollution Interactions and Synergies) model, suggests that with appropriate economic trading mechanisms, the conservative interpretation of pledges would involve no net costs to Annex I countries as a whole. Most of the nominal reductions could be satisfied through accounting of surplus emission permits that are implicit in the current pledges of some countries. Remaining emission cuts could be achieved through low-cost energy efficiency measures which pay for themselves over their lifetime.

Even for the most optimistic 17% emissions reduction, the analysis suggests that mitigation costs would not exceed 0.01-0.05% of the GDP of all Annex I countries, compared to a 42% increase in GDP that is assumed between now and 2020 for these same countries.

A comparison of efforts by individual parties depends on the exact metric that is used. The current negotiation offers imply costs to some countries, while others would receive net revenues from an oversupply of emission allowances. Yet, if 'hot air' emissions were excluded from the analysis and all Annex I parties agree to small positive net mitigation costs, an overall reduction of 24%, instead of 17%, could be achieved by 2020. In addition, exclusion of 'hot air' would provide incentives to invest in measures in developing countries.

The analysis is based on projections made prior to the economic crisis. It is likely that post-crisis emissions will be lower than currently projected, and that the costs of reaching the emission reduction targets will be even less than suggested in this study.

The analysis also reveals significant co-benefits on local air quality as a result of reduced GHG emissions. Despite the low ambition, implied mitigation measures would cut SO_2, NO_x and particulate matter (PM) emissions by approximately 10% at no extra costs, which will reduce local negative health impacts from fine particulate matter (PM2.5) accordingly.

The interactive version of the GAINS model and supporting material is freely available on the Internet at http://gains.iiasa.ac.at.

About the authors

Fabian Wagner and Markus Amann work in the Atmospheric Pollution and Economic Development program at the International Institute for Applied Systems Analysis.

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1 Introduction

As a step in the negotiation process for a comprehensive agreement on the reduction of global greenhouse gas emissions beyond 2012, Annex I parties to the UN Framework Convention on Climate Change (UNFCCC) have announced possible emission targets for 2020. As these targets have been announced by individual countries, it is unclear whether (i) in total the implied emission reductions of all Annex I countries would fall within the corridor of 25-40% that has been referred to by the negotiating parties, and (ii) whether the efforts implied by the current pledges are comparable across parties.

We have collected possible targets for 36 Annex I parties announced by mid-August 2009. For the purpose of this paper we refer to these targets as “pledges” with the understanding that some of them are only indicative numbers that may formally not constitute a Party’s commitment. Pledges of the various countries differ in their content, format and side conditions. Their implications on emission reductions and mitigation costs for the various parties depend on a wide range of factors, such as the assumed baseline economic development and the potential and costs for mitigation of greenhouse gas emissions in each country.

In this document we evaluate the implications of the various pledges put forward by Annex I parties for the year 2020. We use the Greenhouse gas – Air pollution Interactions and Synergies (GAINS) model developed by the International Institute for Applied Systems (IIASA) to analyze the implications on emission reductions and mitigation costs across countries, and to quantify co-benefits of GHG mitigation on the emissions of air pollutants. The GAINS Annex-I model is currently implemented for 36 Annex I parties responsible for 98% of 1990 emissions.

Some pledges leave some ambiguity on how emission reductions will be achieved, i.e., by how much domestic emissions will be reduced, and to what extent flexible instruments such as the Clean Development Mechanism (CDM) and Joint Implementation (JI) are expected to complement domestic reductions. It is also not always clear how and to what extent emission reductions in the LULUCF sector are included. In this paper we assume full flexibility in using the JI and CDM mechanisms. We also include LULUCF emissions/removals in the base year as reported to the UNFCCC in 2008 and reviewed thereafter, noting that the 2009 submission differs. We also include LULUCF as well in the baseline emission scenario, but do not include mitigation options in the LULUCF sector in our economic analysis.

The remainder of this report is organized as follows. Section 2 reviews and interprets the pledges made by countries as of August 2009. Section 3 provides an assessment of the economic aspects of the current pledges, and how implied efforts compare across Annex I parties. We summarize the methodology of the GAINS model and key assumptions, and explore the implications of different interpretations of the pledges. We present co-benefits on air pollution and discuss key uncertainties. Section 4 explores ways in which the overall emission reductions could be brought closer to the target corridor through reducing some of the most striking disparities in mitigation efforts.

2 Pledges of parties as of August 2009

2.1 Summary of pledges

As of mid-August 2009, most Annex I parties to the UNFCCC have presented pledges for the negotiations on a post-2012 climate treaty. These pledges are summarized in Table 2.1 based on announcements made in the press and interpretations thereof. Many pledges maintain some ambiguity, inter alia, about reference levels, mechanisms, side conditions, the inclusion of the LULUCF sector and the willingness to involve international flexible instruments. Given this ambiguity, we distinguish a conservative and an optimistic interpretation of the pledges. It should be noted that this interpretation has been conducted by the authors and does not necessarily represent the official positions of all parties.

Table 2.1: Pledges for emission reductions in 2020, percent of the reference year, for countries currently represented in GAINS (based on information collected from the press and interpretations thereof).

	Conservative interpretation	**Optimistic interpretation**	**Reference year**	**Inclusion of LULUCF**	**Status**
AUSTRALIA	-5%	-25% through -20% cap and trade of domestic emissions and -5% government purchases of international credits	2000	Yes	Officially announced (May 4, 2009)
CANADA	-20%	-20%	2006	t.b.d.	Officially announced
EU	-20%	-30%	1990	Not for the 20% target, t.b.d. for the 30% target	Adopted by legislation
JAPAN	-15% (relative to 2005; through domestic measures)	-25% (relative to 1990)		Not for the 15% target, t.b.d. for the 25% target	Low pledge officially announced June 10, 2009; high pledge demanded by the Democratic Party
NEW ZEALAND	-10%	-20%	1990	Yes (with current rules)	Announced in Bonn (11 August 2009)
NORWAY	-30%	-30%	1990	Yes (with current rules)	Officially announced
SWITZERLAND	-20%	-30%	1990	Yes	Switzerland announced to follow the EU
UKRAINE	-20%	-20%	1990	?	Under consideration
USA	-1% (cap: 6,095 Mt COeq)	-17% (5,123 Mt COeq) (through cap plus complementary measures)	1990	Yes	Waxman & Markey bill as of May 19 (WRI paper 22 June 2009)
RUSSIA	-10%	-15%	1990	?	Announced by president Medvedev

2.2 Implied emission reductions

The following assumptions have been made in interpreting the pledges and deriving quantitative targets for this paper:

- EU: For the lower pledge we assume that the stipulated 20% reduction of EU emissions relates to total EU GHG emissions in 1990 including LULUCF.
- Japan: A reduction target of -15% relative to 2005 has been announced by the government in June 2009. A more ambitious suggestion by the Democratic Party (DPJ) stipulates a 25% reduction relative to 1990. This corresponds to a 30% reduction below 2005. We assume that such a target would include measures abroad through flexible instruments.

- USA: We assume for our conservative estimate that the Waxman & Markey bill will be passed and will enter into force, however only stipulating an absolute emission cap of 6095 Mt CO2eq, i.e., 1% below 1990 (Larsen and Heilmayr, 2009). Our optimistic interpretation assumes reductions down to 5123 Mt CO2eq, or 17% below 1990.

With these assumptions, we derive the quantitative emission caps for the year 2020 listed in Table 2.2.

Table 2.2: Quantitative emission targets derived from the pledges, as used in this study (including emissions from the LULUCF sector). Pledges include CDM/REDD credits unless they are explicitly excluded in the announcement. Historic emissions are taken from the 2008 submission to the UNFCCC, downloaded in August 2009.

	1990	**2005**	**Conservative interpretation for 2020**			**Optimistic Interpretation for 2020**		
	Mt CO2eq	Mt CO2eq	Mt CO2eq	Change to 1990	Change to 2005	Mt CO2eq	Change to 1990	Change to 2005
AUSTRALIA	516	555	499	-3%	-10%	394	-24%	-29%
CANADA	486	726	602	24%	-17%	602	24%	-17%
EU 27	5163	4730	4130	-20%	-13%	3614	-30%	-24%
JAPAN	1180	1262	1074	-9%	-15%	885	-25%	-30%
NEW ZEALAND	41	54	37	-10%	-31%	33	-20%	-38%
NORWAY	36	19	25	-30%	30%	25	-30%	30%
RUSSIA	3506	2283	3156	-10%	38%	2980	-15%	31%
SWITZERLAND	50	53	40	-20%	-24%	35	-30%	-34%
UKRAINE	855	396	684	-20%	73%	684	-20%	73%
USA	5411	6251	6095	13%	-2%	5123	-5%	-18%
TOTAL	**17245**	**16329**	**16343**	**-5%**	**0%**	**14375**	**-17%**	**-12%**

In total for the Annex I countries as a whole, the conservative interpretation of the pledges implies a reduction of total Annex I emissions of 5% compared to 1990, or a stabilization of 2005 emissions. Thereby the overall emission level would be comparable to the target of the Kyoto protocol. The most optimistic interpretation of pledges would imply a 17% reduction relative to 1990 (or 12% compared to 2005), which falls short of the 25-40% corridor set out by the IPCC.

