Why the EU could and should adopt higher greenhouse gas reduction targets

A literature review

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Author(s):
Sander de Bruyn
Agnieszka Markowska
Marc Davidson

The Greens | EFA
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Further information on this study can be obtained from the contact person Sander de Bruyn

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Contents

Summary

Should the EU adopt more ambitious greenhouse gas reduction targets? Recently, from different perspectives, a large number of studies concluded that such higher emission reduction targets are desirable, feasible or necessary. This study reviews recent research and tries to answer the question how to make the EU's GHG reduction target consistent with its goal of limiting the increase in global temperature to below 2ºC above pre-industrial levels.

Summarizing, this study finds six compelling reasons why the EU should be willing to adopt a more ambitious emissions reduction target:

1. To take its share of the global responsibility for delivering emissions reductions, which implies that Annex-I countries are responsible for a greater share of the effort for reducing global emissions compared to business as usual.
2. To take its share of the responsibility among those Annex I countries that are willing to commit to a collective emissions reduction of 30% by 2020 compared to 1990 levels. This share would imply the EU adopting a 30-40% reduction target.
3. To distance itself from the insufficient pledges that have been made by countries like Russia, the United States and Canada in the UN climate negotiations and align itself with those countries that have made more ambitious pledges, such as Australia, Japan, Norway and Switzerland.
4. Because the impact of the current economic recession, combined with the large possibility to offset emissions reductions (through use of flexibility mechanisms like CDM/JI) in the EU's current climate legislation, will result in the phenomenon that 2020 emissions will only be about 4% *below* their expected level in a business as usual scenario. The impact of the economic recession therefore risks making the EU climate policies and instruments like EU ETS void of content if not accompanied by more ambitious reduction targets. Within EU ETS there is a serious risk that supply of credits will outweigh demand undermining the functioning of EU ETS.
5. Because the costs of meeting more ambitious targets are smaller due to the economic crisis. Direct costs of meeting a -30 to -40% reduction target lay between a very moderate 0.1-0.3% of GDP.
6. Investments in emission reductions can have additional benefits, like fostering innovation and creating employment in eco-industries. Such benefits are higher during times of economic crisis underlying the urgency to invest in more ambitious climate change reduction efforts.

Overview of the key findings of the study

Fair share of global responsibility

In order to limit the increase in global temperatures to less than 2º C above pre-industrial levels, global emissions must peak as soon as possible and fall considerably thereafter. Both Annex I and non-Annex I countries are expected to reduce the growth in their emissions by 2020 in order to meet the 2º C goal. The Intergovernmental Panel on Climate Change has recommended that Annex I countries reduce their emissions 25-40% by 2020 compared to 1990, a recommendation supported by other studies. While a number of studies and policy makers have interpreted this to imply a -30% target for Annex I countries, this could not be deemed to be overly ambitious, and results in an absolute reduction in greenhouse gases of only 8 Gt by Annex I countries compared to business as usual. Under this scenario, the comparative reduction expected for non-Annex countries would be 5 Gt compared to the BAU.

Given that Annex I countries are more than ten times richer than average non-Annex I countries this effort seems to be insufficient in the context of international climate negotiations that are supposedly based on the principle of 'common but differentiated responsibility'. Annex I countries, like the EU, should be willing to put forward more ambitious emissions reduction goals. In this context, the EU's 20% reduction target clearly falls short of the EU's share of the responsibility for limiting the global increase in temperatures to below 2° C.

Fair share of responsibility among Annex I countries

If a collective 30% reduction target is to be divided among the Annex I countries, the EU should, according to various comparable effort-sharing models, reduce its emissions 30-40% by 2020 compared to 1990 levels. These models are based on concepts like equalisation of costs or emissions per capita. Hence, a -20% reduction target for the EU is not in line with a notion of 'comparable efforts' between Annex I countries, with a reduction target of 30-40% more appropriate.

Ensure EU pledge comparable with more ambitious pledges

The EU has stated that its eventual emissions target will also depend on what other countries are putting forward as targets in the international climate negotiations. However, even a comparison of those pledges currently on the table demonstrates that the EU's 20% target is comparatively unambitious and more or less comparable to what the USA, Canada and Russia have pledged. Many countries have already pledged more ambitious reduction targets, notably Australia, New Zealand, Japan, Norway, Switzerland and most emerging countries. Therefore, the EU should increase its emissions reduction target to at least 30% to be comparable with current pledges.

Current policies will hardly reduce emissions compared to BAU

The economic crisis will have a larger impact on the EU than on other Annex I countries. The reduction in economic output reduces CO_2 emissions compared to *business as usual* by an estimated 6-12%. Current analysis suggests that total emissions in 2020 will be about 9% lower than was expected in earlier analysis.

The reduction in emissions due to the economic slowdown also impacts on the EU's emissions trading scheme (EU ETS). The resulting unused emissions allowances under the current phase can be banked for use in the 3rd Phase (2013-20) and the current scarcity in the EU market reflects this 'banking'.
In fact, about ¾ of the required cap on EU ETS by 2020 could be delivered through a combination of banking and purchasing overseas emissions credits to offset emissions reductions from 2013-20. However, as there is a fixed supply of EU ETS credits through the renewable energy directive there is a serious risk that supply will outweigh demand resulting in poor functioning EU ETS markets.

The combined impact of EU ETS and non-EU ETS climate policies would only reduce domestic emissions 4% compared with the expected business as usual scenario, corrected for the influence of the economic recession. Hence, the EU climate policies other than the renewable energy directive have hardly an impact in stimulating domestic emissions reductions.

Costs of more ambitious targets are negligible

In this study three alternative policy packages have been formulated that aim to reduce emissions by between 30 and 40% by 2020 compared to 1990. The policy packages differ with respect to their targets and the allowed use of CDM and banked credits.

