GREENHOUSE GAS–AIR POLLUTION INTERACTIONS AND SYNERGIES

GAINS

THE IMPACT OF THE ECONOMIC CRISIS ON GHG MITIGATION POTENTIALS AND COSTS IN ANNEX I COUNTRIES

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This report analyzes how GHG mitigation potentials and costs in the Annex I countries of the UNFCCC are influenced by the current economic crisis.

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

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Executive summary

Estimates of greenhouse gas mitigation potentials and costs are sensitive towards the underlying assumptions on the levels of future economic activities. This paper compares estimates derived with IIASA's Greenhouse gas – Air Pollution Interactions and Synergies (GAINS) model for two economic projections that were developed before and after the current economic crisis, respectively.

The pre-economic crisis projections of future levels of economic activities employs the energy projection published by the International Energy Agency (IEA) in its World Energy Outlook (WEO) in 2008, while the post-crisis projection relies on the 2009 World Energy Outlook of the IEA. In 2020, projected GDP in Annex I countries is 7% lower in the 2009 projection compared to what was assumed the pre-crisis 2008 outlook. This lower level of economic activity implies 8% less greenhouse gas emissions, if no further climate measures were taken. Thereby, Annex I emissions would decline by 6% in 2020 relative to 1990 (compared to an increase of 2% in the IEA WEO 2008).The post-crisis energy structure also affects the potential for and costs of mitigating greenhouse gas emissions. For instance, for a carbon price of 50 €/t CO_2 Annex I countries could reduce their emissions by 27% below 1990 levels, compared to a 17% potential that is calculated for the WEO 2008.

As a consequence, emission caps that are determined based on pre-economic crisis activity projections might not require any dedicated mitigation efforts if economic activities develop along the post-crisis projections. The implications of post-crisis activity projections on the current pledges for GHG reductions for a post-2012 climate agreement are analyzed in a companion paper (Wagner and Amann, 2009b).

Due to measures for which cost savings over their technical life time exceed the up-front investments (i.e., measures with negative mitigation costs over their life cycle), total Annex I emissions could be reduced by 23% below 1990 levels without net costs over the life cycle. For a pre-crisis projection this potential was estimated at only 14%.

While total mitigation costs are small compared to the assumed baseline increase in GDP, up-front investments are significant. For instance, to achieve the 23% reduction of Annex I GHG emissions in 2020, annual investments in the period 2011-2020 amount to approximately 0.5% of the GDP. As pointed out above, however, cost savings from the subsequent reduced energy demand compensate these costs in the following years until the end of the technical life time of the investment, so that such a reduction will not involve net costs to society in the long run. Up-front investments are most significant in the domestic sector, where such a 23% reduction in total emissions would require annual investments of approximately €120 bn/yr in the period 2011-2020. In contrast, investments in the power sector would be €20 bn/yr lower than in the baseline case, due to lower electricity demand resulting from the energy efficiency improvements in the end use sectors.

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

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Acknowledgements

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1 Introduction

Robust quantification of the future potentials and costs for mitigating greenhouse gases in different countries could provide important information to the current negotiations on a post-2012 climate agreement. However, such information is not readily available from statistical sources, but requires the use of complex models that combine economic, technological and social aspects. A recent comparison of estimates from eight models demonstrated that future economic development has a strong impact on the efforts necessary to achieve given emission reduction levels (Amann *et al.*, 2009).

Once corrected for different assumptions on future economic development, the time window for implementation, the model approach (e.g., inclusion of macro-economic feedbacks), and the definition of the baseline and how measures with negative costs are treated, models show striking agreement on the potentials and costs for GHG mitigation.

For the negotiations on a post-2012 climate agreement, Wagner and Amann, 2009a have analyzed the pledges made by countries as of August 2009 and how implied efforts compare across Annex I parties. It was concluded that, 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 analysis suggested 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 proposed 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.

This analysis of Wagner and Amann, 2009a was based on the projection of economic development that has been presented by the International Energy Agency (IEA) in November 2008 in its World Energy Outlook 2008 (IEA, 2008). Dating back to 2008, this projection clearly reflects a perspective before the economic crisis. In the meantime, however, the economic crisis has profoundly modified the expectations on economic growth for the year 2020. In particular, the forthcoming World Energy Outlook 2009 of the IEA projects GDP to increase by 32% by 2020, compared to a growth of 42% in the 2008 World Energy Outlook (IEA, 2009).

The question arises how the lower levels of economic activities that are suggested by post-crisis projections influence potentials for and costs of greenhouse gas mitigation in the Annex I countries. Using IIASA's GAINS model, this report compares mitigation potentials and costs in Annex I countries for the activity projections of the World Energy Outlook (WEO) 2008 with those of the 2009 Outlook.

The remainder of this report is organized as follows: Section 2 briefly reviews methodology and key assumptions of the analysis and compares the economic development trends assumed in the World Energy Outlooks of 2008 and 2009. Section 3 compares resulting

GHG mitigation potentials and costs, outlining differences in baseline emissions, and mitigation potentials. It discusses total mitigation costs over the technical lifetime of investments, and contrasts them with the associated up-front investments that occur up to 2020. Conclusions are drawn in Section 4.

2 Approach and assumptions

A quantification of national efforts that are involved with the current pledges in the context of capabilities and mitigation potential requires model-based analyses. The GAINS model provides such 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 provide consistent insights (OECD, 2009, Amann *et al.*, 2009).

2.1 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.*, 2008a, Borken-Kleefeld *et al.*, 2008; Amann *et al.*, 2008b; 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).

2.2 Assumptions

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.

The analysis presented in this report assumes 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., 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, the 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. A summary of key assumptions is provided in Table 2.1.

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.

Table 2.1: Summary of key assumptions

• ACTIVITY PROJECTIONS OF IEA WORLD ENERGY OUTLOOK 2008/2009 AND FAO 2003, I.E. A 42%/32% 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
• LULUCF EMISSIONS ARE EXCLUDED
• 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

2.3 Baseline assumptions on future economic activities

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 for and costs of GHG mitigation within a given country (Amann *et al.*, 2009). The GAINS analysis adopts such baseline projections as an exogenous input.

This report compares GHG mitigation potentials and costs estimated by GAINS for two different economic projections that reflect pre- and post-crisis perspectives, respectively. In particular, the analysis employs the energy and economic projections of the World Energy Outlooks that have been presented in 2008 and 2009 by the International Energy Agency (IEA, 2008, IEA, 2009), complemented by country-specific information for the EU Member States from the PRIMES model[1]. It should be noted that both projections of the World Energy Outlook reflect business-as-usual scenarios without dedicated policies to reduce greenhouse gas emissions. As corresponding projections for agricultural activities are not available, for both cases the projections of the Food and Agriculture Organization (FAO, 2003) are employed, although different economic development is likely to influence agricultural production.

While the assumptions on population development differ only slightly between the WEO 2008 and 2009 (Table 2.2, Figure 2.1), there are significant differences in the assumed economic development (Table 2.3, Figure 2.3). The World Energy Outlook published in 2008 assumed a continuous growth in GDP up to 2020, leading to 42 percent increase in GDP relative to 2005 (expressed in purchasing power parity (PPP)) for the Annex I countries considered in this analysis (Figure 2.2). In contrast, in view of the current economic crisis the 2009 Outlook anticipates for 2010 a recovery of GDP to the 2005 level, and assumes for the time thereafter similar annual growth rates as in the WEO 2008. This implies for 2020 a 32% increase in GDP relative to 2005, so that total GDP in 2020 would be 7% lower than assumed in the 2008 Outlook. Obviously there are wide variations across countries.

[1] The IEA World Energy Outlooks do not provide country-details for Norway and Switzerland, and group these countries together with Turkey. For the GAINS analysis a baseline projection of these two countries has been constructed based on national information and post-crisis trends of similar EU countries. However, as at the time of writing only one such projection is available, the analysis in this paper employs for Norway and Switzerland the same projection for the WEO 2008 and 2009 cases.

Furthermore, as the WEO does not provide projections for individual EU Member States, the GAINS analysis presented in this report employs the 2007 and 2009 country-specific projections developed with the PRIMES energy model for the European Commission, respectively. In aggregate for the EU-27 these scenarios match closely the IEA WEO projections.