3 Economic aspects of the pledges

A quantification of national efforts that are involved with the current pledges in the context of capabilities and mitigation potential requires model-based analyses. In this paper we use the GAINS model, which provides a bottom-up assessment based on technical mitigation potential and costs.

The GAINS model estimates mitigation costs for the Annex I parties, based on exogenous projections of future activity rates. These estimates can be used to quantify costs that are associated with the implementation of the pledges, and to compare them across Annex I parties. However, an analysis of the costs involved in the current pledges requires additional assumptions on factors that are exogenous to the GAINS model, such as the baseline economic development and the availability and costs of CDM/REDD permits for the implementation of emission reductions in non-Annex I countries.

Other modeling tools exist to quantify mitigation potentials and costs. A comparison of these models demonstrated that, while results are not always directly comparable at the country level, models do consider consistent insights (OECD, 2009, Amann *et al.*, 2009).

3.1 Approach

3.1.1 THE GAINS MODEL

To assess mitigation potentials and costs in Annex I countries, we employ IIASA's Greenhouse gas – Air pollution Interactions and Synergies (GAINS) model. The GAINS (and its predecessor, the RAINS) models have been applied before in international negotiations to identify cost-effective air pollution control strategies, and to study the co-benefits between greenhouse gas mitigation and air pollution control in Europe and Asia (Hordijk and Amann, 2007; Tuinstra, 2007).

The GAINS model provides a framework for a coherent international comparison of the potentials and costs for emission control measures, both for greenhouse gases and air pollutants. It estimates with which measures in which economic sector emissions of the six greenhouse gases could be reduced to what extent, as well as the costs for such action. It identifies for each country the portfolio of measures that achieves a given reduction target in the most cost-effective way, and provides national cost curves that allow a direct comparison of mitigation potentials and associated costs across countries. Using a bottom-up approach that distinguishes a large set of specific mitigation measures, relevant information can be provided on a sectoral basis, and implied costs can be reported in terms of upfront investments, operating costs and costs (or savings) for fuel input. An on-line calculator is available on the Internet (http://gains.iiasa.ac.at/MEC) that enables a comparison of mitigation efforts between Annex I countries for four different regimes of flexible instruments (i.e., with and without JI trading of carbon permits within Annex I countries, and the use of CDM credits from non-Annex I countries).

Detailed documentation of the methodologies and assumptions that have been employed for the analysis of the various source sectors is available in companion documents (Amann *et al.*, 2008, Borken-Kleefeld *et al.*, 2008; Cofala *et al.*, 2008; Höglund-Isaksson *et al.*, 2008).

Open access to all input data that are used for the assessment is provided through the on-line implementation of the GAINS model (http://gains.iiasa.ac.at/Annex1.html).

While we have made assumptions about baseline emissions/removals from LULUCF in 2020 (see below), we do not consider mitigation measures in the LULUCF sector in this analysis. Thus overall cost could potentially be further reduced through mitigation measures, such as forest management.

3.1.2 ASSUMPTIONS

Methodology and concept

The analysis presented in this paper is based on a number of assumptions that have important impact on the results. We assume as a starting point the baseline economic development as presented in the energy projections of the World Energy Outlook 2008 of the International Energy Agency (IEA, 2008) and the agricultural projection of the Food and Agriculture Organization (FAO, 2003). Furthermore, it is assumed that implementation of mitigation measures will start in 2010, and that no early retirement of capital stock that was built before 2010 will take place (i.e., we assume that less-GHG emitting capital stock will be implemented at current replacement rates, or existing stock retro-fitted to the extent technically possible). Furthermore, a range of other important assumptions relate to the chosen bottom-up methodology for the assessment. For instance, our methodology does not consider possible macro-economic feedbacks, e.g., associated with increased prices for energy, and it neglects the mitigation potential that could result from changes in consumer's behavior. Similarly, potential carbon leakage, i.e., the transfer of carbon-intensive production to non-Annex I countries is not considered in our approach. For joint implementation, we do not take into account provisions for banking of permits, and how they could influence the carbon market in 2020. These assumptions are discussed in more detail in Amann *et al.*, 2008. A summary of key assumptions is provided in Table 3.5.

The analysis presented in this report includes Annex I countries with the exception of Belarus, Croatia, Iceland, Liechtenstein, Monaco and Turkey, and thereby covers 98% of 1990 emissions in Annex I countries.

Baseline economic development

Most model approaches for quantifying greenhouse gas mitigation costs derive their estimates from the difference between a baseline reference case (without dedicated mitigation measures) and a scenario in which emissions are reduced. Obviously, the choice and definition of the reference baseline has crucial impacts on the resulting cost estimates. In addition, the assumed evolution of the overall economy, and in particular of the energy and agricultural systems, has important implications for the physical potentials of and costs of GHG mitigation within a given country (Amann *et al.*, 2009). The GAINS analysis adopts such baseline projections as an exogenous input.

For the central case analyzed in this report we assume the economic development as implied in the energy projections of the World Energy Outlook 2008 of the International Energy Agency (IEA, 2008) and the agricultural projections of the Food and Agriculture Organization (FAO, 2003) as a starting point.

The baseline projection assumes a 10 percent increase in total population of the Annex I countries compared to 1990. GDP is assumed to almost double in this period (based on purchasing power parity (PPP)); compared to 2005, a 42% increase is assumed. There is wide variation between countries, both in terms of population and economic development (Table 3.1).

Table 3.1: Baseline assumptions on population and GDP development (based on IEA, 2008)

	Population (million people)			**GDP (PPP), billion €/yr**		
	1990	2020	Change to 1990	1990	2020	Change to 1990
AUSTRALIA	17.2	23.6	38%	330	768	133%
CANADA	27.7	36.6	32%	601	1263	110%
EU 27	473	496	5%	7052	12781	81%
JAPAN	123	124	1%	2572	3783	47%
NEW ZEALAND	3.4	4.7	39%	50	113	125%
NORWAY	4.2	4.8	12%	86	194	127%
RUSSIA	148	132	-11%	1505	2755	83%
SWITZERLAND	6.7	8.2	22%	189	286	52%
UKRAINE	52	43	-17%	249	422	70%
USA	254	344	35%	6449	13772	114%
TOTAL	**1109**	**1217**	**10%**	**19082**	**36137**	**89%**

Baseline emissions for the non-LULUCF sectors

The baseline projection of the International Energy Agency assumes continuation of current trends in autonomous energy efficiency improvements, so that in 2020 the starting point for additional GHG mitigation measures will be more technically advanced than today. This is in contrast to some other studies which assume a ‘frozen technology’ baseline as their starting point. The GAINS baseline emission projection takes into account (in addition to the changes in activity levels) progressive implementation of already committed mitigation measures (e.g., mitigation measures that are taken to meet the Kyoto protocol in 2012).

For non-LULUCF related sectors, the baseline projection suggests a 2% increase in greenhouse gas emissions between 1990 and 2020, or a 6% increase between 2005 and 2020 (Table 3.2). There is large variation in the development for individual countries, ranging from a 50% decline in the Ukraine to a 44% increase for Australia (relative to 1990).