The analysis show that with these policy packages EU domestic emissions would be reduced by between 13 and 23% compared to business as usual giving a more significant reduction than the present policy package. Costs are expected to be very moderate. The average costs can be expected to range between 0.1 to 0.3% of annual GDP.

Additional benefits of more ambitious climate policies

Benefits of more ambitious climate policies are now more pronounced as some studies suggest that climate policies can have additional employment benefits. Moreover, the cost of investment of more ambitious climate polices are during times of economic recession providing an alternative for business investments during times that profitability is difficult to find. Innovation could also be stimulated making costs of future climate change policies lower. Ambitious climate policies and the resultant investment in green technologies can alleviate unemployment and provide an impetus for innovation and sustainable growth.

1 Introduction

1.1 A plea for higher GHG targets

In March 2007, the European Council endorsed an EU objective of a 30% reduction in greenhouse gas emissions (GHG) by 2020 provided that other developed countries would commit themselves to comparable emission reductions and economically more advanced developing countries contribute adequately according to their responsibilities and respective capabilities. Now, almost three years later, a debate is going on whether the EU should agree upon these more stringent reduction of greenhouse gas emissions – or stick to the more conservative goal of -20%.

In this debate several arguments have been put forward that would justify more stringent targets. First, several authors argue that a target of -30% is more in line with the obligations the EU has in keeping global temperature below the 2 degree Celsius. Second, many have argued that the impact of the economic crisis results in lower costs to achieve more ambitious targets. Third, arguments have been made that more strict targets are feasible and can be achieved with minor policy changes compared to what was already agreed upon by the EU. Fourth and finally, several authors have pointed at eventual benefits that may occur from more stringent targets relieving some of the unemployment burden that is nowadays plaguing European economies again.

Over the last year more than 30 studies have appeared that have addressed the possibility, desirability and affordability of more stringent targets. The Climate Core Group of the European Greens has asked CE Delft to conduct a literature review of the studies that have appeared last year and to investigate the plea for higher GHG reduction targets by the EU.

1.2 Content and main conclusions

In chapter 2 we will address the question what the EU needs to do to keep the global temperature within the 2° C threshold. Clearly, the EU alone cannot combat climate change and is dependent on the efforts of other countries as well. But what would constitute a *fair share* of reduction targets for the EU given the announced policy plans in other countries? How should we interpret the often used phrase of 'comparable efforts'? Can that phrase be quantified in some ways? The literature here is in general in favour of accepting more strict targets, but a lot of variability can be identified between the studies.

Then in chapter 3 we will investigate the impacts of the economic recession on the climate change policies of the EU. We will argue that the economic crisis has the effect of rendering EU climate policies unambitious compared to business as usual. Moreover, some instruments, like EU ETS, can become ineffective. Therefore the conclusion of this chapter is that more stringent targets are required to keep EU climate policies functioning.

Subsequently, in chapter 4, we investigate what is needed in terms of policy packages to achieve these more ambitious targets. We will investigate four policy targets and discuss costs and potential benefits from applying these. The conclusion of this chapter is that more stringent targets are feasible technologically and operationally at very moderate costs. In addition, some benefits can be expected from more ambitious climate change policies.

Conclusions are presented in chapter 5. The overall conclusion is that the literature by large points at the desirability of adopting more stringent targets for the EU. Higher reduction targets in the EU are now cheaper due to the impact of the economic crisis.

1.3 Disclaimer

Most of the literature that is cited in this study uses models to forecast future economic development, costs of abatement and effectiveness of climate change policies. We have not investigated in this research the likeliness of these models, their underlying assumptions and general validity of the modelling approach. Most studies use a top-down approach. Such an approach, although being popular in economics and other system-analytical research areas, has it's flaws and demerits, especially on the level of detail and the impossibility of capturing more holistic phenomena like recursivity, learning-by-doing and creativity. Therefore, rather than presenting an absolute truth, these studies merely present a likely vision of future developments. Future itself, however, remains still to be revealed.

This study is also not a cost benefit analysis in which the costs of further mitigation efforts are compared to the benefits, such as averting social and economic crisis due to climatic change. As climate change is a global environmental problem, cost-benefit analysis can only be conducted at the level of the entire globe (see e.g. the Stern Review). There is no point in conducting such an analysis for the EU alone as the success of EU climate policies in terms of reduced risks of catastrophes depends to a very high extent on the climate actions in the rest of the world.

2 Fair share of global reductions

2.1 Introduction

Both in scientific and political fora a general consensus has been reached that most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic GHG concentrations. While in the pre-industrial era concentration of GHGs was at the level of approximately 280 ppm, in 2008 it reached a level of approximately 385 ppm (CDIAC, 2009), which is the highest concentration since at least 800 000 years. Since 1880, temperature of the earth has risen by 0.8° C.[1] Alleviating global warming will depend on our success to curb emissions downwards. If no successful mitigation strategies are going to be deployed, by 2010 global temperature will be 3-7° C higher compared to pre-industrial levels.

2.2 Two degrees Celsius as a scientific and political threshold

According to IPCC, ambitious action on global scale should be taken to mitigate global warming so as to keep global temperature rise below 2° C as compared to pre-industrial level. Why is the threshold of 2° C so important? To some extent it is of course a political decision because most changes occur continuously, some impacts of global warming can be experienced already now and they will simply get more intensive over time. However, a few tipping elements have been identified, and triggering these tipping elements may lead to catastrophic consequences. The most important among these are:
- Change in ocean currents.
- Dieback of the Amazon rainforest.
- Shifts in the monsoon system.
- Irreversible destabilisation of large ice masses.