Table 2.2: Assumptions on population development (million people)

			2020			
	1990	2005	WEO 2008	Change to 1990	WEO 2009	Change to 1990
AUSTRALIA	17.2	20.5	23.6	37%	23.9	39%
CANADA	27.7	32.3	36.6	32%	37.1	34%
EU-27	473.0	489.2	496.4	5%	508.1	7%
JAPAN	123.0	127.8	124.3	1%	124.0	1%
NEW ZEALAND	3.4	4.1	4.7	38%	4.7	39%
NORWAY	4.2	4.6	4.9	18%	4.9	18%
RUSSIA	148.0	143.1	131.6	-11%	131.6	-11%
SWITZERLAND	6.7	7.3	7.5	12%	7.5	12%
UKRAINE	52.0	46.9	43.1	-17%	44.0	-15%
USA	254.0	301.3	343.9	35%	344.1	35%
TOTAL	**1109.0**	**1177.1**	**1216.7**	**10%**	**1230.0**	**11%**

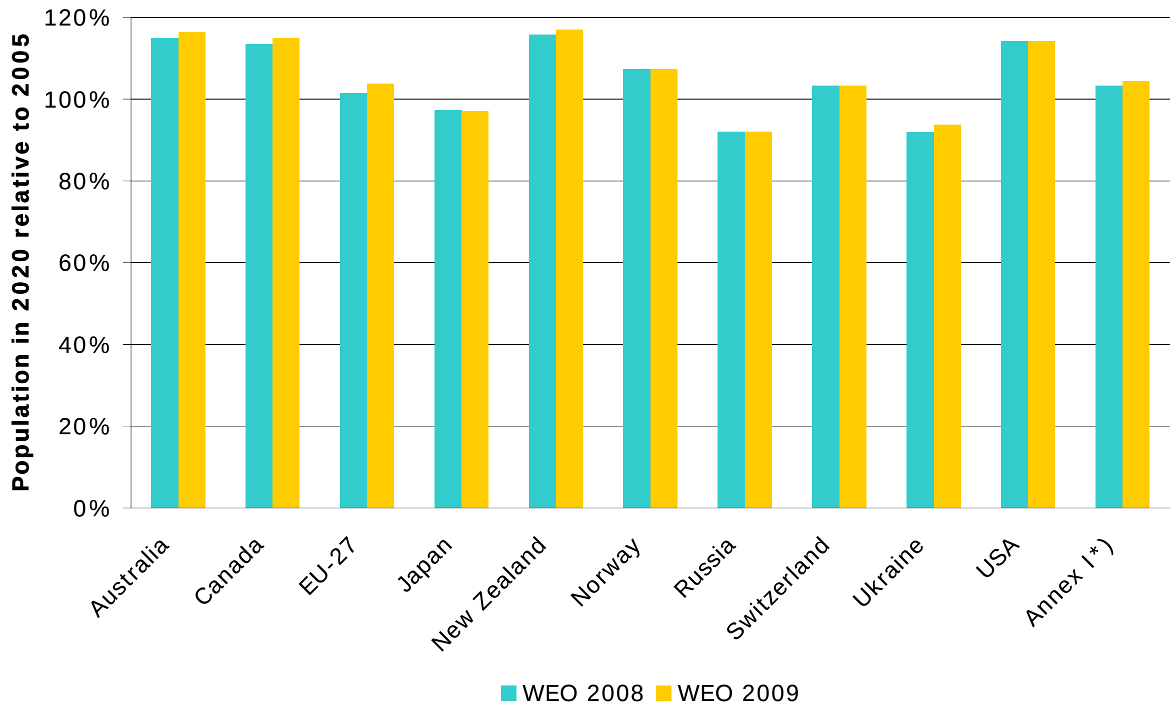


Figure 2.1: Change in population for 2020 assumed in the World Energy Outlooks 2008 and 2009 (relative to 2005).
*) Note that the total shown for Annex I does not include Turkey.

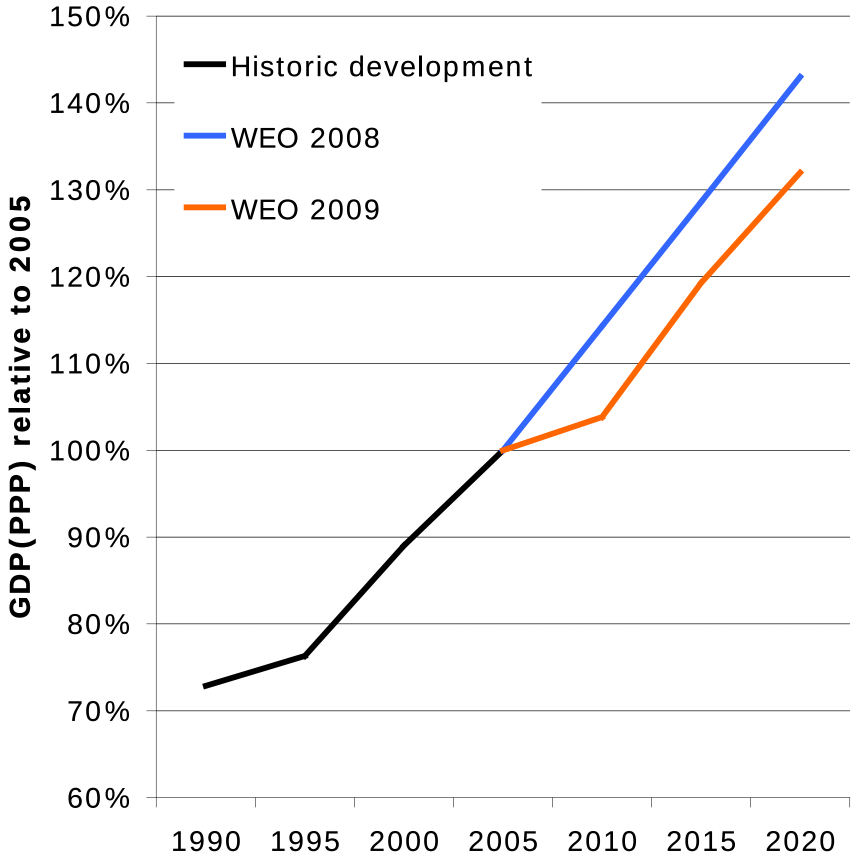


Figure 2.2: Assumed development of GDP(PPP) for the Annex I countries

Table 2.3: Assumed development of GDP(PPP) in 2020 (billion €)

			2020 (WEO 2008)			2020 (WEO 2009)		
	1990	2005		Change to 1990	Change to 2005		Change to 1990	Change to 2005
AUSTRALIA	330	541	768	133%	42%	723	119%	33%
CANADA	601	909	1263	110%	39%	1215	102%	34%
EU-27	7052	10498	15214	116%	45%	13302	89%	27%
JAPAN	2572	3107	3783	47%	22%	3634	41%	17%
NEW ZEALAND	50	79	113	125%	42%	106	112%	33%
NORWAY	86	161	192	124%	19%	192	124%	19%
RUSSIA	1505	1362	2755	83%	102%	2483	65%	82%
SWITZERLAND	189	217	259	37%	19%	259	37%	19%
UKRAINE	249	207	422	69%	104%	359	44%	74%
USA	6449	9976	13772	114%	38%	13435	108%	35%
TOTAL	**19082**	**27058**	**38541**	**102%**	**42%**	**35707**	**87%**	**32%**

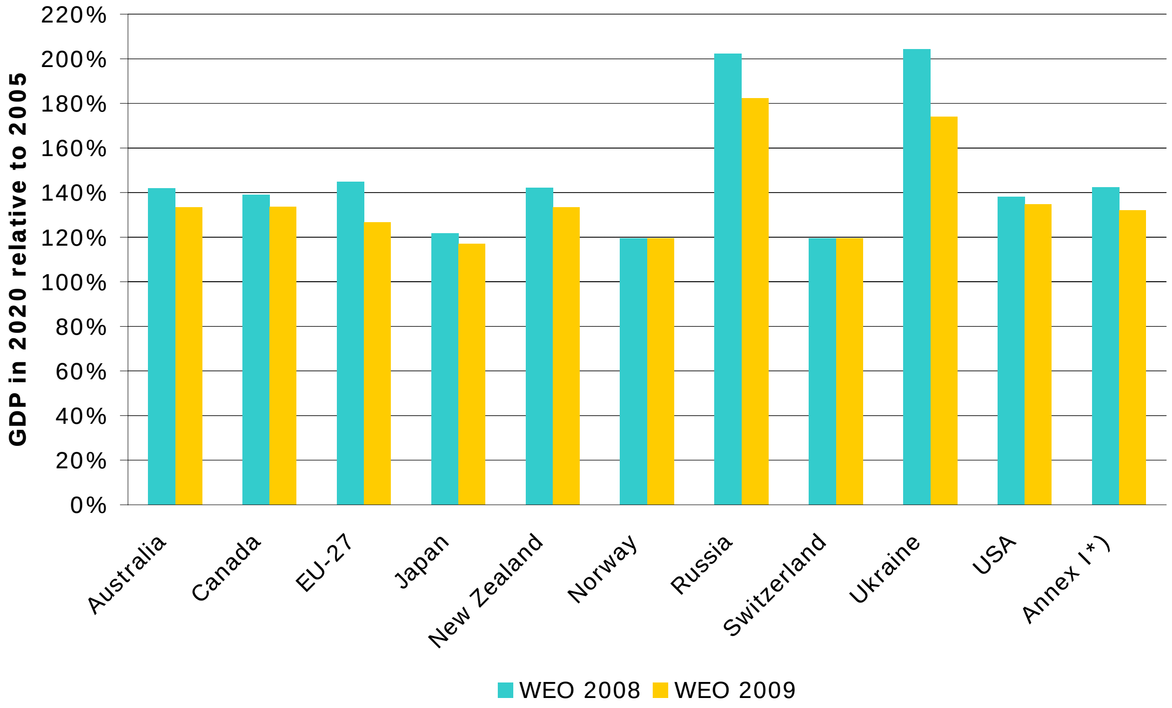


Figure 2.3: GDP (PPP) in 2020 relative to 2005 as assumed in the World Energy Outlooks 2008 and 2009
*) Note that the total shown for Annex I does not include Turkey.