Table 3.2: GHG emissions in 1990 and 2005, and the baseline projection for 2020 (excluding LULUCF)

	1990	2005	Baseline 2020		
	Mt CO2eq	Mt CO2eq	Mt CO2eq	Change to 1990	Change to 2005
AUSTRALIA	416	530	597	44%	13%
CANADA	592	734	804	36%	9%
EU 27	5568	5147	5407	-3%	5%
JAPAN	1272	1358	1332	5%	-2%
NEW ZEALAND	62	77	83	35%	8%
NORWAY	50	54	62	24%	15%
RUSSIA	3326	2123	2672	-20%	26%
SWITZERLAND	53	54	49	-8%	-10%
UKRAINE	922	426	460	-50%	8%
USA	6135	7107	7244	18%	2%
TOTAL	**18396**	**17610**	**18711**	**2%**	**6%**

Baseline emissions for the LULUCF sector

There is less robust information available about the likely evolution of LULUCF emissions and the associated potentials and costs for mitigation. As some of the pledges explicitly include LULUCF emissions, we have derived the baseline projection of LULUCF emissions based on the following assumptions:

- For Australia, New Zealand, Switzerland and the USA we use projections submitted in the Fourth National Communication (NC4) (as of 2008). Whenever there are alternative projections we use the one with lower emissions or higher removals.
- EU27 and Japan show relatively constant removals over the past 15 years, so we extrapolate this and assume the average of the years 1996-2005 as a projection for 2020.
- For Canada and Russia we also extrapolate recent trends and assume zero net emissions from the LULUCF sector in 2020. For these two countries large fluctuations in the LULUCF emissions/removals can be observed in the annual inventories. For Canada zero emission/removals from LULUCF would mean a significant emission increase relative to 1990 (a year in which removals were high), while for Russia zero emissions would mean a significant reduction in emissions relative to 1990 when large emissions were reported.
- For the Ukraine we assume that the sink capacity stabilizes at current levels, i.e., at around 30 Mt CO2eq removals per year in 2020.
- For Norway we assume removals of 20 Mt CO2eq per year. These removals are lower than reported for 2006, but higher than in 1990. The cost for reaching the mitigation target stipulated in the pledge for Norway depends crucially on whether

Norway will be able to keep current net removal levels or whether the size of the sink will decline.

In 1990, total Annex I LULUCF emissions were accounted as a carbon sink of 1.15 Gt CO2eq. With the assumptions outlined above, the sink would grow by about nine percent to 1.25 Gt CO2eq in 2020 (Table 3.3).

Table 3.3: LULUCF emissions and removals in 1990 and assumed values for the 2020 baseline (Mt CO2eq)

	1990	**2020**	**Changes 1990-2020**	
	Mt CO2eq	Mt CO2eq	% of 1990 LULUCF emissions	% of 1990 total emissions
AUSTRALIA	100	43	-57%	-11%
CANADA	-107	0	-100%	22%
EU	-403	-430	7%	-1%
JAPAN	-92	-96	4%	0%
NEW ZEALAND	-21	-9	-56%	28%
NORWAY	-14	-20	46%	-18%
SIA	180	0	-100%	-5%
SWITZERLAND	-3	-2	-38%	2%
UKRAINE	-67	-30	-55%	4%
USA	-725	-709	-2%	0%
TOTAL	**-1150**	**-1253**	**9%**	**-1%**

Total baseline emissions

With these LULUCF figures the baseline projections of total greenhouse gas emissions show a slightly lower growth, leading to a one percent increase relative to 1990, or a 7% increase relative to 2005 (Table 3.4).

The different trends in LULUCF emissions magnify the variation in the development for individual countries. If LULUCF emissions are included, changes in baseline emissions relative to 1990 range from a 50% decline in the Ukraine to a 79% increase in New Zealand.

Table 3.4: GHG emissions in the base years and the baseline projection for 2020 (including LULUCF)

	1990	2005	Baseline 2020		
	Mt CO2eq	Mt CO2eq	Mt CO2eq	Change to 1990	Change to 2005
AUSTRALIA	516	555	640	24%	15%
CANADA	486	726	804	65%	11%
EU 27	5163	4730	4977	-4%	5%
JAPAN	1180	1262	1236	5%	-2%
NEW ZEALAND	41	54	74	79%	38%
NORWAY	36	19	42	17%	118%
RUSSIA	3506	2283	2672	-24%	17%
SWITZERLAND	50	53	47	-6%	-11%
UKRAINE	855	396	430	-50%	9%
USA	5411	6251	6535	21%	5%
TOTAL	**17245**	**16329**	**17458**	**1%**	**7%**

Summary of assumptions

Key assumptions of the analysis are summarized in Table 3.5.

Table 3.5: Summary of key assumptions

- ACTIVITY PROJECTIONS OF IEA WORLD ENERGY OUTLOOK 2008 AND FAO 2003, I.E. A 42% INCREASE IN GDP COMPARED TO 2005
- IMPLEMENTATION OF MITIGATION MEASURES STARTS IN 2010
- NO EARLY RETIREMENT OF EXISTING CAPITAL STOCK
- BOTTOM-UP METHODOLOGY FOR ESTIMATING MITIGATION POTENTIALS AND COSTS, I.E., NO ADJUSTMENTS OF CONSUMER DEMAND TO INCREASED CARBON PRICE
- NO MITIGATION MEASURES FOR LULUCF EMISSIONS
- NO MACRO-ECONOMIC FEEDBACKS
- NO BEHAVIORAL CHANGES
- NO CARBON-LEAKAGE TO NON-ANNEX I COUNTRIES, I.E., PRODUCTION LEVELS ASSUMED IN THE BASELINE PROJECTION REMAIN UNCHANGED
- COST CALCULATION ASSUMES PRIVATE PAY-BACK PERIODS AND TRANSACTION COSTS
- NO BANKING OF CARBON PERMITS

3.2 Emission reductions implied by the pledges compared to the baseline

Given that countries envisage different paths of economic development, the pledges imply different GHG reductions in relation to the business-as-usual cases. For instance, in comparison to the baseline projection the conservative interpretation of the pledges range from a 44% emission cut in Norway to a 60% increase in emissions for the Ukraine (Table 3.6). Overall, the conservative interpretation of pledges for total Annex I implies a 6% emission cut in relation to baseline emissions, while the optimistic interpretation would lead to a 18% reduction in 2020 (Figure 3.1).

It is noteworthy that for Russia and the Ukraine the pledges assumed in this paper result in 18 – 23% higher emissions than the baseline projections estimated by GAINS. This means that these pledges would not require any mitigation measures in these countries, and offer a potential source of free carbon credits that could be sold to other countries under a suitable arrangement of flexible instruments.

Table 3.6: Comparison of pledges in relation to the baseline projection (including LULUCF)

	1990	**2020 baseline**	**Conservative interpretation of pledges**		**Optimistic interpretation of pledges**	
	Mt CO2eq	Mt CO2eq	Mt CO2eq	Change to baseline	Mt CO2eq	Change to baseline
AUSTRALIA	516	640	499	-22%	394	-39%
CANADA	486	804	602	-25%	602	-25%
EU 27	5163	4977	4130	-17%	3614	-27%
JAPAN	1180	1236	1074	-13%	885	-28%
NEW ZEALAND	41	74	37	-50%	33	-55%
NORWAY	36	42	25	-40%	25	-40%
RUSSIA	3506	2672	3156	18%	2980	12%
SWITZERLAND	50	47	40	-15%	35	-25%
UKRAINE	855	430	684	59%	684	59%
USA	5411	6535	6095	-7%	5123	-22%
TOTAL	**17245**	**17458**	**16343**	**-6%**	**14375**	**-18%**