While it is impossible to predict which changes are likely to occur at which temperatures, there are some forecasts in scientific literature which indicate that going beyond 2° C of global warming may have disastrous consequences. For instance the Greenland ice sheets would melt completely with a prolonged period of more than 1.9° C, which would cause the global sea level rise by about 7 m (IPCC, 2007d). According to IPCC (2007b), global warming in excess of 2° C threatens to accelerate the loss of genetic and species biodiversity. Change in climatic conditions due to this degree of temperature rise may place such a strain on the nature adaptive and regenerative capacity that this could lead to irreversible loss of 20-30% of animal and plant species. Biodiversity loss would entail loss of ecosystem resources and services such as protection against storms and coastal erosion, provision of clean drinking water and genetic resources, which would hinder the ability to adapt to climate change and thus aggravate the situation.

[1] This temperature rise is mainly due to anthropogenic activities. Natural factors have also some influence on climate but at the moment they are not determining the trend of temperature rise; in the last 50 years the influence of natural factors is slightly cooling, mainly because declining brightness of the sun (Lockwood and Frohlich, 2007).

The scientific evidence has led to a consensus regarding setting a 2° C allowable warming as a general goal – also adopted by politics. The European Union's Council of Environment Ministers set 2° C as the EU's target ceiling already back in 1996 based on the IPCC's Second Assessment Report and this has been followed by more countries. In July 2009 in L'Aquila, the G8 stated that global warming is to be restricted to 2° C by the year 2050 – which forms another restatement of the EU long-term target in climate policies.

The 2° C target has been incorporated in the Copenhagen agreement of 18 December 2009, which states: "We agree that deep cuts in global emissions are required according to science, and as documented by the IPCC Fourth Assessment Report with a view to reduce global emissions so as to hold the increase in global temperature below 2 °C (COP15, 2009b)". This statement was supported by 55 countries representing almost 80% of global emissions.

There is considerable uncertainty about what level of GHG concentrations in the atmosphere are compatible with the 2° C threshold. Back in 1996, during the Second Assessment Report, it was believed that stabilisation of atmospheric CO_2-equivalent concentrations at below 550 ppm would safeguard the 2° C outcome[2]. However in recent years these figures have been scaled downwards. Now it is being estimated that in order to have a 50% chance of avoiding more than 2° C global warming, the greenhouse gas emission concentrations must be kept between 445 and 495 ppm CO_2 equivalent (IPCC, 2007b). There are, however, numerous scientists who claim that even lower concentrations are required. The IPCC AR4 suggested that stabilisation at 400 ppm CO_2 could lead to a temperature rise already up to 2.5° C and some have suggested that there is no possibility for future growth in concentrations at all (Hansen et al., 2008).

2.3 Global emission reduction scenarios

Continuing with the global trend in GHG emissions would lead to a rapid increase in atmospheric greenhouse gas concentrations of approximately 1,000 ppm CO_2 equivalent in 2100 and contribute to the depletion of fossil fuels. By 2100 this would lead probably to a global temperature rise of 6° C, an average sea level rise of 3.7 meters, 50% loss of coastal wetlands, extinction of 40% of the world's species, food shortage, droughts and a run out of oil and gas (IEA, 2009)[3].

To stay within the 2° C threshold would imply absolute reductions in GHG emissions compared to present levels and compared to business-as-usual growth scenarios. IEA (2009) estimates that if no additional mitigation efforts are being taken upon currently agreed policies, global emissions of GHG will *increase* by about 60% between 2005 and 2050. However, if the target of 2 degrees Celsius will have to be in reach, total emissions should *decline* by 50-80% in 2050 compared to 2005 levels. Given the fact that global emissions have been higher every decade since the start of the industrial era, the required decline implies a complete break in the current trend of more GHG emissions.

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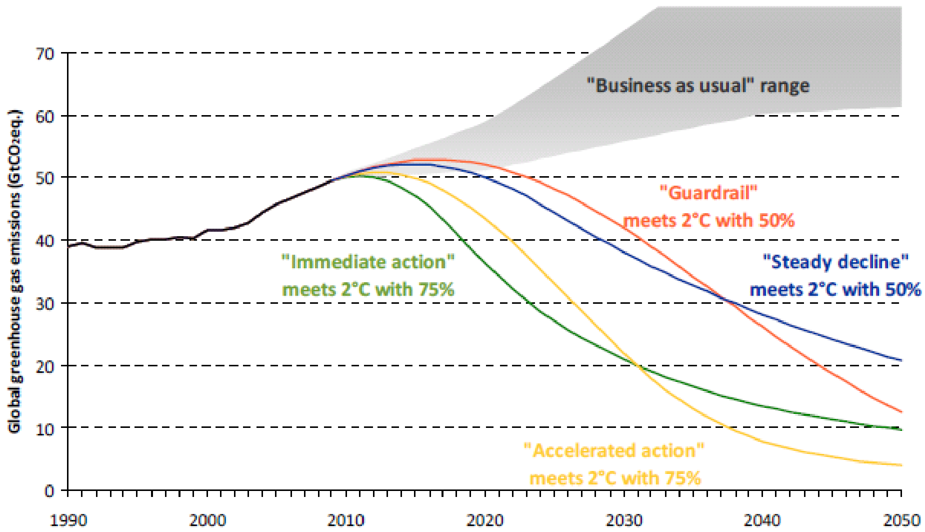
[2] Current greenhouse gas concentrations are about 385 ppm CO_2 equivalent, with a current growth rate of approximately 2 ppm per year (NOAA, 2010).

[3] Coal would still be available, but in marginal amounts (IEA, 2009).

Similar conclusions are arrived by Ecofys (2009a) and WBGU (2009). Ecofys (2009a) estimates the maximum level of GHG emissions necessary to achieve the 2 degrees Celsius target depending on the probability of meeting this target. It was estimated that in order to have a 50% chance to meet the 2° C target, CO_2 emissions can accumulate up to the level of 2,000 Gt between the years 2000 and 2050. Increasing the probability of meeting such a target to 75% would mean that a maximum of 1,500 Gt can be allowed within this period. Between 2000 and 2010, global emissions will account already for roughly 500 Gt of CO_2. This implies that between 2010 and 2050, a maximum of **1,000-1,500** Gt can be emitted in order to meet the 2° C target with a probability of 75% and 50%, respectively.