Together with a host of other assumptions the World Energy Outlook relates these GDP projections to future energy consumption. The 7% lower GDP of the WEO 2009 compared to the WEO 2008 translates into 11% less energy demand for the industrial sector, 8% less demand for transport, 7% less for power generation and 6% less for the domestic sector (Figure 2.4). Use of coal, oil and natural gas is between 9% and 11% lower than in the WEO 2008, and only partially compensated by higher consumption of biomass and other renewable energy.

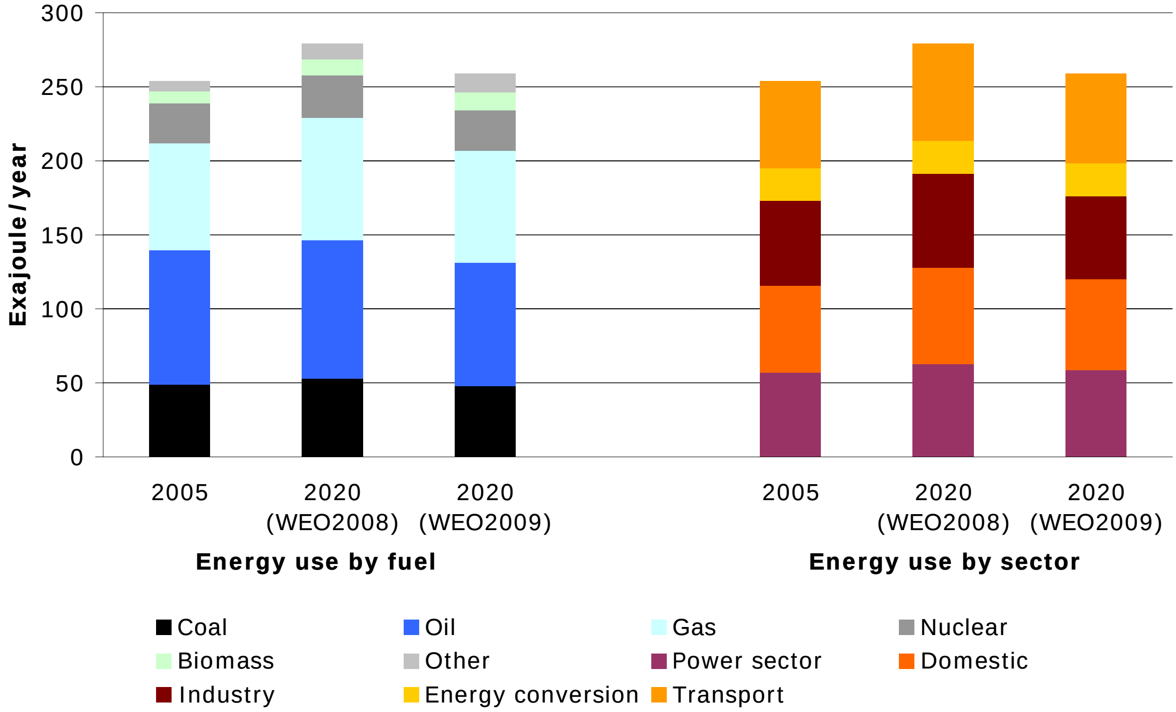


Figure 2.4: Energy use by fuel and by sector for the Annex I countries, comparison of 2005 with the projections for 2020 of the World Energy Outlooks 2008 and 2009

3 Mitigation potentials and costs in 2020

3.1 Baseline emissions

The baseline emission projection calculated by GAINS takes into account changes in activity levels and the progressive implementation of already committed mitigation measures (e.g., mitigation measures that are taken to meet the Kyoto protocol in 2012). Based on the WEO it implies 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.

For non-LULUCF related sectors, the baseline projection for the WEO 2008 activity levels suggests a 2% increase in greenhouse gas emissions between 1990 and 2020, or a 6% increase between 2005 and 2020 (Table 3.1). 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).

All other factors equal, the 2009 assumptions on economic development imply for 2020 a 6% decrease in baseline emissions relative to 1990 (or -2% relative to 2005). Compared to the WEO 2008 projection, the 7% lower GDP assumed for 2020 by the WEO 2009 leads to 8% less GHG emissions.

Table 3.1: Baseline emission projections (excluding LULUCF emissions)

	1990	2005	WEO 2008 for 2020			WEO 2009 for 2020			
	Mt CO2eq	Mt CO2eq	Mt CO2eq	Change to 1990	Change to 2005	Mt CO2eq	Change to 1990	Change to 2005	Difference to WEO 2008
AUSTRALIA	416	530	597	44%	13%	573	38%	8%	-4%
CANADA	592	734	804	36%	9%	766	29%	4%	-5%
EU 27	5564	5154	5407	-3%	5%	4671	-16%	-9%	-14%
JAPAN	1272	1358	1332	5%	-2%	1199	-6%	-12%	-10%
NEW ZEALAND	62	77	83	35%	8%	82	32%	6%	-2%
NORWAY	50	54	63	26%	17%	63	26%	17%	0%
RUSSIA	3326	2123	2672	-20%	26%	2481	-25%	17%	-7%
SWITZERLAND	53	54	48	-9%	-11%	48	-9%	-11%	0%
UKRAINE	922	426	460	-50%	8%	422	-54%	-1%	-8%
USA	6135	7107	7244	18%	2%	6969	14%	-2%	-4%
TOTAL	**18393**	**17616**	**18711**	**2%**	**6%**	**17274**	**-6%**	**-2%**	**-8%**

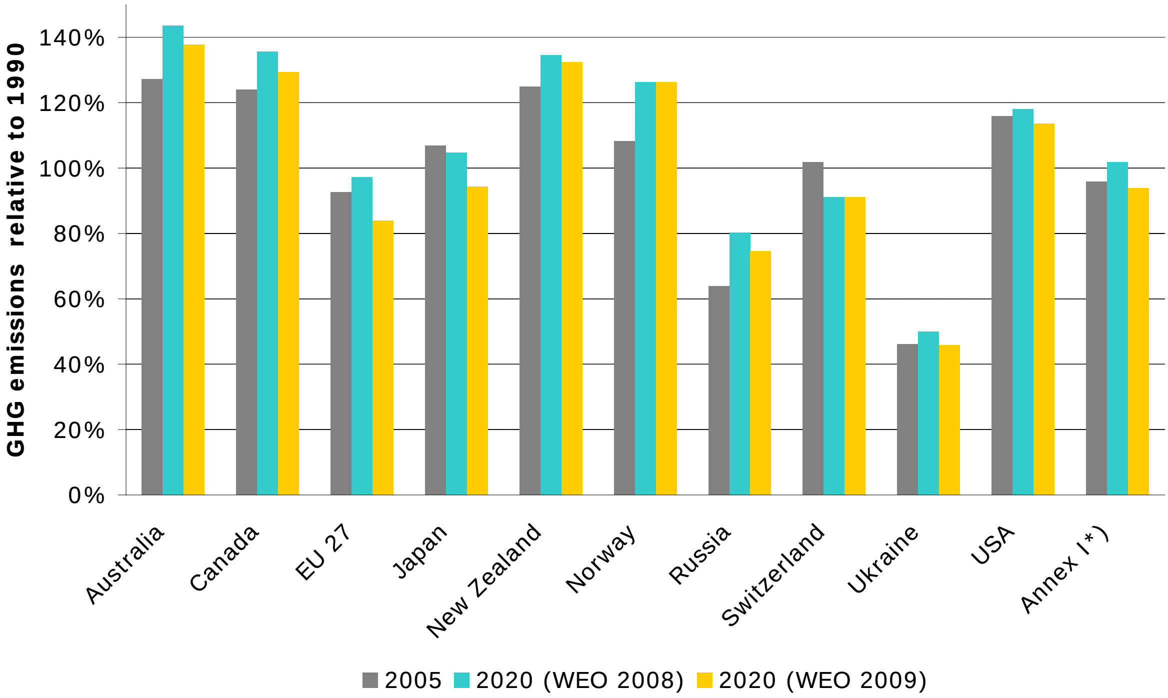


Figure 3.1: Change in GHG emissions relative to 1990 (excluding LULUCF), for 2005 and the baseline projections of the WEO 2008 and 2009

3.2 GHG mitigation potentials and costs

Based on a detailed assessment of available mitigation options in each country, the GAINS model provides for each country a ranking of mitigation measures according to their marginal costs. This can be plotted in form of 'marginal abatement cost' (MAC) curves that display on the x-axis the available mitigation potential and on the y-axis the associated marginal costs (carbon prices) for GHG mitigation.