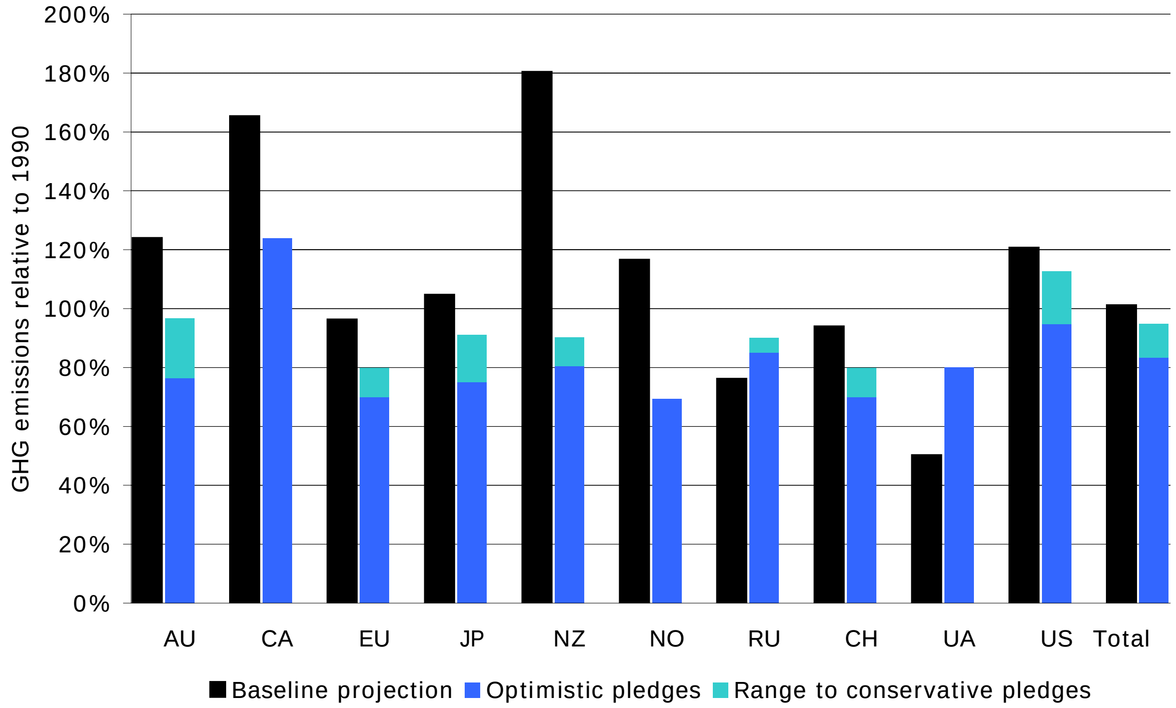

Figure 3.1: GHG emissions (including LULUCF) relative to 1990

3.3 Mitigation costs

Estimates of costs for implementation of the pledges require model-based analyses of the future mitigation potentials and associated costs for all Annex I countries. In addition, an assessment needs to consider how flexible instruments, such as joint implementation (JI), i.e., emission trading among Annex I countries, and the use of CDM/REDD permits, i.e., exchange of carbon permits with non-Annex I countries, would influence the final allocation of measures.

The GAINS model has been used to provide information on national mitigation potentials and costs for the Annex I countries, and to analyze how the pledged reductions (see Table 2.2) could materialize under the assumption that (i) Annex I countries are allowed to trade emission permits among themselves (JI), and (ii) that CDM/REDD permits could be used to complement domestic measures in the implementation of the pledged reductions.

3.3.1 COSTS FOR IMPLEMENTING THE CONSERVATIVE INTERPRETATION OF PLEDGES

As mentioned above, the conservative interpretation of pledges results for total Annex I in a 5% reduction of GHG emissions relative to 1990, or a 6% cut relative to baseline emissions projected for 2020. For estimating costs, it is important that the conservative set of pledges includes substantial over-allocations of emissions (‘hot air’) to Russia and the Ukraine. In total, their emission targets are 738 Mt CO_2 (23%) above their baseline emissions projected for 2020.

If these volumes are brought into an international carbon market arrangement to substitute for domestic mitigation measures in other Annex I countries, they amount to 4.3% of total Annex I emissions (relative to 1990). Thus, 40% of the required cuts in emissions from other Annex I countries could be settled through these permits, so that remaining Annex I countries would need to reduce an additional 1,110 Mt CO2eq either through domestic measures, through investing in other Annex I countries (JI) or through CDM/REDD credits from non-Annex I countries. Based on the GAINS cost curves, the economically efficient allocation of these reductions could theoretically be achieved at a negative carbon price within Annex I (Table 3.7).

Table 3.7: Cost-efficient allocation of emissions satisfying the conservative interpretation of pledges (including LULUCF), for JI only. Emission credits bought from abroad are indicated through negative numbers, the sale of permits with positive signs.

	1990	Total emissions		Domestic emissions		International credits
	Mt CO_2	Mt CO_2	Change to 1990	Mt CO_2	Change to 1990	Mt CO_2
AUSTRALIA	516	499	-3%	629	22%	-130
CANADA	486	602	24%	734	51%	-132
EU 27	5564[1)]	4451	-20%	4954	-11%	-503
JAPAN	1180	1074	-9%	1163	-2%	-89
NEW ZEALAND	41	37	-10%	72	75%	-34
NORWAY	36	25	-30%	39	9%	-14
RUSSIA	3506	3156	-10%	2503	-29%	652
SWITZERLAND	50	40	-20%	43	-15%	-2
UKRAINE	855	684	-20%	402	-53%	282
USA	5411	6098	13%	6127	13%	-30
TOTAL	**17646**	**16667**	**-6%**	**16667**	**-6%**	**0**

[1)] without LULUCF emissions

However, the economically efficient allocation of measures is unlikely to be achieved in reality through market instruments as, due to the oversupply of permits to some countries, the market is calculated to clear at a negative carbon price. Thus, due to possible strategic behavior of suppliers and the uncertainties associated with the banking of permits, the realization of the market equilibrium is unlikely to emerge in reality. A sensitivity case in which 'hot air' permits for Russia and the Ukraine have been excluded results in an equilibrium carbon price of 1 €/t CO_2.

3.3.2 COSTS FOR IMPLEMENTING THE OPTIMISTIC INTERPRETATION OF PLEDGES

The optimistic interpretation of pledges suggests an overall emission reduction of Annex I countries of 17% compared to 1990, to be achieved through domestic measures, JI/ET and CDM/REDD mechanisms. As the GAINS model does not represent the global carbon market, assumptions on the price at which CDM/REDD permits would be available at sufficient quantities need to be made. Given the uncertainty about this issue, two alternative cases are presented: (i) without use of CDM/REDD permits, i.e., implementation of the pledges only through measures within Annex I countries, and (ii) with CDM/REDD credits from non-Annex I countries at a price of 20 €/t CO_2.

In the first case we explore the situation without use of CDM/REDD permits to determine the carbon price that would emerge from emission trading within Annex I countries. In this case, Russia, the Ukraine and Canada emerge as sellers of permits at a price of 39 €/t CO_2 (Table 3.8). Note that 90% of these permits originate from the over-allocation of (‘hot air’) permits to Russia and the Ukraine, i.e., that they are not associated with dedicated mitigation measures.

Flexible mechanisms with non-Annex I parties would not change this allocation as long as the price at which sufficient quantities of CDM/REDD credits are available on the market is higher than this internal equilibrium price. If the price is below, Annex I countries could reduce costs through these mechanisms and substitute some of their domestic efforts with these credits.

A case has been analyzed for an assumed CDM/REDD price of 20 €/t CO_2 (Table 3.9). As the GAINS model does not address the global carbon market, this has to be seen as an arbitrary choice. For this assumed price of CDM/REDD permits, Annex I countries would acquire credits from non-Annex I countries for 455 Mt CO_2. This makes up for 2.6% of their 1990 emissions and thereby constitutes only a small fraction of the 17% reduction that is implied in the optimistic interpretation of the pledges. Due to the lower carbon price Annex I countries would generally make larger use of the internal trade within Annex I countries through JI/ET mechanisms. In this case Russia and the Ukraine would sell almost 1200 Mt CO_2 permits to other Annex I countries, with 70% of these permits resulting from ‘hot air’ allocation.

Table 3.8: Allocation of emissions satisfying the optimistic interpretation of pledges (including LULUCF) through measures within Annex I countries only, i.e., through domestic action and JI/ET mechanisms. Emission credits bought from abroad are indicated through negative numbers, the sale of permits with positive signs.

	1990	Total emissions		Domestic emissions		International credits
	Mt CO_2	Mt CO_2	Change to 1990	Mt CO_2	Change to 1990	Mt CO_2
AUSTRALIA	516	394	-24%	564	9%	-170
CANADA	486	602	24%	592	22%	10
EU 27	5163	3614	-30%	3933	-23%	-319
JAPAN	1180	885	-25%	1098	-7%	-213
NEW ZEALAND	41	33	-20%	63	54%	-30
NORWAY	36	25	-31%	36	0%	-11
RUSSIA	3506	2980	-15%	2070	-41%	910
SWITZERLAND	50	35	-30%	41	-18%	-6
UKRAINE	855	684	-20%	348	-59%	336
USA	5411	5123	-5%	5631	4%	-508
TOTAL	**17244**	**14375**	**-17%**	**14376**	**-17%**	**0**
JI/ET CREDITS						920

Table 3.9: Cost-efficient allocation of emissions satisfying the optimistic interpretation of pledges (including LULUCF), assuming a price of CDM/REDD permits of 20 €/t CO_2. Emission credits bought from abroad are indicated by negative numbers, the sale of permits with positive signs.