The reversal of the emissions trend must start as soon as possible – any delay will result in higher annual reduction requirements necessary to reach the 2° C goal. Ecofys describes a total of four scenarios achieving the stipulated target, differing regarding the probability of achieving the goal and the peak emissions year. Figure 1 gives a summary of these scenarios.

Figure 1 Global annual emission paths according to various scenarios



Source: Ecofys, 2009a.

Both the probability of achieving the 2° C goal and the desired emission path determine the eventual outcomes in 2020. Accepting less risk (and thus a higher probability) results in higher global reduction targets. Moreover, the reductions should take place in the immediate future: global emissions would have to peak between 2011 (immediate action scenario) and 2017 (guardrail scenario). Early peaks have the advantage that in later years fewer emissions have to be reduced.

Postponing the peak level with two years leads, according to Ecofys (2009a), to an additional reduction effort in 2050 of about 12-16% (e.g. 6-8 Gt) compared to present levels. In terms of cost of meeting the 2º C threshold, this seems to be an argument for pressing for action as soon as possible.[4]

It can be noted that the Ecofys (2009a) estimates are more or less consistent with various studies. For instance according to WBGU (2009), in order to achieve the 2º C goal with a probability of 67%, emissions of CO_2 during the period 2010-2050 cannot exceed 750 Gt. If we add 500 Gt emitted from 1990-2010 we get the volume of emissions equal to 1,250 Gt, which is just in between the estimates of Ecofys, while the probability of meeting the goal is also in the middle of the range assumed in the Ecofys estimates.

2.4 Sharing the burden of emission reductions

Global emissions of GHG have to be reduced drastically if world climate is to stay within the 2º C threshold. The question is how this reduction is to be divided among the various countries and regions. Here the notion of 'comparability of efforts' has been introduced in the climate debate.

The concept of comparability of efforts is based on the notion of equal treatment of countries with similar level of socio-economic development. If there are significant differences in the level of economic development, these differences should be taken into account in sharing the effort of mitigating global warming. Thus comparability relates to the idea of proportional rather than equal efforts. However this proportionality may be defined using various methods. In the literature one can distinguish the proportionality between Annex I and non-Annex I countries and the proportionality between countries of Annex I. Below both concepts will be elaborated. In Annex A a more conceptual treatment of the concept of comparability is being described.

2.4.1 Conceptual approaches towards comparability

Comparability may be defined in different ways. In general one distinguishes approaches that orient on a 'comparable burden' from approach that orient on 'comparable end-points'. Comparability of burdens indicate that the efforts of countries to reduce GHG should be equal taking into account differences in income, climatic conditions, past-efforts, etc. 'Efforts' can be measured in different ways: per capita, % reduction, costs or % of GDP. Comparability of end-points implies that in the long-run countries converge to a common end-point such as sectoral efficiencies (e.g. efficiency in steel making) or per capita emissions. In Annex A various approaches towards comparability are described in more detail.

Especially for the first category of approaches one should decide whether only present emissions are taken into account, or whether also historical emissions matter. As most Annex I countries have a much more long history of emitting GHG in the atmosphere, their reductions are more fierce if also historical emissions are taken into account.

[4] This point of view challenges older literature that advocated delayed response to benefit from better technology and higher CO_2 fertilization rates from natural systems at later points in time (e.g. Wigley et al., 1996; Tol, 2000). However, the question whether early action is beneficial compared to a postponed delay can probably not be answered solely with respect to cost-benefit analysis as the outcome of such analysis crucially hinges on the choice of the discount rate – upon which economists have not reached agreement.

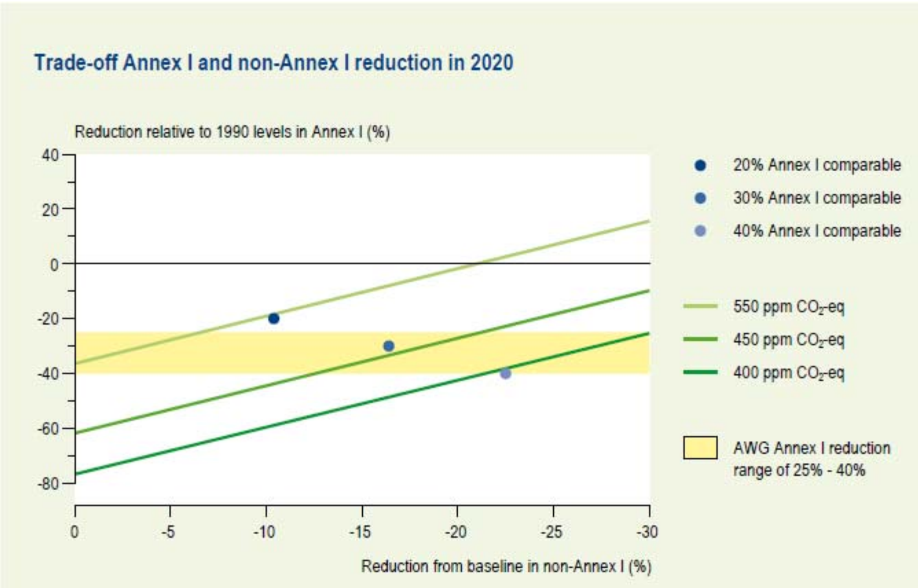
In general, ‘comparability of burdens’ seems to be more in line with the thinking in the IPCC than comparability of end-points. There is a lack of common opinion on the question whether present or historical emissions should be taken into account. This may, amongst others, depend on the question if countries could be made responsible for emissions of GHG when they did not yet know that these would result in climate change.