A comparison of the curves for the WEO 2008 and WEO 2009 projections reveals significant differences in mitigation potentials and costs that result solely from the different assumptions on economic baseline development (Figure 3.2). As explained above, baseline emissions (without further mitigation measures) are 2% above the 1990 level for the 2008 projection, while they are 6% below the 1990 level for the 2009 projection. For total Annex I, the GAINS model estimates that GHG emissions can be reduced by 5% below 1990 level at negative marginal costs, while for the 2009 projection such measures lead to a 12% reduction of GHG emissions compared to 1990. For a carbon price of 50 €/t CO2eq, Annex I countries could cut their GHG emissions by 18% for the WEO 2008, while the potential extends to 27% below 1990 for the levels of economic activities of the 2009 projection. For a carbon price of 200 €/t CO2eq, emissions could be reduced by 32% and 37%, respectively.

Cost curves for the individual Annex I countries are provided in the Annex.

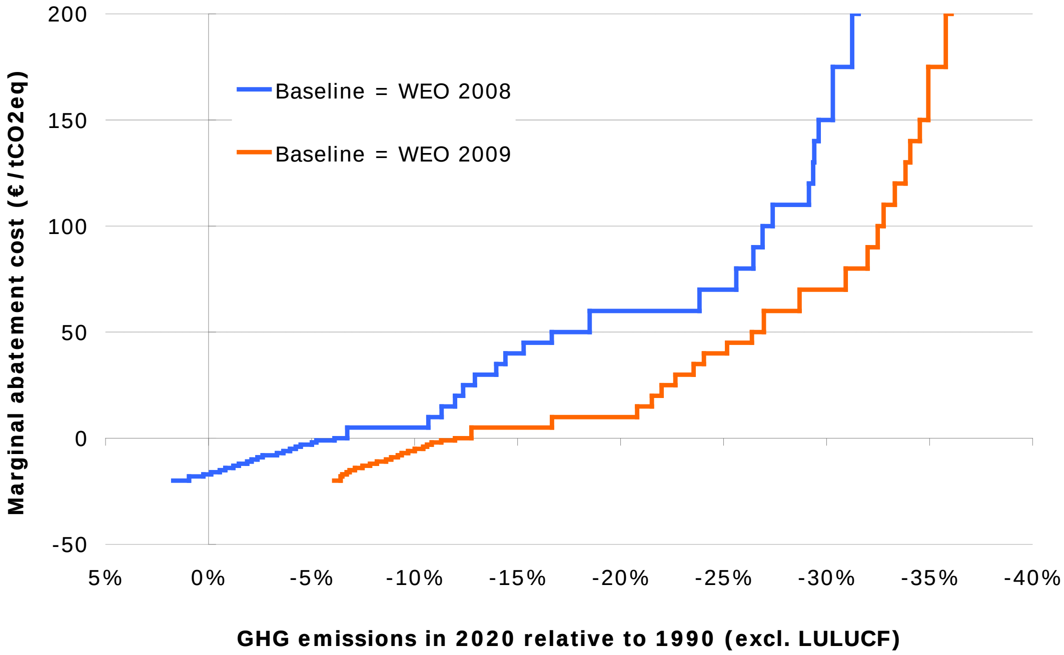


Figure 3.2: Marginal abatement cost curves for the WEO 2008 and 2009 projections for the emissions of Annex I countries in 2020 (excl. LULUCF)

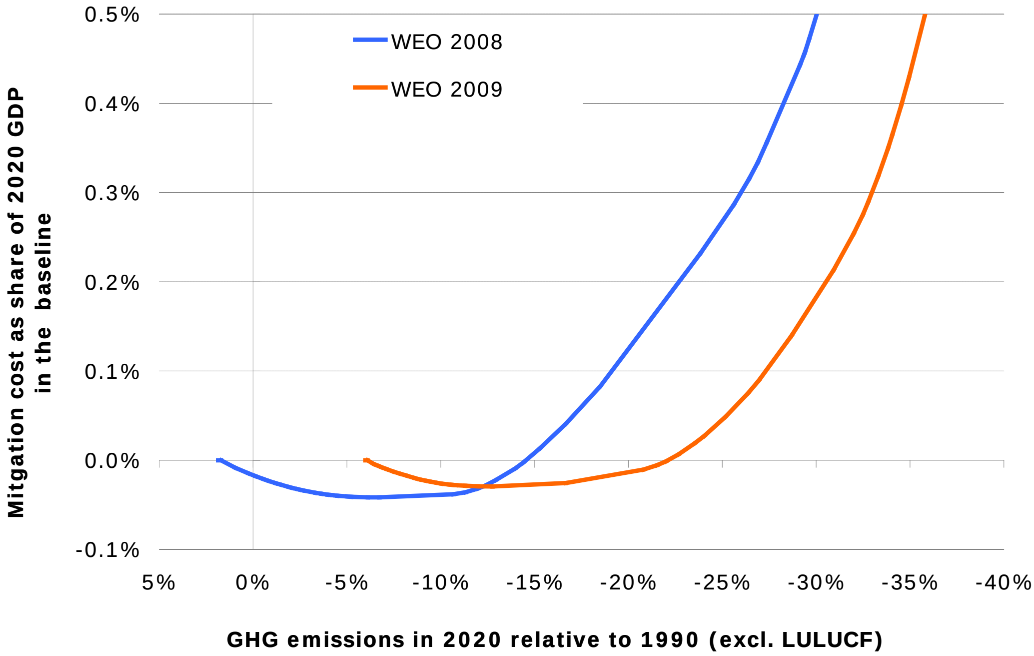


Figure 3.3: Total GHG abatement costs in Annex I for the WEO 2008 and 2009 projections for 2020 (excl. LULUCF)

3.3 Investments and life cycle costs

The GAINS model employs a bottom-up approach to estimate costs of mitigation. It quantifies costs of resources that are diverted from other productive use in the economy for the purposes of greenhouse gas mitigation (Amann *et al.*, 2008a), and distinguishes resource costs that emerge from a social planner's perspective and transaction costs that reflect additional costs seen by private actors.

Resource costs include investments and operating costs, as well as costs and savings from modified fuel and material input. Costs are calculated for the entire technical lifetime of the investment. Pay-back periods for investments cover the full technical lifetime, and savings are accounted over the full period a plant is in operation. For annualizing investments over the full lifetime, a social discount rate that reflects the long-term productivity of capital (4%/year) is employed.

In addition, the GAINS approach considers transaction costs that reflect additional costs that are seen by private actors. These include costs for conveying necessary technical information to investors and for overcoming technical and institutional implementation barriers (e.g., for resolving the 'principal agents' problem, when benefits of a measure do not occur to the investor but to other persons). They also reflect higher capital costs associated with shorter pay-back periods and market interest rates, profits, taxes and subsidies, and exclude cost savings that occur after the pay-back period.

These two perspectives can lead to very different cost estimates for measures that require high up-front investments and/or lead to energy savings over their full technical lifetime. For instance, insulating a house with high initial investments but long-term energy cost savings appears very cost-effective under a social planner's perspective, while it can be "expensive" from the perspective of a private actor. To illustrate how different costing perspectives affect cost estimates, Figure 3.4 compares for the WEO 2008 marginal mitigation cost curves for total Annex I estimated by the GAINS model based on the private investor's perspective (with short pay-back periods) and the social planner's perspective (using a long pay-back period).

Most notably, bottom-up cost estimates typically calculate for certain measures negative life cycle costs, i.e., where a measure leads to cost savings over the full technical lifetime of the equipment. While engineering analyses that focus on a social planner's perspective often reveal a significant potential for measures with negative costs (the red line in Figure 3.4), consideration of transaction costs reduce this potential to a large extent (the blue line in Figure 3.4). However, a certain potential for measures with net cost savings is highlighted by most bottom-up models that employ a private actors perspective, even after accounting for transaction costs (Amann *et al.*, 2009).