	1990	Total emissions		Domestic emissions		International credits
	Mt CO_2	Mt CO_2	Change to 1990	Mt CO_2	Change to 1990	Mt CO_2
AUSTRALIA	516	394	-24%	580	+12%	-186
CANADA	486	602	+24%	624	+28%	-22
EU 27	5564	3614	-30%	4242	-24%	-628
JAPAN	1180	885	-25%	1074	-9%	-189
NEW ZEALAND	41	33	-20%	64	+56%	-31
NORWAY	36	25	-30%	36	0%	-11
RUSSIA	3506	2980	-15%	2106	-40%	+874
SWITZERLAND	50	35	-30%	42	-16%	-7
UKRAINE	855	684	-20%	361	-58%	+323
USA	5411	5123	-5%	5702	+5%	-579
TOTAL ANNEX I	**17646**	**14375**	**-17%**	**14831**	**-16%**	**-455**
TOTAL CREDITS						1652
JI/ET						1197
CDM/REDD						-455

The critical role played by flexible instruments has important implications for the costs of implementing the optimistic interpretation of pledges. Accounting for the full cost savings from energy conservation measures over the lifetime, the GAINS model estimates total costs for all Annex I countries at 3.5 billion €/yr, i.e., 0.01% of the GDP projected for 2020 if no use were made of CDM/REDD permits. Without these savings, costs are calculated at 19.6 billion €/yr, i.e., 0.05% of GDP (Table 3.10). However, the significant amount of JI/ET credits implies a transfer of 48.5 billion €/yr from the buyer countries (0.12% of the buyer countries' GDP) mainly to Russia and the Ukraine, where this income would constitute 1.2% of the GDP in Russia and 2.9% in the Ukraine.

Increased flexibility through involvement of credits from non-Annex I countries through a lower CDM/REDD price would reduce overall costs. For example, for an assumed CDM/REDD price of 20 €/t CO_2, total costs for Annex I would range between close to zero and 16 billion €/year (i.e., between 0.00 and 0.04% of GDP), depending on the chosen cost concept (Table 3.11).

Table 3.10: Costs for implementing the optimistic interpretation of the pledges (billion €/year) without CDM/REDD permits. Revenues and cost savings are indicated by negative signs.

	Costs for domestic measures	Costs for inter-national meas.	Total costs (billion €/yr)	Costs as % of GDP in 2020	Per-capita costs (€/person/year)
AUSTRALIA	0.4 - 0.6	6.6	7.0 - 7.2	0.91% - 0.94%	297 - 305
CANADA	0.0 - 1.0	-0.4	-0.4 - 0.6	-0.03% - 0.05%	-11 - 18
EU 27	4.8 - 9.8	12.3	17.1 - 22.1	0.13% - 0.17%	34 - 45
JAPAN	-0.4 - 0.7	8.2	7.8 - 8.9	0.21% - 0.24%	63 - 72
NEW ZEALAND	0.0 - 0.0	1.2	1.2 - 1.2	1.07% - 1.11%	256 - 266
NORWAY	0.0 - 0.0	0.4	0.4 - 0.4	0.21% - 0.23%	84 - 93
RUSSIA	0.4 - 2.8	-35.1	-34.7 - -32.3	-1.26% - -1.17%	-264 - -246
SWITZERLAND	0.0 - 0.1	0.2	0.2 - 0.3	0.07% - 0.09%	24 - 31
UKRAINE	0.4 - 0.7	-13.0	-12.6 - -12.3	-2.99% - -2.93%	-292 - -286
USA	-2.1 - 3.8	19.6	17.5 - 23.4	0.13% - 0.17%	51 - 68
TOTAL	**3.5 - 19.6**	**0.0**	**3.5 - 19.6**	**0.01% - 0.05%**	**3 - 16**
COSTS/ INCOME FROM JI		-48.5			
COSTS FOR CDM		0			

Table 3.11: Costs for implementing the optimistic interpretation of the pledges (billion €/year) with use of CDM/REDD permits for 20 €/t CO_2. Revenues and cost savings are indicated by negative signs.

	Costs for domestic measures	Costs for inter-national measures	Total costs (billion €/yr)	Costs as % of GDP in 2020	Per-capita costs (€/person/year)
AUSTRALIA	0.0 - 0.2	3.7	3.7 - 3.9	0.48% - 0.51%	157 - 165
CANADA	-0.9 - 0.1	0.4	-0.5 - 0.5	-0.04% - 0.04%	-14 - 15
EU 27	-4.1 - 0.9	12.6	8.5 - 13.5	0.07% - 0.11%	17 - 27
JAPAN	0.9 - 2.0	3.8	4.7 - 5.8	0.12% - 0.15%	38 - 47
NEW ZEALAND	0.0 - 0.0	0.6	0.6 - 0.6	0.53% - 0.58%	128 - 138
NORWAY	0.0 - 0.0	0.2	0.2 - 0.2	0.10% - 0.12%	42 - 50
RUSSIA	-0.8 - 1.6	-17.5	-18.3 - -15.9	-0.66% - -0.58%	-139 - -121
SWITZERLAND	-0.1 - 0.0	0.1	0.0 - 0.1	0.00% - 0.02%	0 - 7
UKRAINE	0.0 - 0.3	-6.5	-6.5 - -6.2	-1.54% - -1.48%	-151 - -145
USA	-4.3 - 1.6	11.6	7.3 - 13.2	0.05% - 0.10%	21 - 38
TOTAL	**-9.3 - 6.8**	**9.0**	**-0.3 - 15.8**	**0.00% - 0.04%**	**0 - 13**
COSTS/ INCOME FROM JI		24			
COSTS FOR CDM		9			

3.4 Comparison of efforts

While the above section evaluates mitigation costs that can be estimated for the pledges that have been presented by Annex I countries, meaningful comparisons of efforts should relate them to various indicators of national circumstances that characterize differences in capabilities across countries. However, comparing efforts involved with the pledges is a delicate process as there are no simple objective methods available for establishing comparability (OECD, 2009).

Indicators can be defined that relate to national circumstances that can be simply derived from available historical statistics, such as population, the level of economic activity, and historic emission levels. Such indicators are transparent and can be easily understood. As examples, Figure 3.2 and Figure 3.3 compare emissions implied by the pledges on a per-capita and a per-GDP basis.

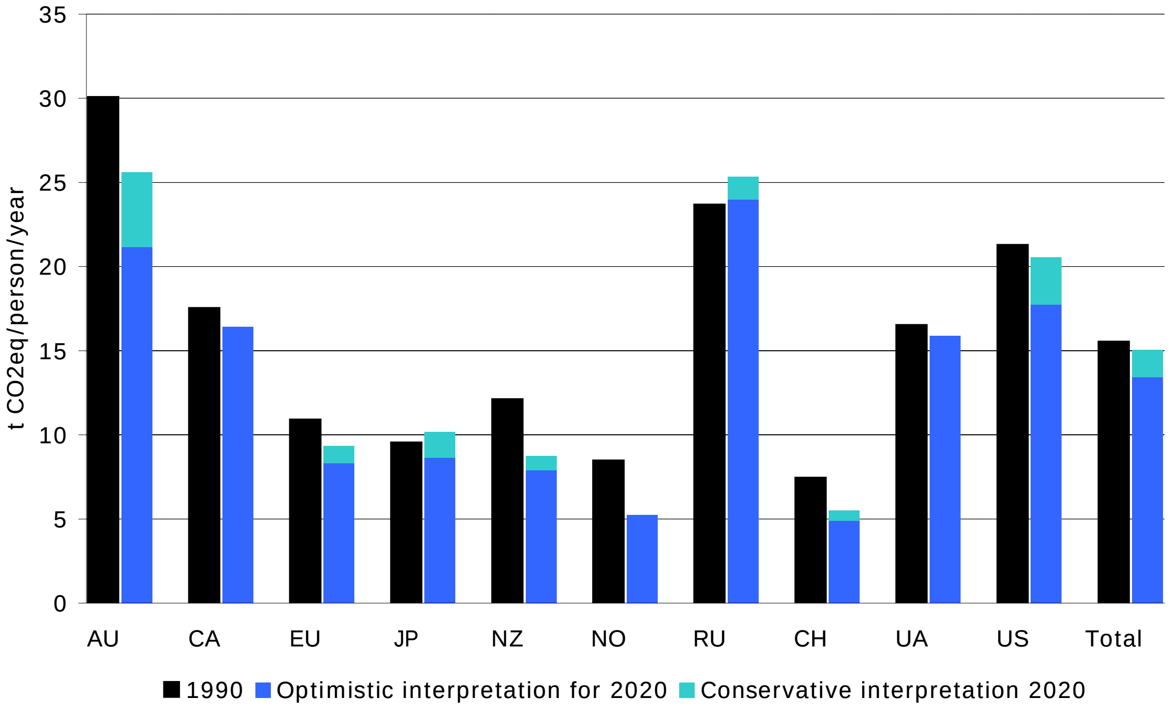

Figure 3.2: Per-capita GHG emissions in 1990 and for the two interpretations of pledges for 2020 (including LULUCF emissions; for 2020 projected population numbers are used)