2.4.2 Comparability between Annex I and non-Annex I countries

In order to achieve the 450 ppm CO_2 eq. target aiming to limit global temperature rise to 2° C, various studies have summarized the necessary emission reductions in Annex I and non-Annex I countries. The IPCC, for example, states that emissions in Annex I countries need to be –25 to –40% below the 1990 level in 2020 to be able to stay within the 450 ppm atmospheric concentrations.

Figure 2 below shows the trade-off in emission reductions for Annex I and non-Annex I countries as presented in PBL (2008).[5] For Annex I, on the y-axis, percentage reductions as compared to the level of 1990 are given while for non-Annex I the reductions are given relative to a scenario where emissions are not to be reduced. Figure 2 shows the trade-off: if Annex I is going to reduce more emissions, non-Annex I has to reduce less. For the 450 ppm scenario, non-Annex I does not have to adhere to climate change policies if Annex I is willing to reduce it’s emissions by more than 60% in 2020 compared to 1990. As such goals are conceived as unattainable, both Annex I and non-Annex I countries should be willing to put effort in reducing climate change emissions.

Figure 2 Trade off between Annex I and non-Annex I countries in reduction efforts in 2020



Source: PBL, 2008.

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[5] PBL (2008) reports results of a simulation of various targets of emission reduction assumed for Annex I and non-Annex I countries using different methods of effort sharing. The calculations are made using the FAIR 2.2 model designed for the quantitative assessment of the cost and emission reduction of various climate regimes. The model uses the baseline emission scenarios and MAC curves from the integrated climate assessment model IMAGE (MNP, 2006). The socioeconomic and energy sector projections represent the reference scenario developed for the ADAM project (Van Vuuren et al., 2008).

In the scenario of 450 ppm, this figure shows that if Annex I countries are going to reduce their emissions by 30%, the corresponding baseline for non-Annex I countries would be -16%. This situation is represented in the Figure 2 by a blue dot in the middle of the 25-40% range reductions for Annex I countries. Emissions of Annex I countries in 1990 amounted to about 19 Gt of CO_2 eq. (UNFCCC, 2009) thus 30% reduction by would mean reaching the level of about 13 Gt per year in 2020. Currently, emissions of Annex I countries are at the level of about 18 Gt per year thus as compared to today's levels, this group of countries has to reduce annual emissions by 5 Gt of CO_2 eq. in 2020 compared to present levels. This corresponds to a cut of about 8 Gt as compared to business as usual (BAU) in 2020.[6]

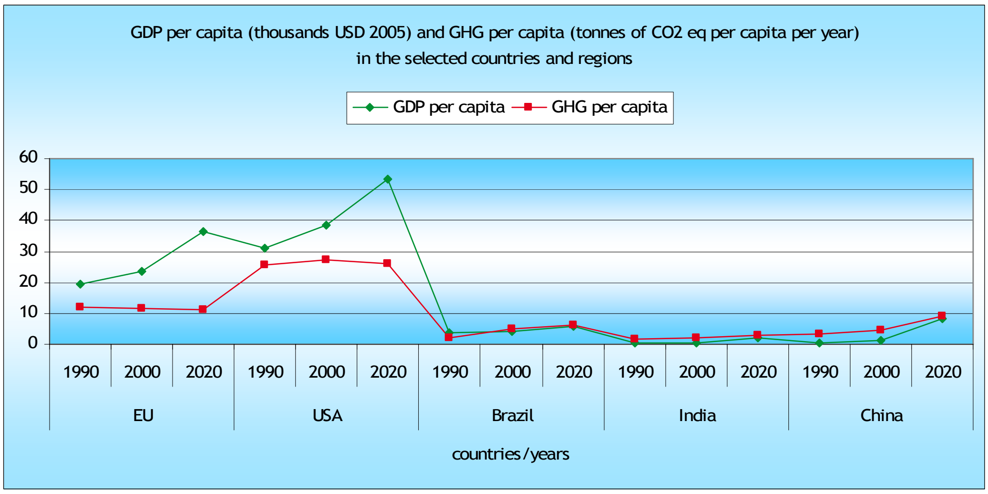
Emissions of non-Annex I countries are currently at the level of about 20 Gt CO_2 eq. per year and in the baseline scenario they are expected to grow to 23-35 Gt in 2020 depending on the pace of economic development, with 33 Gt being the number suggested in PBL (2008) based on the estimates of the EU ADAM project. Thus in non-Annex I countries 16% reduction from the baseline would imply achieving a level of about 28 Gt per year in 2020. This would mean that annual emissions would grow in absolute terms with such a reduction by about 8 Gt in 2020 as compared to the current levels but at the same time they would have to be about 5 Gt less than in the BAU scenario.

It should be noted that quite demanding reductions for the non-Annex I countries are assumed to be acceptable because part of this reduction can be achieved by carbon trade and various mechanisms of support from the Annex I countries. The reductions per capita in Annex I countries as compared to BAU in 2020 would amount to approximately 6 t while the relevant reductions per capita in non-Annex I countries would amount to about 0.8 t. Hence, the reductions per capita in Annex I countries in this scenario would be about 7-8 times higher in Annex I countries than in non-Annex I countries. However GDP per capita in Annex I countries is on average more that ten times higher than in non-Annex I countries. This rough comparison indicates that financial flows in the direction from Annex I to non-Annex I countries for mitigation of global warming is justified. In addition, historically, Annex I countries bear much more responsibility for current GHGs concentrations and this is also often raised argument supporting financial transfers from more developed economies to support developing countries in their global warming mitigation efforts.