The economic literature argues for a social planner's perspective as the appropriate basis for long-term policy decisions. In contrast, e.g., for simulating the behaviour of individual actors, the private investor's perspective will be more relevant (e.g., to determine the carbon price resulting from trading among private enterprises).

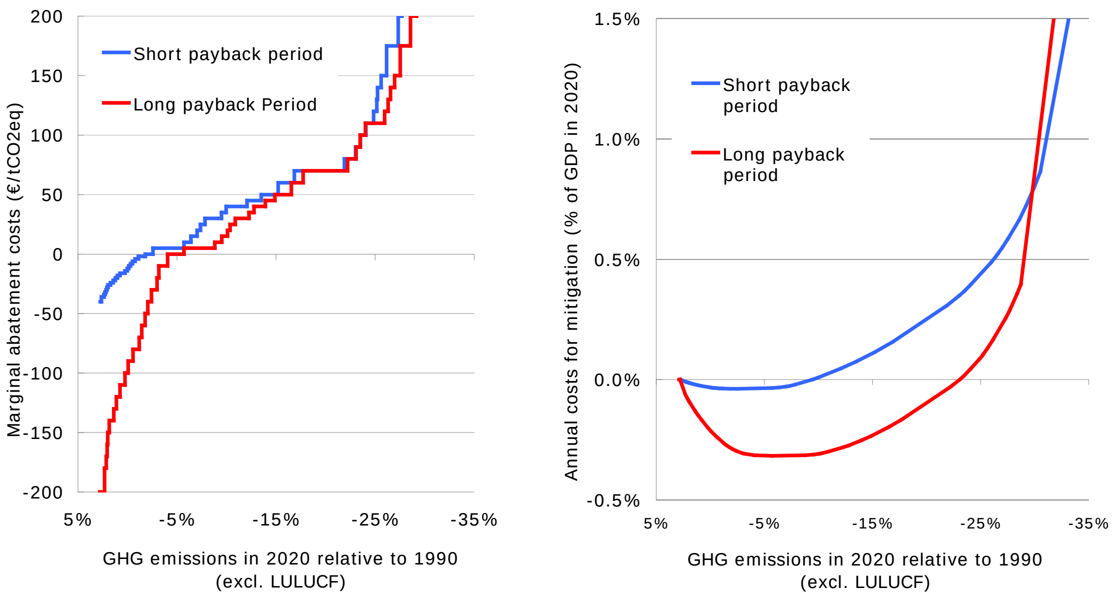


Figure 3.4: Comparison of mitigation cost curves with short (private perspective) and long (social planner's perspective) pay-back periods, cost curves derived with the GAINS model for total Annex I in 2020. Left panel: marginal abatement costs, right panel: total annual costs. Calculation for the WEO 2008 activity projection.

As a consequence of the measures for which net cost savings are calculated, in a least-cost portfolio of measures total mitigation costs in a country turn negative for low overall emission reductions, until the cost savings are compensated by costs of more expensive measures. Thus, cost curves that represent total mitigation costs in a country turn negative for a certain emission reduction below the baseline level.

In many cases decision makers are less familiar with total mitigation costs over the lifetime of measures, as such calculations are often unavailable, and are more concerned about immediate investment needs that are implied in mitigation strategies. Obviously, initial investments can be considerable, even if these costs are compensated in the long run by cost savings.

An example how initial investments relate to life cycle costs is presented in Figure 3.5 for upgrading an existing house with 136 m^2 in Canada to higher energy efficiency standards. Total investments assumed by GAINS amount to €5597. Distributed over an assumed life time of 20 years and using a 4% interest rate for annualizing the investment, annual capital expenditures amount to €412/yr over the 20 years life time. At the same time, this upgrade leads to savings for heating of €137/yr, and of electricity of €252/yr. In total, net annual costs for this measure amount to €22/yr, and this number is used for constructing the cost curve of total mitigation costs. However, this measure involves upfront investments of €5597.

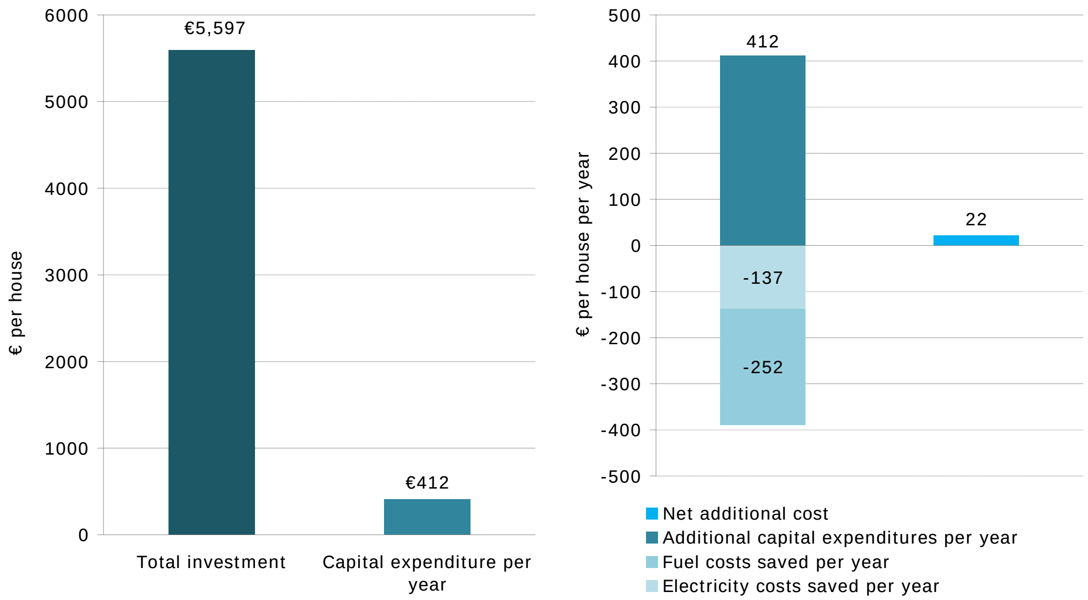


Figure 3.5: Investment needs and costs for retrofitting a representative house (136 m^2) in Canada to an improved energy efficiency standard. Left: a total investment need of €5597 per house translates into an annual capital cost of 412 €/yr, calculated over the lifetime of 20 years, using a real interest rate of 4% p.a. Right: This capital expenditure is nearly compensated by fuel and electricity cost savings. Note that the actual costs are more than two orders of magnitude smaller than the total investment costs.

This disparity between upfront investments and full life cycle costs is an important feature of greenhouse gas mitigation strategies, as many mitigation measures are capital intensive. While total investment costs can be rather low or even negative (e.g., they turn positive for the WEO 2009 projection only beyond a 25% reduction of total Annex I GHG emissions), upfront investments during the 2011 to 2020 period are significantly higher. For instance, for a 25% reduction of emissions in 2020, 0.55% of the GDP that is assumed in the baseline is required (Figure 3.6).

It is interesting to note and relevant for policy discussions that investments are not evenly distributed across economic sectors. Largest investments are required in the domestic sector for refurbishing buildings and improving the energy efficiency of appliances. In contrast, for low GHG mitigation targets the power sector would face lower investment needs than in the baseline without climate measures due to the reduction in electricity demand that results from more efficient appliances in households and industry.

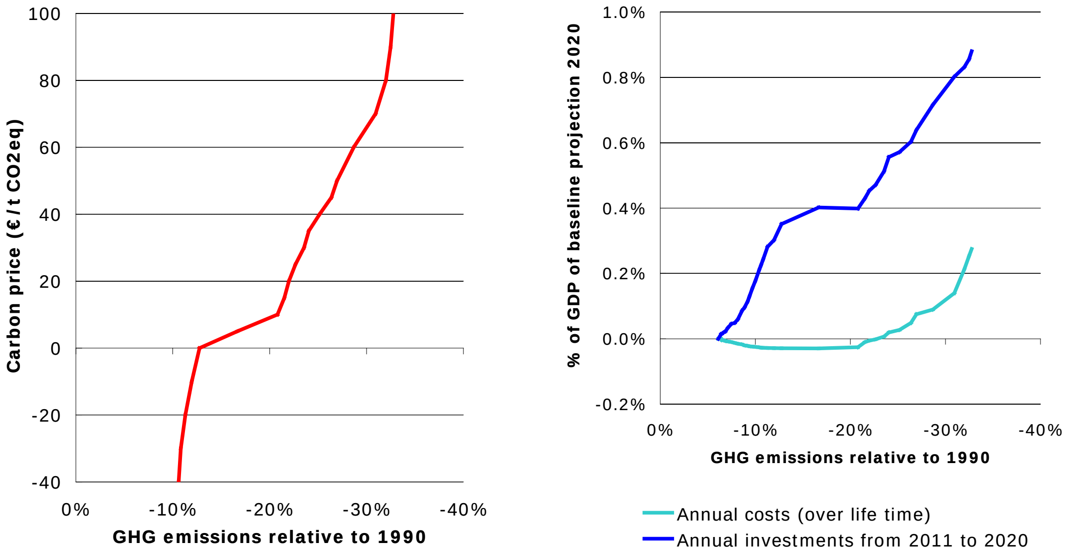


Figure 3.6: Marginal costs (left panel) total mitigation costs annualized over the full life time and annual upfront investments in the period 2011 to 2020 (right panel) for the WEO 2009 projections of Annex I countries in 2020.