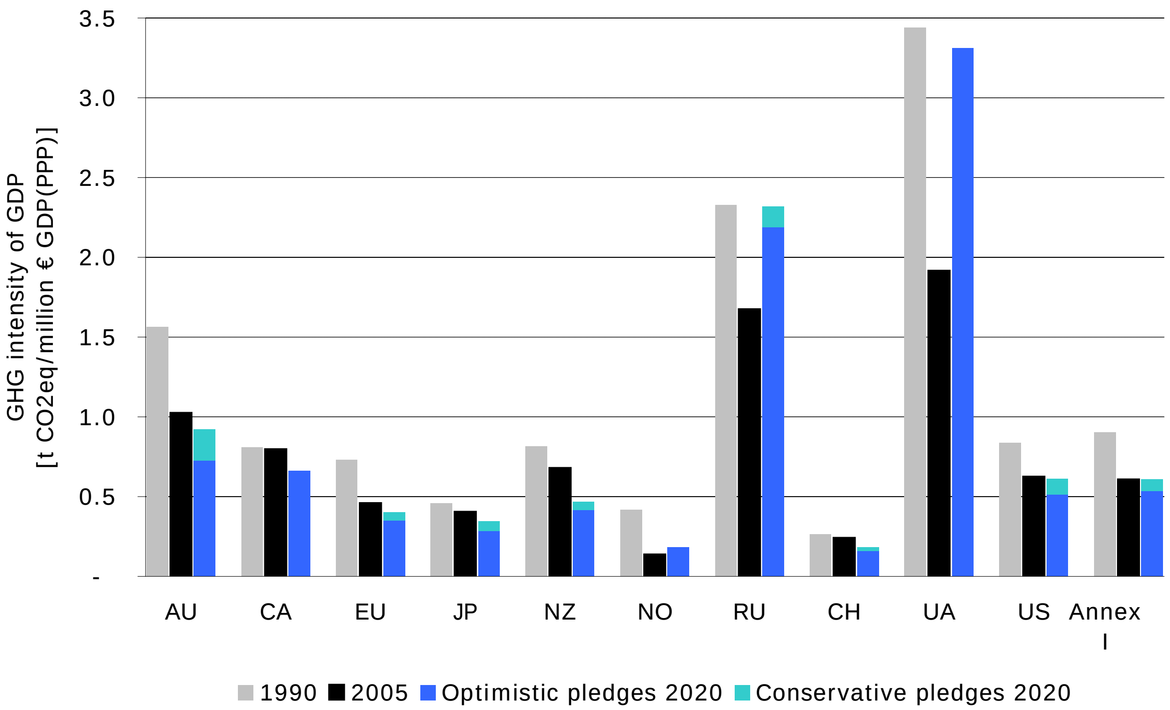

Figure 3.3: Greenhouse gas intensities of Annex I countries in 1990 and 2005 and for the 2020 pledges calculated from historic statistics (Intensities for 2020 are calculated with 2005 GDP numbers.)

While these indicators are indisputable, they do not necessarily reflect the efforts that are involved in pledges in the context of current and future national capability and mitigation potential. However, neither the future evolution of population trends and economic development nor the potentials and costs for future greenhouse gas mitigation can be extracted from historical statistics; models are a prerequisite for comparing economic efforts that are involved in the pledges.

It has been shown before that the low pledges, in the presence of the substantial amount of 'hot air' allowances, will most likely not lead to a functioning carbon market, so that mitigation costs are difficult to assess in an accurate manner.

For the optimistic interpretation of the pledges, total costs amount in the worst case (without CDM) to 0.01 - 0.05% of the GDP(PPP) for all Annex I countries together. However, there are large differences across countries. Some countries are facing significant costs (e.g., 1.1% for New Zealand), while others enjoy net revenues - up to 2.9% of the GDP for the Ukraine - from the sale of permits (Table 3.12). Use of CDM/REDD credits will reduce costs, and differences between countries will decline (Figure 3.4).

On a per-capita basis, costs without permits range from almost 300 €/person/year for Australia to an income of 290 €/person/year for the Ukraine (Figure 3.5).

Table 3.12: Comparison of economic efforts for the optimistic interpretation of the pledges. Note that negative figures indicate financial revenues. The cost range reflects different assumptions on the accounting of cost savings from energy conservation measures.

	Per-capita costs (€/person/year)		**Costs % of GDP(PPP) in 2020**	
	Without CDM	for a CDM price of 20 €/t CO_2	Without CDM	for a CDM price of 20 €/t CO_2
AUSTRALIA	292 - 301	157 - 165	0.90 - 0.92%	0.48 - 0.51%
CANADA	-11 - +18	-14 - +15	-0.03 - +0.05%	-0.04 - +0.04%
EU 27	34 - 45	17 - 27	0.13 - 0.17%	0.07 - 0.11%
JAPAN	63 - 72	38 - 47	0.21 - 0.24%	0.12 - 0.15%
NEW ZEALAND	256 - 266	128 - 138	1.07 - 1.11%	0.53 - 0.58%
NORWAY	84 - 93	42 - 50	0.21 - 0.23%	0.10 - 0.12%
RUSSIA	-264 - -246	-139 - -121	-1.26 - -1.17%	-0.66 - -0.58%
SWITZERLAND	24 - 31	0 - 7	0.07 - 0.09%	0.00 - 0.02%
UKRAINE	-290 - -284	-151 - -145	-2.96 - -2.90%	-1.54 - -1.48%
USA	51 - 68	21 - 38	0.13 - 0.17%	0.05 - 0.10%
TOTAL	**3 -16**	**0 - 13**	**0.01 - 0.05%**	**0.00 - 0.04%**

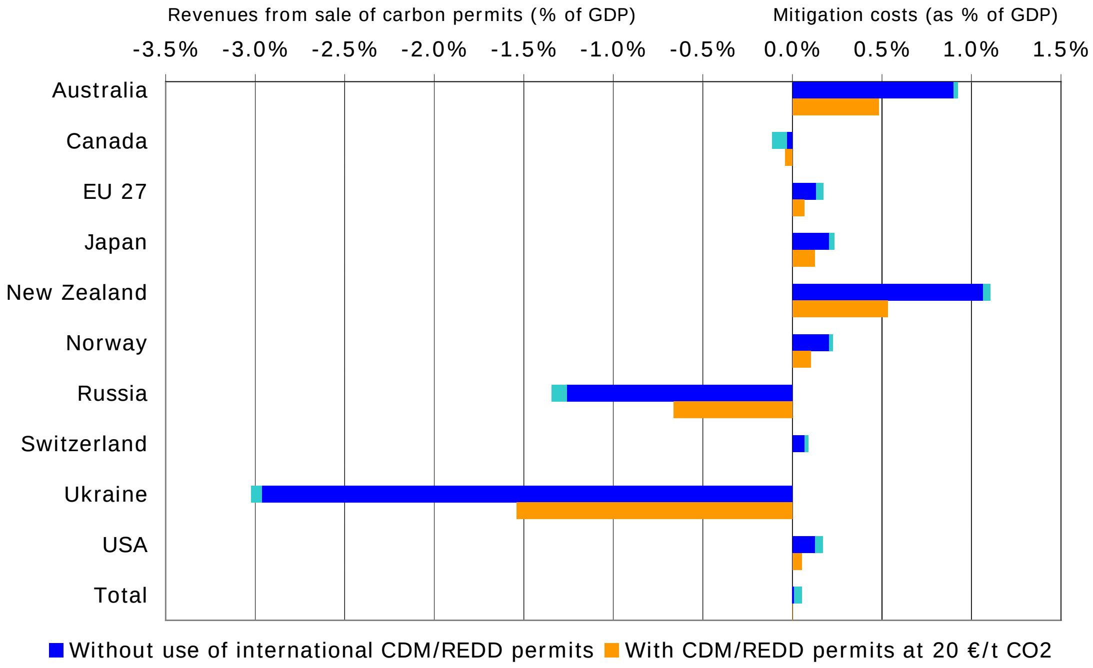

Figure 3.4: Costs and revenues for the implementation of the optimistic interpretation of the pledges as a percentage of GDP (PPP) in 2020. Light bars indicate the uncertainty resulting from the treatment of cost savings from energy conservation measures.