Figure 3 shows GDP per capita and GHG per capita in five selected countries and regions, with a forecast for the year 2020 based on the data for the ADAM baseline scenario published in PBL (2008). It is evident that GHG per capita are related to GDP per capita. In order to make it possible that the trend of GHG per capita in developing countries decouples from the increasing trend of GDP per capita, financial flows from more advanced economies seem to be necessary and justified.

[6] PBL (2008) shows predicted GHG emissions levels for Annex I and non-Annex I countries according to the reference scenario used in the ADAM project of the EU (ADAM stands for Adaptation and Mitigation Strategies and it was a project of the EU 6th Framework Programme finishing in July 2009). According to these predictions, which are considered to represent a 'median baseline', in 2020 emissions of Annex I countries would amount to approximately 21 Gt while emissions of non-Annex I countries would amount to approximately 33 Gt.

Figure 3 **Relationship between GDP per capita and GHG per capita in selected countries**

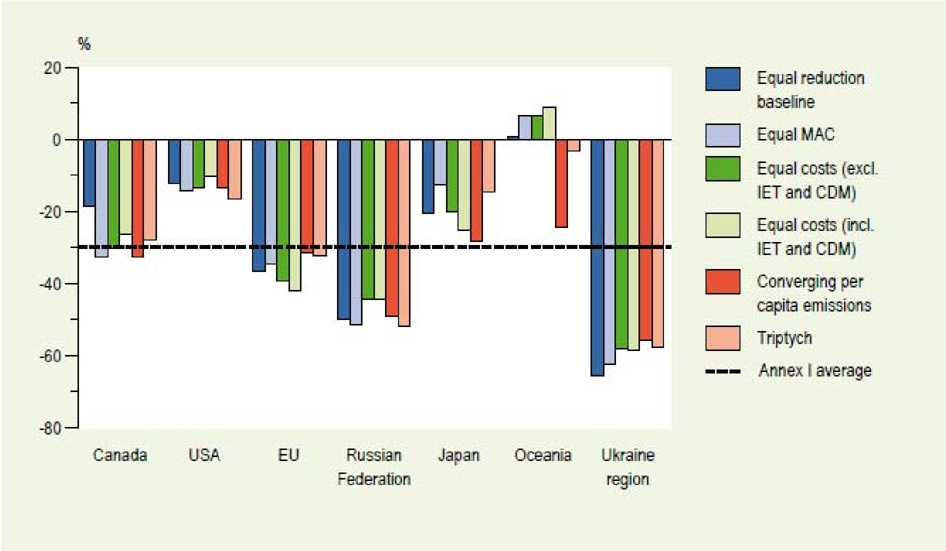


Therefore, a 30% reduction target for Annex I countries can only be perceived as 'fair' if this is going to be accompanied with substantial financial transfers from Annex I to non-Annex I countries for financing their own CO_2 reductions. Flexible mechanisms, as CDM, can be suitable for this purpose if the CDM credits come additional to the domestic reduction efforts of -30%.

2.4.3 Allocating emission reductions within Annex I countries

Given the generally accepted target of -30% domestic reduction in Annex I countries, the question comes how this target is going to be divided between the various countries and regions. PBL (2008) has modelled six effort-sharing approaches (see Annex A for detailed description of these): equal reduction baseline, equal marginal abatement costs, equal total abatement costs as a percentage of GDP by 2020 excluding international emissions trading and CDM, equal total abatement costs as a percentage of GDP by 2020 including international emissions trading (IET) and CDM, converging per capita emissions (in 2050) and Triptych. Figure 4 below give a summary of the reduction targets in percentage of the 1990 levels to be achieved by 2020 for the Annex I countries and regions if the scenario of 30% reduction of emissions for the whole group of countries is to be achieved using various effort-sharing approaches.

Figure 4 **Reductions in 2020 compared to 1990 emissions, 30% overall reduction scenario for Annex I countries according to various effort sharing approaches**

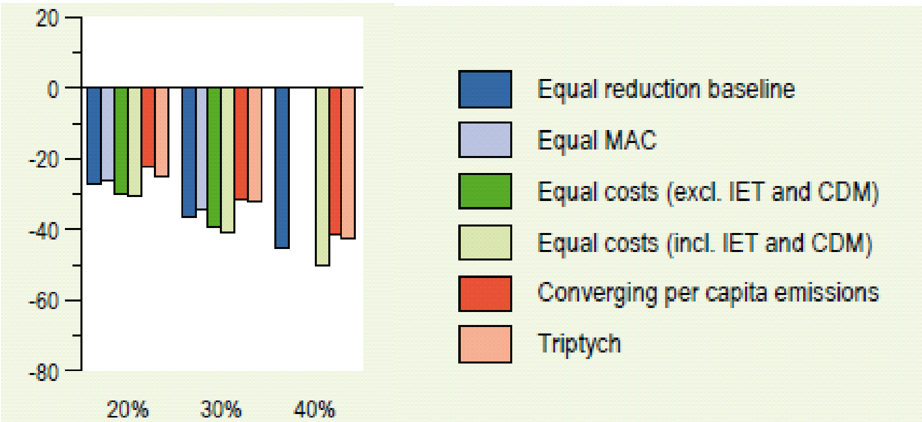


Source: PBL, 2008.

The results from these modelling efforts show that the Ukraine region and Russia should meet the highest reductions compared to 1990 levels. The EU should reduce more than 30% in all effort-sharing approaches if the overall target of Annex I is to be -30%.[7]

Also for the other scenarios, with 20% and 40% overall target, the EU has to reduce more than these targets according to all effort-sharing schemes – see Figure 5.[8]

Figure 5 **Comparison of 20%, 30% and 40% reduction targets scenarios for the EU according to various effort-sharing schemes**



Source: PBL, 2008.

7 These results have been established under the assumption that Annex I countries achieve 80% of emission reductions domestically, the rest being achieved through trading and CDM.