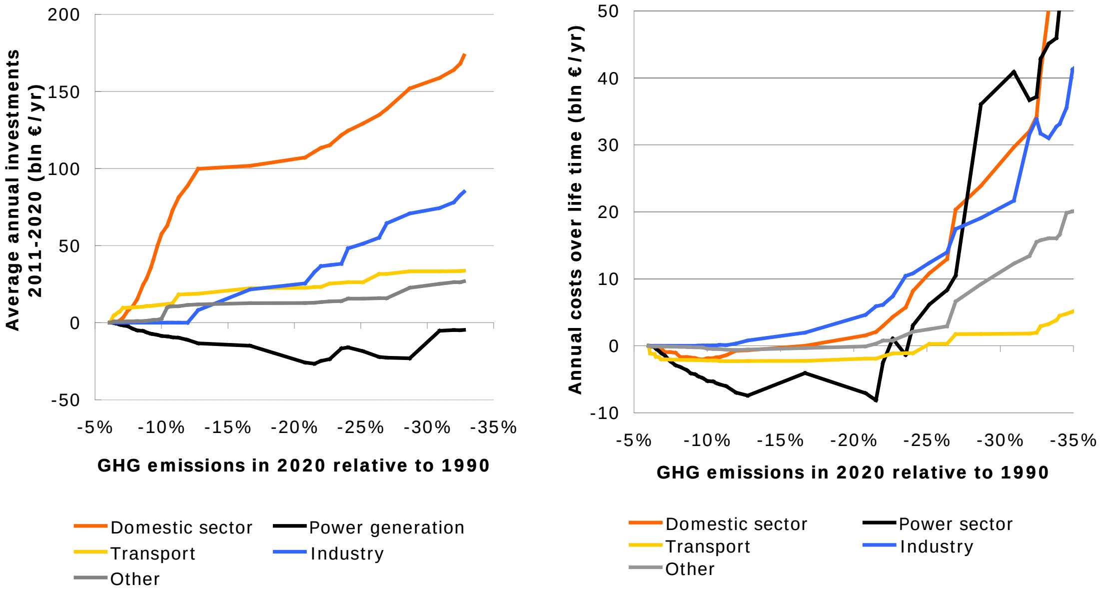


Figure 3.7: Average annual upfront investments in the period 2011-2020 and annualized mitigation costs over the full life cycle by sector for reducing GHG emissions in Annex I countries in 2020 (excluding LULUCF)

4 Conclusions

Estimates of mitigation potentials and costs are sensitive towards assumed economic development. Thus lower activity projections that reflect the impacts of the current economic crisis lead to lower GHG mitigation costs than estimates that were produced before the crisis.

Compared to the 2008 perspective, future energy use as projected by the 2009 World Energy Outlook (WEO) of the International Energy Agency implies for the Annex I countries 8% lower GHG emissions in the baseline case without further climate measures. Thereby, without further climate measures, Annex I emissions would decline by 6% in 2020 relative to 1990 (compared to an increase of 2% that is calculated for the IEA WEO 2008).

The post-crisis energy structure also increases the potential for GHG mitigation and reduces costs for achieving a given emission target. For instance, for a carbon price of 50 €/t CO_2 Annex I countries could reduce their emissions by 27% below 1990 levels, compared to a 17% potential that is calculated for the WEO 2008.

Due to measures for which cost savings over their technical life time exceed the up-front investments (i.e., measures with negative mitigation costs over their life cycle), total Annex I emissions could be reduced by 23% below 1990 levels without net costs over the life cycle. For a pre-crisis projection, this potential was estimated at only 14%.

While total mitigation costs are small compared to the assumed baseline increase in GDP, up-front investments are significant. For instance, to achieve the 23% reduction of Annex I GHG emissions in 2020, annual investments in the period 2011-2020 amount to 0.5% of the GDP. As pointed out above, however, cost savings from the subsequent reduced energy demand compensate these costs in the following years until the end of the technical lifetime of the investment, so that such a reduction will not involve net costs to society in the long run.

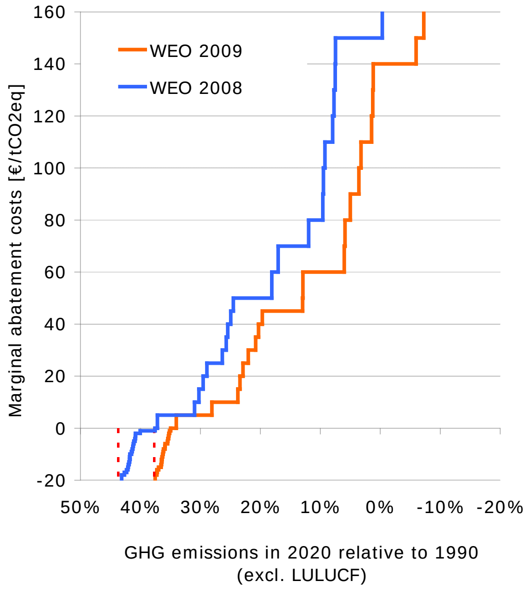
Up-front investments are most significant in the domestic sector, where such a 23% reduction in total emissions would require annual investments of approximately €120 bn/yr in the period 2011-2020. In contrast, investments in the power sector would be €20 bn/yr lower than in the baseline case, due to lower electricity demand resulting from the energy efficiency improvements in the end-use sectors.

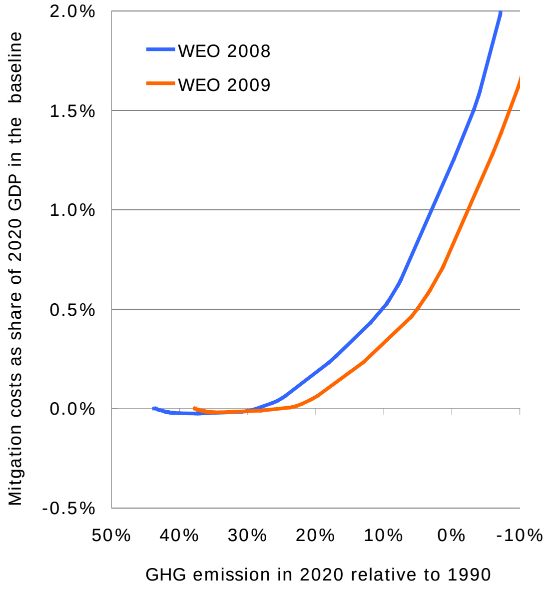
The implications of post-crisis activity projections on the current pledges for GHG reductions for a post-2012 climate agreement are analyzed in a companion paper (Wagner and Amann, 2009b).