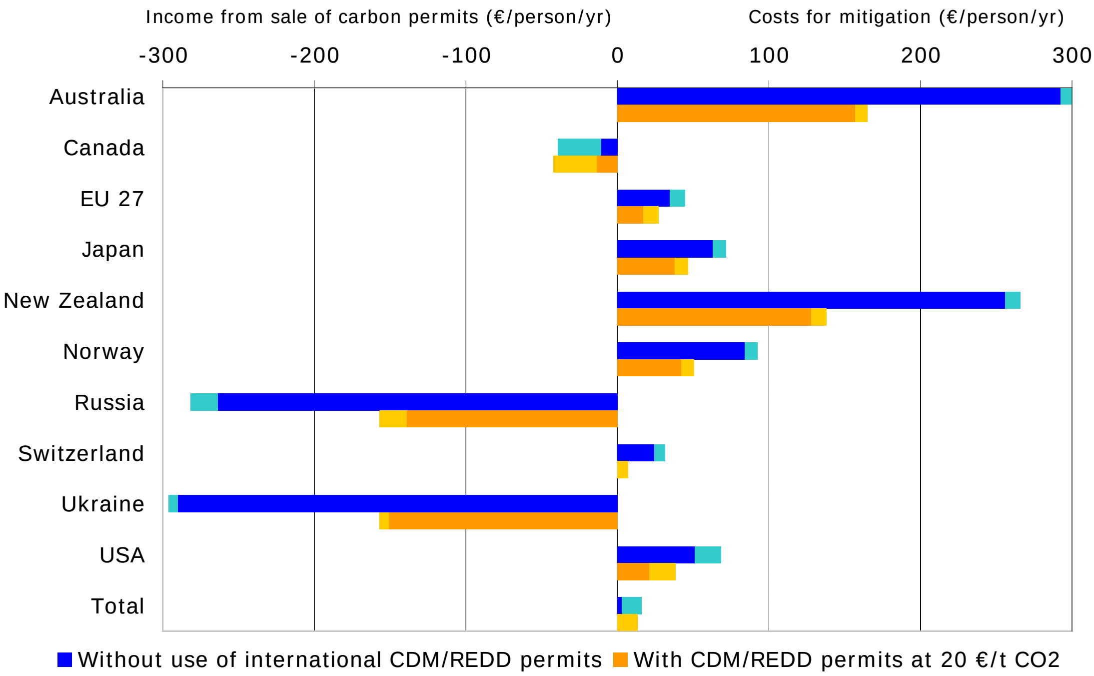

Figure 3.5: Costs and revenues for the implementation of the optimistic interpretation of the pledges on a per-capita basis. Light bars indicate the uncertainty resulting from the treatment of cost savings from energy conservation measures.

3.5 Co-benefits on air pollution

In many cases greenhouse gas mitigation is achieved through measures that reduce the combustion of the most carbon-intensive fossil fuels, such as energy conservation and substitution of coal by natural gas and other fuels. The resulting decline in fossil fuel consumption is not only beneficial for greenhouse gas emission, but at the same time it also reduces emissions of conventional air pollutants. Analysis with the GAINS model, which quantifies emissions of a suite of atmospheric pollutants, demonstrates that this co-control is significant.

Obviously, such co-benefits on local air quality depend crucially on the extent to which measures are implemented at home, as a transfer of mitigation measures to other countries will also shift these co-benefits to these countries. For the case that achieves most reductions within Annex I countries, i.e., the optimistic interpretation of pledges without use of CDM/REDD permits, emissions of local air pollutants would decline in Annex I countries by about 10 percent compared to baseline emissions (Table 3.13). For the other scenarios that imply less domestic measures co-benefits are somewhat smaller.

Table 3.13: Change in emissions of air pollutants that result from implementation of the GHG mitigation measures, relative to the emission levels projected for the baseline in 2020.

	Change in domestic GHG	**Change in air pollutant emissions (relative to the baseline case in 2020)**		
	(relative to 1990)	SO_2	NO_x	PM2.5
OPTIMISTIC INTERPRETATION OF PLEDGES WITHOUT USE OF CDM				
AUSTRALIA	9%	-14%	-13%	-32%
CANADA	22%	-11%	-13%	-11%
EU 27	-24%	-20%	-11%	-10%
JAPAN	-7%	-11%	-7%	-5%
NEW ZEALAND	54%	-8%	-7%	-16%
NORWAY	0%	-7%	-3%	-1%
RUSSIA	-41%	-18%	-8%	-7%
SWITZERLAND	-18%	-12%	-9%	-3%
UKRAINE	-59%	-6%	-6%	-13%
USA	4%	-3%	-7%	-10%
TOTAL ANNEX I	**-17%**	**-12%**	**-9%**	**-9%**
OPTIMISTIC INTERPRETATION OF PLEDGES, WITH CDM				
TOTAL ANNEX I	-14%	-9%	-7%	-8%
CONSERVATIVE INTERPRETATION OF PLEDGES				
TOTAL ANNEX I	-6%	-6%	-6%	-5%

3.6 Uncertainties

Obviously, the results from the model analysis presented in this paper depend on a number of assumptions and methodological choices. The following paragraphs discuss key factors that contribute to uncertainties, their importance, and how they have been addressed in the analysis.

Formulation of pledges

In some cases the formulation of announced pledges is not always unambiguous and a quantitative interpretation requires some subjective judgments and assumptions. Thus, we present two cases in this paper, i.e., a conservative and an optimistic interpretation.

Quantification of mitigation potentials and costs

The economic assessment of the mitigation potentials and costs requires complex models, which in themselves employ numerous assumptions and methodological choices. A recent intercomparison exercise of eight models demonstrates that results of the GAINS model, which is used for the analysis presented in this paper, fall well within the range of other bottom-up models (Amann *et al.*, 2009). However, top-down models that include the response of economic actors to increased carbon prices and other macro-economic feedbacks suggest significant larger mitigation potentials at typically only half of the costs calculated by bottom-up models. Thus, the cost figures presented in this paper should be seen as an upper bound, and costs estimated by, e.g., computable general equilibrium (CGE) models are likely to be substantially lower.

However, there is an issue about costs of measures whose initial investments are compensated by subsequent cost savings, e.g., from reduced fuel consumption over the full technical lifetime. Although engineering analyses show negative costs of such measures, in practice they are often not adopted by consumers. A variety of arguments is delivered to explain this behavior, including shorter subjective pay-back periods of private actors, the principal agent problem, transaction and information costs. While the GAINS model includes some of these factors in its analysis, a strict analysis still results in some negative cost measures (e.g., for improved insulation of houses or fuel-saving measures for commercial trucks). Other models take different approaches, e.g., by assuming that such measures are per definition included in the baseline development, or by specifying empirical transaction costs that eliminate these cost savings.

For this report we calculate two sets of cost estimates: one following the strict interpretation with negative life-cycle costs for some measures, and another more conservative interpretation where we assume costs in such a way that all measures are associated with positive costs.

While these two approaches do not cause major differences for mitigation strategies that aim at the stabilization of greenhouse gas concentrations in the atmosphere, they result in somewhat different cost estimates for less ambitious strategies that involve only few (and cheap) mitigation measures.

Emissions from the LULUCF sector

A particular source of uncertainties is associated with the quantification of emissions from the LULUCF sector. Our analysis employs a baseline projection of future LULUCF emissions, so that the percentage reduction targets of the pledges are applied to the appropriate base year and baseline figures. We use LULUCF inventory data from the 2008 submission to the UNFCCC and baseline projections as reported by countries in their national communications, and extrapolate current inventories for countries that did not provide such numbers to UNFCCC. LULUCF emissions reported by some countries (e.g., Russia, Canada) for different years show large inter-annual fluctuation, and it is uncertain whether the mean number would apply for the target year 2020.

Since Russia reported relatively high emissions from LULUCF in 1990, extrapolating a zero emission trend could lead to an underestimation of 2020 baseline emissions, and thus an underestimation of costs. In contrast, Canada has reported relatively high removals for 1990, so an extrapolation of the current trend could lead to an overestimation of baseline emissions and thus an overestimation of costs.

Furthermore, as the GAINS model does not yet include an assessment of mitigation measures and costs for the LULUCF sector, we do not consider such measures in our analysis. If measures turn out to be cost-effective, they would substitute more expensive measures assumed in our analysis for other sectors and thus reduce total costs.

Baseline against which costs are evaluated

As concluded at the recent model intercomparison exercise at IIASA, model estimates of mitigation potentials and costs are sensitive towards exogenous assumptions on baseline economic development (Amann *et al.*, 2009). The assessment presented above is based on the most recent projection of economic activities of the World Energy Outlook 2008 of the International Energy Agency (IEA, 2008). This scenario assumes for 2020 an oil price of 104 US-$_{2005}$/barrel and a growth of GDP in Annex I countries by 42% relative to 2005.