8 Please note that for the 40% reduction scenario, the approaches based on equal costs could not be modeled, as mitigation measures in the model were insufficient for some groups to attain the required reduction level.

2.5 Political implications of 'comparable efforts'

The EU announced an objective of a 30% reduction in GHGs by 2020 as compared to the level of 1990 provided that other developed countries would commit themselves to comparable emission reductions and that economically more advanced developing countries contribute adequately according to their responsibilities and respective capabilities. On the basis of the aforementioned PBL-reports (PBL, 2008 and 2009), it is possible to assess the current pledges in the international climate change negotiations versus the assessment of 'comparability' according to the model.

2.5.1 Comparability of pledges within Annex-I countries

In the report of PBL (2009), the selection of effort-sharing methods and division into regions/countries was slightly changed in modelling as compared to the PBL (2008). The report published in 2009 compares countries' pledges in international climate negotiations[9] with the targets resulting from modelling using various effort-sharing approaches. Such a comparison allows taking some conclusions regarding the question if the specific countries do commit to comparable effort sharing or not. Table 1 and Figure 6 below give a summary of findings from this modelling exercise.[10]

Table 1 Countries' pledges in climate negotiations versus targets resulting from modelling

Country	Pledge	Conclusions from modelling	Comments
Australia	5-25% reduction by 2020 as compared to 2000.	Significant pledge, especially the higher limit.	Comparison depends heavily on the definition of the rules for LULUCF.
Canada	17% reduction by 2020 as compared to 2005.	In most approaches, the pledge of Canada is below the reduction targets resulting from modelling.	Results are highly dependent on the effort-sharing approach. Specific situation of Canada, with large gas and oil industry and relatively low population.
Japan	25% reduction by 2020 as compared to 1990, conditional on international agreement.	The pledge of Japan is on the ambitious end of the results of modelling.	Results are highly dependent on the rules for LULUCF.
New Zealand	10-20% reduction by 2020 as compared to 1990.	The pledge of New Zealand is on the ambitious end of the results of modelling.	Results are highly dependent on the rules for LULUCF.
Norway	30% reduction by 2020 as compared to 1990, 40% conditional on international agreement.	The pledge of Norway is without doubt the most ambitious of all countries and above results of modelling for all approaches.	Results are highly dependent on the rules for LULUCF.

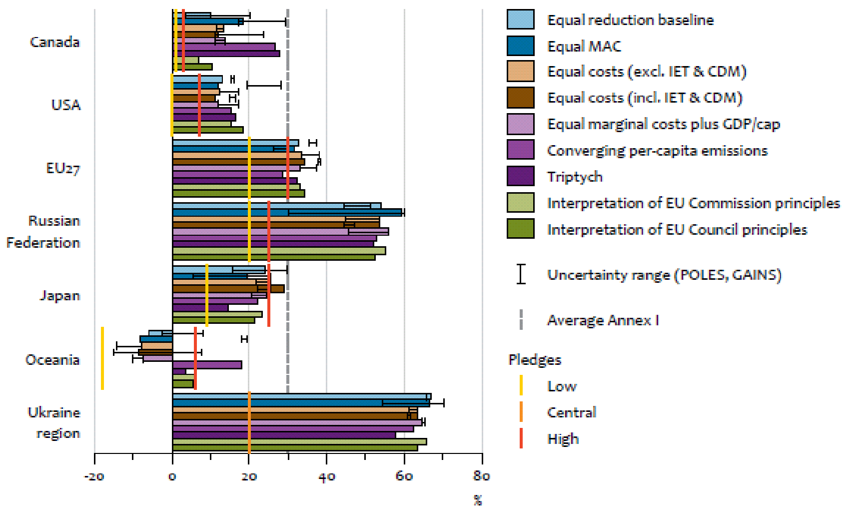
9 Countries pledges as reported in PBL (2009) have been updated and verified against the pledges published in UNFCCC (2010).

10 Please note that the selection of countries included in the table and in the graph is slightly different, which is due to the fact that not all countries presented in the table are included in the FAIR model.

Country	Pledge	Conclusions from modelling	Comments
Russia	25% reduction by 2020 as compared to 1990 conditioned on international agreement.	The pledge of Russia is not ambitious as compared to the results of modelling. All effort-sharing approaches suggest higher targets.	Results are highly dependent on the rules for LULUCF.
Switzer-land	20-30% reduction by 2020 as compared to 1990.	The pledge of Switzerland, and especially the higher end, is in line with the targets resulting from modelling.	Results are highly dependent on the rules for LULUCF.
USA	No official pledge; president Obama has stated that USA could remove emissions to 1990 levels; planned legislation is taken as the more ambitious target in the range of 17% reduction by 2020 as compared with 2005 level.	The current version of the legislation is less ambitious than the reduction range calculated in the model unless financing of reducing emissions from deforestation in developing countries is included.	Results are highly dependent on the rules for LULUCF.

Source: Based on PBL (2009) and UNEP (2010).

Figure 6 GHG emission reduction targets 1990-2020, Annex I countries and regions



From Table 1 and Figure 6 it is evident that in general, according to this model (PBL, 2009), the pledges made by Annex I countries and regions are not sufficient for reaching GHG emission reductions needed to secure the 30% overall reductions in this group of countries (which is assumed to be necessary for meeting the goal of maximum 2° C global warming).

According to this analysis, the current pledge of 20% reduction in the EU is not ambitious enough for meeting the overall target of 30% for Annex I countries. According to the model, the EU in all comparable effort-sharing approaches, except for converging per-capita emissions, should commit to more than 30%

reductions (between 30 and 40%). The EU -20% reduction target would in that line be similar to the highest pledges from Canada, Ukraine, Russia and the USA. However, this should not fully restrict the EU from accepting higher targets as the higher range of pledges from Japan and Australia/New Zealand (as well as Norway and Switzerland) would be in line with the EU -30% target. So the question is in essence here: who does the EU want to follow: the disappointing climate policies of USA and Russia, or the more ambitious proposals of Australia, New Zealand and Japan along with the non-EU European countries?