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

Annex: Cost curves for individual countries

Australia:





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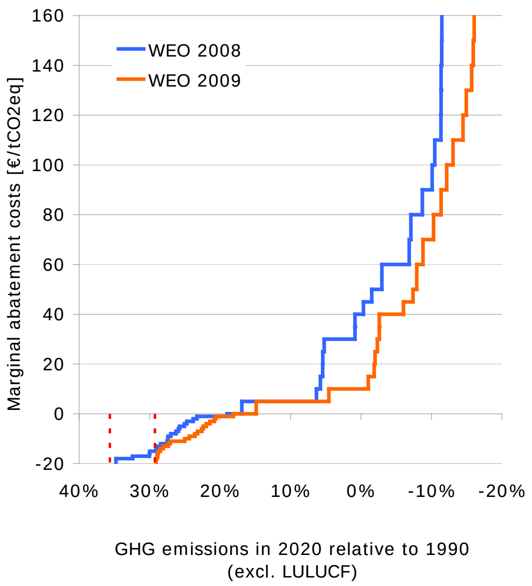

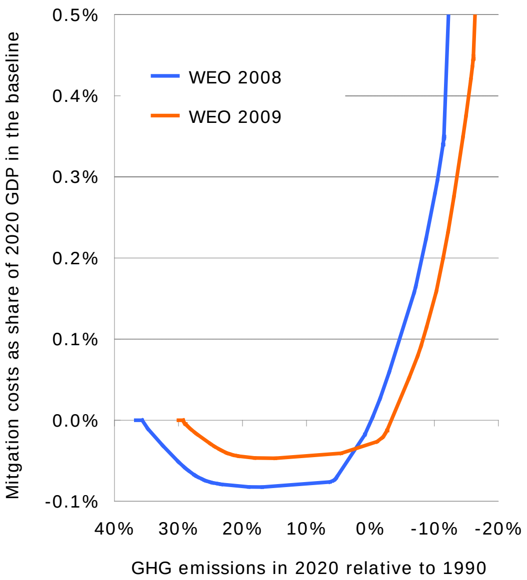

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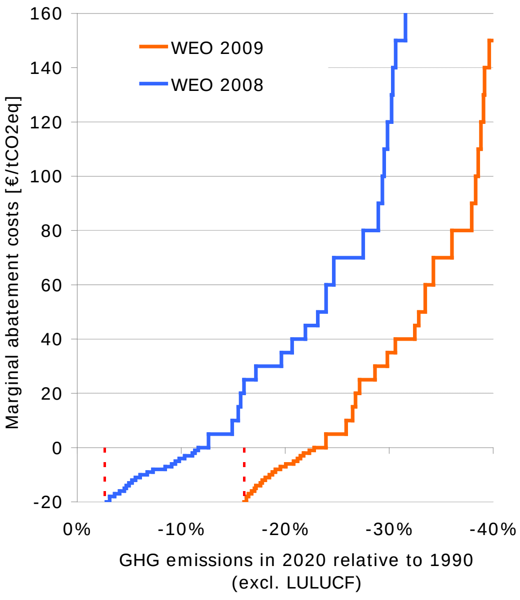

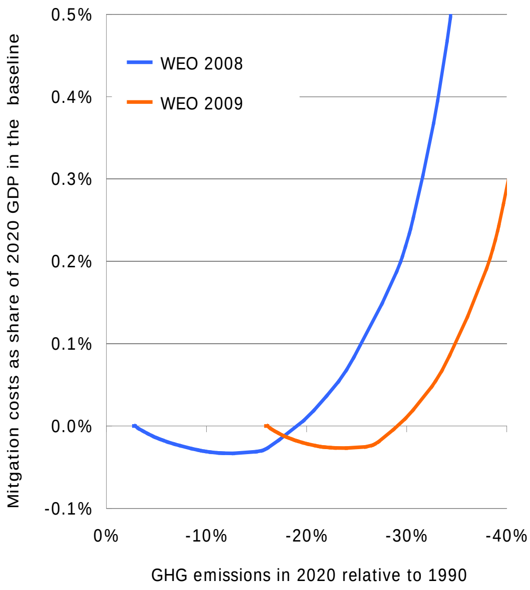

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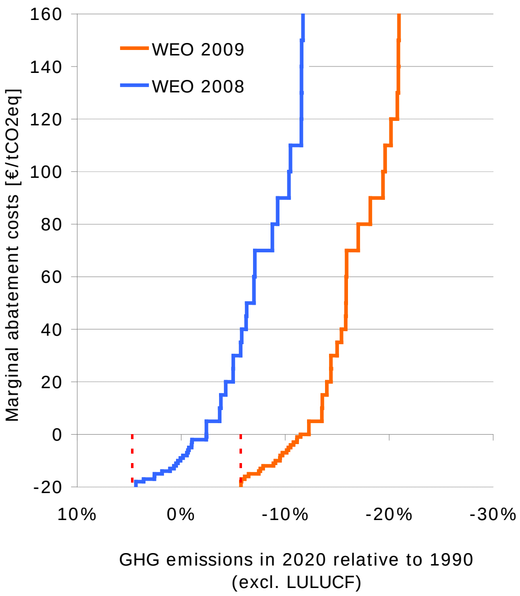

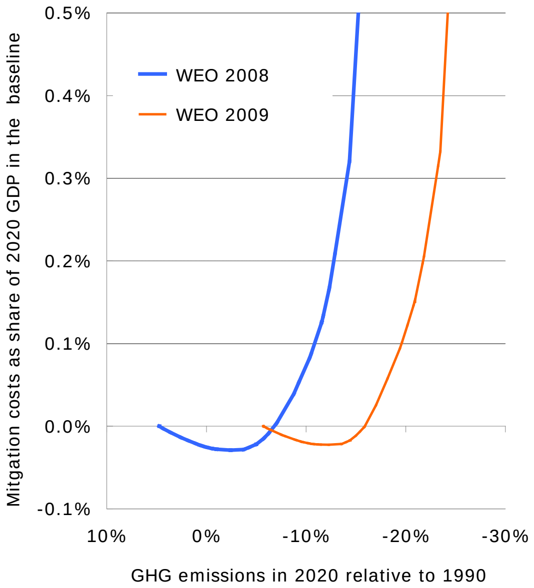

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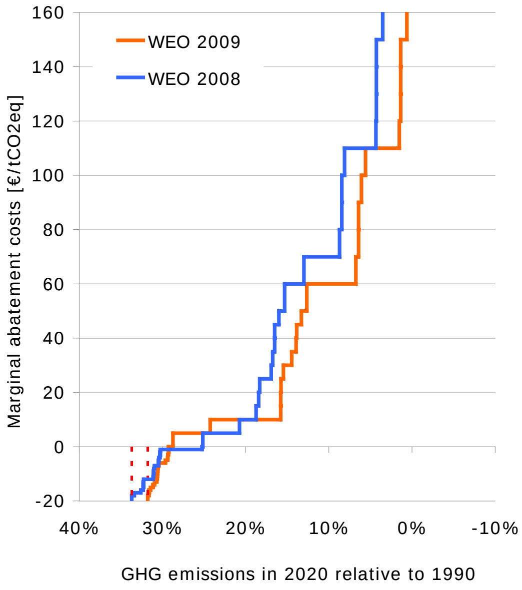
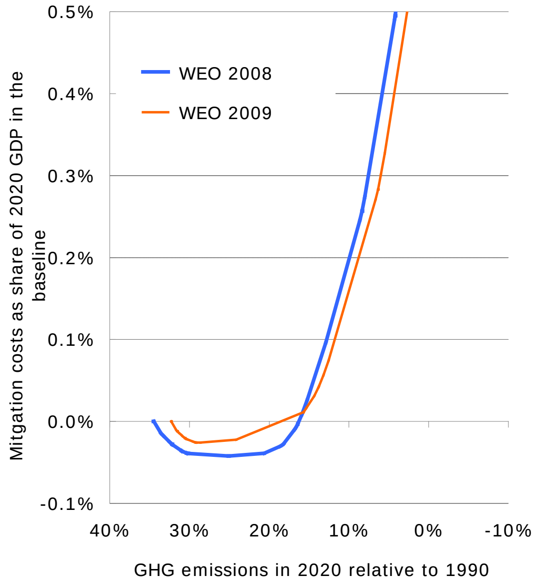
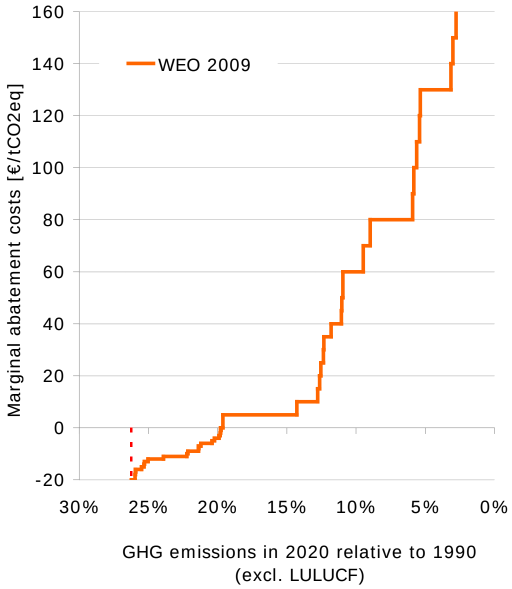
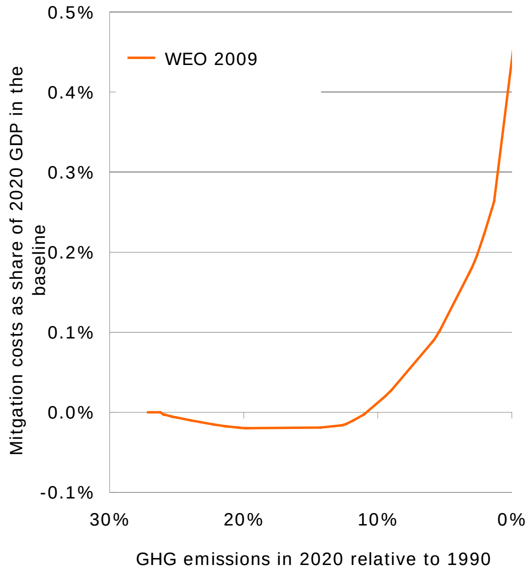