A sensitivity analysis has been conducted to explore how conclusions presented in this paper change for different assumptions on economic development. This sensitivity analysis adopts the economic projections of the IEA World Energy Outlook 2007 as the reference baseline case, assuming for 2020 slightly higher economic growth (+44% of Annex I GDP relative to 2005) and an oil price of 57 US-$/barrel in 2020 (IEA, 2007).

While a different economic baseline does not influence the quantitative emission targets implied by the pledges, it leads to different cost estimates for meeting these targets. The higher energy consumption of the IEA 2007 projection that results from the assumptions on higher economic growth and lower oil prices implies in 2020 a 6% increase of baseline GHG emissions relative to 1990 (compared with a 1% increase of the 2008 projection). However, with current pledges there are sufficient 'hot air' permits on the market to comply with the conservative interpretation of the pledges even for this higher projection, so that no meaningful cost estimate can be provided also in this case. Implementation of the optimistic interpretation of pledges without CDM would involve total costs of 25.3 billion €/yr (0.06% of GDP), compared to 3.5 billion €/yr for the low growth case. Use of CDM/REDD credits would reduce costs, e.g., to 21 billion €/yr (0.05% of GDP) for a carbon price of 20 €/t CO_2.

While this analysis demonstrates the critical impact of the assumed economic baseline development on mitigation costs, it refers in both cases to projections before the current economic crisis. Based on the findings above one could argue that, if the current crisis leads to lower economic activity in 2020 than projected in the 2008 baseline, also mitigation costs will be lower than those presented here for this central case.

4 Discussion

The above analysis demonstrates that a conservative interpretation of the current pledges for greenhouse gas reductions implies for 2020 a decline of total Annex I emissions by 5% relative to 1990, which does not go beyond what has been agreed in the Kyoto protocol for 2012. Because of the large amount of 'hot air' allowances that are implied by the current pledges of some parties, it is unlikely that a significant carbon market would emerge that would lead to an economically efficient allocation of mitigation measures.

Our optimistic interpretation of pledges would lead by 2020 to a reduction in Annex I greenhouse gas emissions of 17% relative to 1990. However, implied emission cuts would still remain below the 25-40% corridor that has been referred to by negotiating parties (cf. paragraph 16 in UNFCCC document FCCC/KP/AWG/2007/5).

While an in-depth comparison of individual parties' efforts depends on the metrics used, the analysis reveals that the current negotiation offers imply costs to some countries, while others would receive net revenues from an oversupply of emission allowances. This would lead to significant financial transfers to countries that argue for an oversupply of credits, so that these Annex I countries would receive financial revenues from an international climate accord without taking actual mitigation measures. This is in contrast to the other Annex I parties who have with their pledges indicated their willingness to spend resources for greenhouse gas mitigation.

The question about appropriate additional measures that could bring the emission trajectory of Annex I countries into the target corridor cannot be decided on a purely scientific basis, as it requires political judgment and negotiations.

Without embarking on a particular political judgment on the comparability of efforts, an illustrative analysis has been conducted that explores to what extent an adjustment of the optimistic pledges could eliminate the striking disparity in mitigation costs and bring total Annex I emissions closer to the target corridor. Our basic rationale assumes that (a) countries whose pledges involve positive mitigation costs will implement them according to our optimistic interpretation, and (b) Annex I countries with pledges that lead to net financial revenues would accept targets that involve at least small positive costs. This would avoid allocation of surplus permits and lead to all parties participating in a meaningful carbon market that minimizes overall costs.

With the help of the GAINS model we analyze such a case under the assumption that JI/ET trading would be allowed among Annex I countries and that CDM/REDD permits from non-Annex I countries can be acquired at a carbon price of 20 €/t CO_2 (Table 4.1).

Table 4.1: A hypothetical case based on the optimistic interpretation of pledges, with reductions adjusted so that mitigation costs in all Annex I countries are positive. Ranges given for cost estimates refer to different interpretations of measures with negative costs. Figures printed in italic denote emission changes relative to 1990.

	Emissions (Mt CO2eq)					Costs (billion €/yr)			
	Total		Domestic emissions		Credits	for domestic measures	for credits	Total costs	% of GDP
AUSTRALIA	394	*-24%*	580	*12%*	-186	0.0-0.2	3.7	3.7-3.9	0.48-0.51%
CANADA	578	*19%*	624	*28%*	-46	-0.9-0.1	0.9	0.0-1.1	0.00-0.08%
EU 27	3614	*-30%*	4242	*-18%*	-628	-4.1-1.0	12.6	8.5-13.5	0.07-0.11%
JAPAN	885	*-25%*	1113	*-6%*	-227	-0.8-0.3	4.5	3.7-4.8	0.10-0.13%
NEW ZEALAND	33	*-19%*	64	- *57%*	-31	0.0-0.0	0.6	0.6-0.6	0.52-0.57%
NORWAY	25	*-30%*	36	*1%*	-11	0.0-0.0	0.2	0.2-0.2	0.10-0.12%
RUSSIA	2062	*-41%*	2106	*-40%*	-44	-0.8-1.5	0.9	0.1-2.4	0.00-0.09%
SWITZERLAND	35	*-30%*	42	*-17%*	-7	-0.1-0.0	0.1	0.1-0.1	0.03-0.05%
UKRAINE	361	*-58%*	361	*-58%*	0	0.0-0.3	0.0	0.0-0.3	0.00-0.06%
USA	5123	*-5%*	5702	*5%*	-579	-4.3-1.7	11.6	7.3-13.2	0.05-0.10%
ANNEX I	**13110**	***-24%***	**14870**	***-14%***	**-1760**	**-11.0-+5.0**	**35.2**	**24.2-40.2**	**0.07-0.11%**

In such a case total Annex I emissions in 2020 (including LULUCF) would be 24% lower than in 1990. Total costs in Annex I range between 0.07 and 0.11% of GDP depending on the chosen cost concept, and no country would see negative costs. It is interesting to point out that, with an assumed price of CDM/REDD credits of 20 €/t CO_2, 35 billion €/yr (0.1% of GDP) would be invested in measures in developing countries, compared to 9 billion €/yr in the arrangement with ‘hot air’ allowances.

5 Conclusions

The greenhouse gas (GHG) emission reductions currently proposed by industrialized countries fall short of the pathway to reaching a 2 degree target that has been referred to by the UNFCCC Kyoto Protocol negotiating group, despite the fact that the cost of meeting these pledges is much lower than anticipated. Depending on the conditions associated with the pledges, by 2020 total GHG emissions of industrialized (Annex I) countries would decline by between 5% and 17%, relative to 1990. The aggregate proposal falls short of the 25-40% range. In particular, a reduction by only 5% would merely carry forward the Kyoto Protocol targets to the next decade.

The analysis, conducted using IIASA's GAINS (Greenhouse Gas and Air Pollution Interactions and Synergies) model, suggests that with appropriate economic trading mechanisms, the conservative interpretation of pledges would involve no net costs to Annex I countries as a whole. Most of the nominal reductions could be satisfied through accounting of surplus emission permits that are implicit in the current pledges of some countries. Remaining emission cuts could be achieved through low-cost energy efficiency measures which pay for themselves over their lifetime.

Even for the most optimistic 17% emissions reduction, the analysis suggests that mitigation costs would not exceed 0.01-0.05% of the GDP of all Annex I countries, compared to a 42% increase in GDP that is assumed between now and 2020 for these same countries.

A comparison of efforts by individual parties depends on the exact metric that is used. The current negotiation offers imply costs to some countries, while others would receive net revenues from an oversupply of emission allowances. Yet, if 'hot air' emissions were excluded from the analysis and all Annex I parties agree to small positive net mitigation costs, an overall reduction of 24%, instead of 17%, could be achieved by 2020. In addition, exclusion of 'hot air' would provide incentives to invest in measures in developing countries.

The analysis is based on projections made prior to the economic crisis. It is likely that post-crisis emissions will be lower than currently projected, and that the costs of reaching the emission reduction targets will be even less than suggested in this study.

The analysis also reveals significant co-benefits on local air quality as a result of reduced GHG emissions. Despite the low ambition, implied mitigation measures would cut SO_2, NO_x and particulate matter (PM) emissions by approximately 10% at no extra costs, which will reduce local negative health impacts from fine particulate matter (PM2.5) accordingly.

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