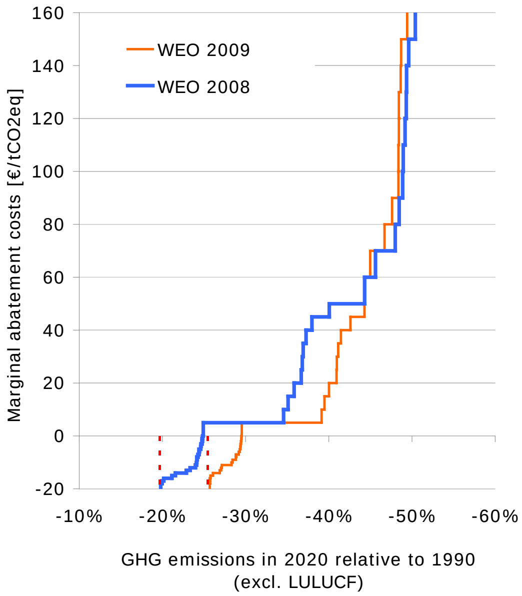


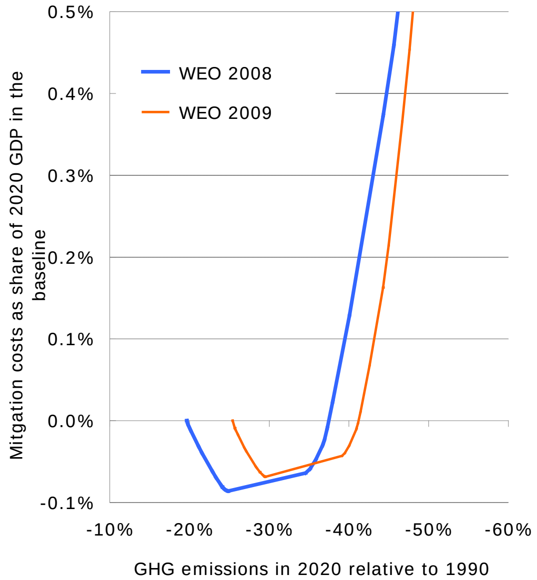
Norway:



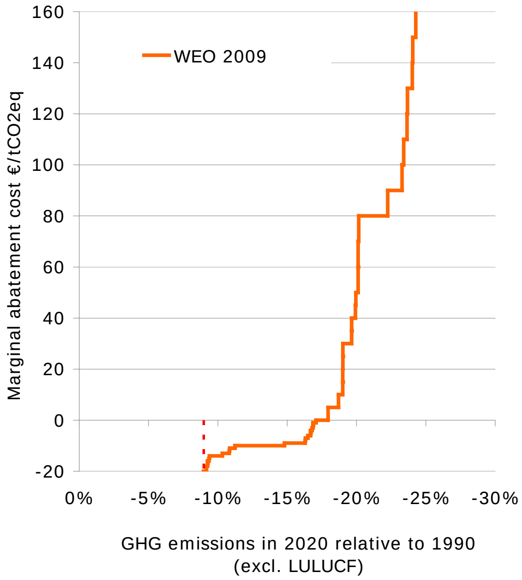


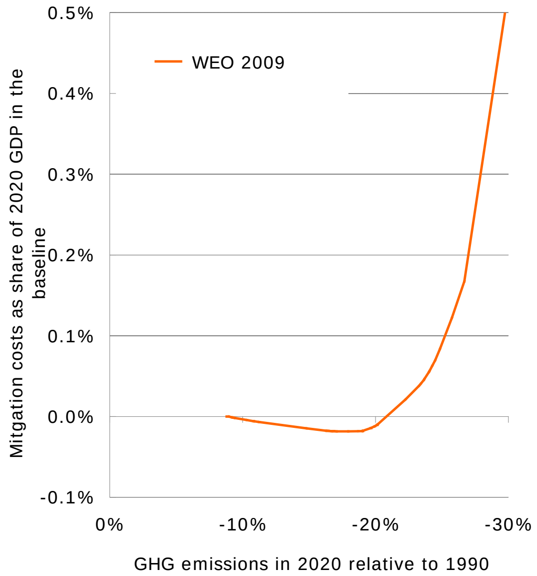
Russia:



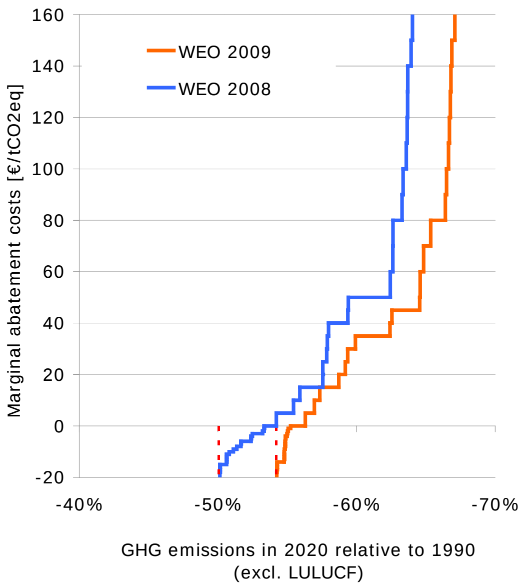


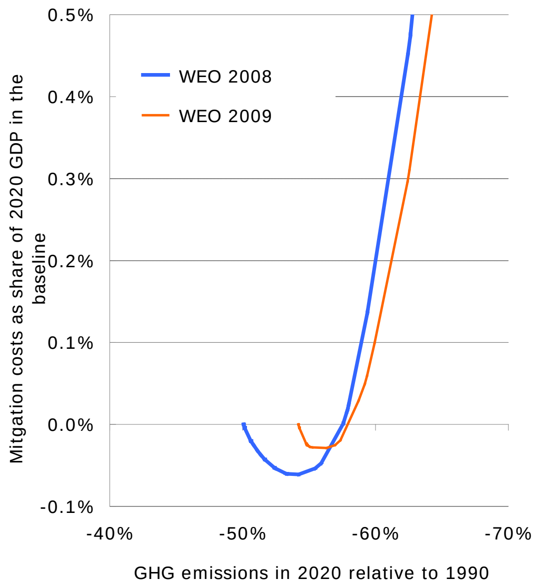
Switzerland:



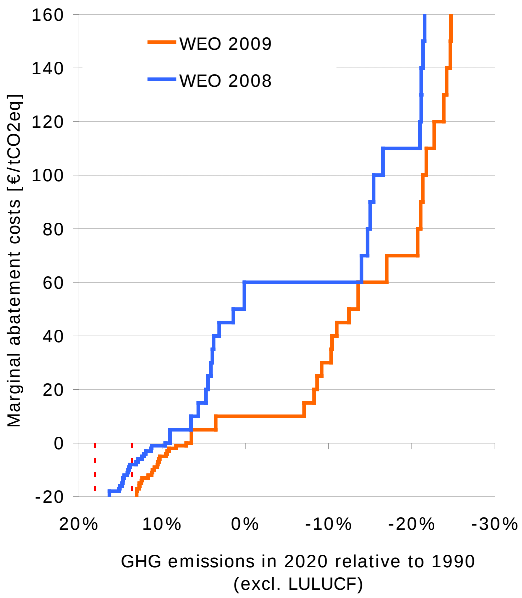


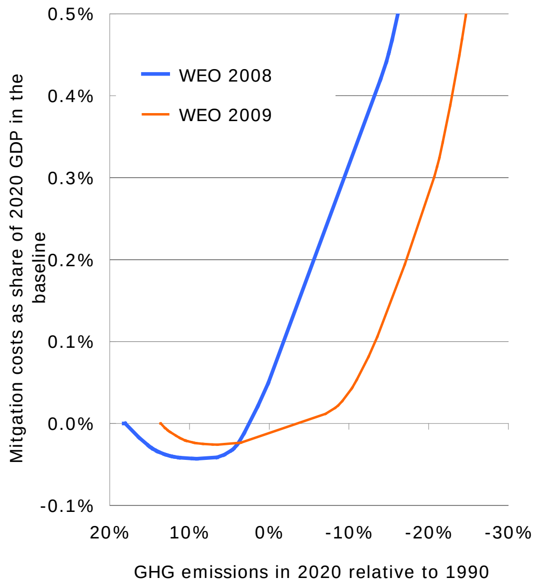
Ukraine:





United States:





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