2.5.2 Comparability of pledges for emerging economies

Not only the reduction efforts in Annex-I but also in non-Annex I countries matter for the possibility of staying within 2° C increase in global temperature.

Current positions of emerging economies on GHG reduction are much more difficult to assess than the positions of countries representing more developed economies. Ecofys (2009b) provides such a preliminary evaluation.[11] The evaluation is performed by comparing the current and projected performance of a given country with the target of 15-30% reduction below a reference scenario, which is consistent with the scenario of keeping global warming below 2° C increase in temperature while Annex I countries reduce in total 30% of emissions (in 2020 as compared to 1990). The main findings of this analysis are summarised in Table 2.

Table 2 Current pledges of the selected emerging economies and their evaluation regarding comparable effort-sharing

Country	Pledge	Evaluation
China	40-45% reduction by 2020 as compared with 2005.	No quantitative emission target has been proposed. China's domestic plans include targets and policies which are ambitious and would rate as moderate to sufficient.
India	No overall quantitative target has been announced. The announced endeavour is to reduce emissions intensity of GDP by 20-25% by 2020 as compared to the level of 2005.	India's goals stated in a national climate plan are rated medium.
Brazil	36-39% as compared to reference emissions projected for 2020, which would approximate 1994 emission levels.	Ambitious target. The most important measure planned is to reduce the deforestation rate in the Amazon region by 80% between 2005 and 2020.
South Africa	34% below a reference scenario for 2020.	Ambitious target although it is not clear what measures will be implemented.

[11] The evaluation of Ecofys has been updated and verified using the data from UNEP (2010).

Country	Pledge	Evaluation
Mexico	21% below a reference scenario in 2020 and -30% with international financing.	Ambitious goals and a detailed climate plan. However the reductions after 2012 are conditional on external financing.
South Korea	30% below reference emissions in 2020, which is 4% below 2005 level.	Relatively ambitious target however the comparable effort ranges would require more ambitious reductions due to the relatively high level of development.

Source: Based on Ecofys (2009b) and UNEP (2010).

The differences in the ambition level between the countries in this group are large. Brazil ranks high, Mexico and Korea are in the middle of the range, while the targets of China and India are at the moment impossible to assess in qualitative terms.

Ecofys (2009) estimates that the actions proposed by emerging economies and developing countries according to their current pledges could lead to a reduction in GHG emissions in this group of countries at the level of 5-15% below BAU scenario by 2020. This is not enough to meet the 16% reduction target for the 2° C increase in temperature goal but quite close. Therefore the conclusion holds that developing countries could be closer to meeting this target than Annex I countries to their 30% target. Such assessment is surrounded with huge uncertainty due to data limitations and a very little level of precision in information obtained from the group of developing countries.

2.6 Conclusions

In order to keep world climate within the range of 2° C warming, it is required that worldwide emissions are to fall considerably. From the total emission space that is available between 2000 and 2050 the world has already consumed 25-35% in the last ten years. Worldwide emissions need to be curbed downwards in the next few years; otherwise the goal of 2° C warming cannot be met.

Both Annex I and non-Annex I countries should reduce their emissions by 2020 in order to keep track of the 2° C threshold. According to the IPCC, a reduction goal of Annex I countries of 25-40% in 2020 compared to 1990 is required to stay below a 2 degrees Celsius global warming. According to several studies, we need to stay within the high end of 25%-40% reductions to have a higher chance of meeting the 2 degrees threshold (precautionary principle!). Another reason to stay within the high end of this range is that this seems to be more fair to non-Annex I countries. With an average of 30% reduction in Annex I countries, the non-Annex I countries must reduce their emissions by 16% in 2020. This reduction of 16% in non-Annex I countries corresponds to a cut of about 5 Gt of emissions predicted in BAU scenario in 2020.

Given the low financial possibilities to reduce emissions, this seems an ambitious reduction target for non-Annex I countries. Annex I countries can assist them to make the necessary transformation by providing loans. Alternative means would be to make greater use of flexible mechanisms like

CDM; however these should then preferably come on-top of the 30% reduction target.

If the 30% target is to be divided among the Annex-I countries, the EU should, according to various comparable effort-sharing approaches, reduce between the 30-40% compared to 1990 levels. Such higher reduction targets stem from concepts like equalisation of costs or emissions per capita, according to various scenarios. Hence a -20% target in the EU is not in line with a notion of ‘comparable efforts’ to keep global temperature below the 2° C.

The eventual EU target will also depend on what other countries are putting forward as targets in the international climate negotiations. By comparing the pledges of the various countries in Copenhagen, one may arrive at the conclusion that a -20% target is disappointing and more or less comparable to what the USA, Canada and Russia have suggested. However many countries have put forward more ambitious reduction targets, like Australia/New Zealand, Japan, Norway, Switzerland and most non-Annex I countries. Therefore, also from a political perspective, the EU should feel pressurized to increase its target to -30% at least.

3 Impacts of economic crisis on EU policies

3.1 Introduction

When the EU agreed upon the 20% reduction target and the 20-20-20 policy plan, considerable concern was expressed on the economic costs of meeting such targets and policy plans. Industry typically claimed that costs could become so high that it would deteriorate the competitive position of the EU. Despite the fact that this claim was not really justified by independent research, it can be expected that an increased target of the EU should result in similar resistance. The more so since the economic crisis has weakened the financial resources of companies and governments.

However, the economic crisis also has had an impact on the amount of CO_2 emissions, which are now lower than before the economic crisis. So how should we balance both influences? How does the economic crisis impact on the affordability of climate change policies and are more stringent targets now easier to reach or more difficult?

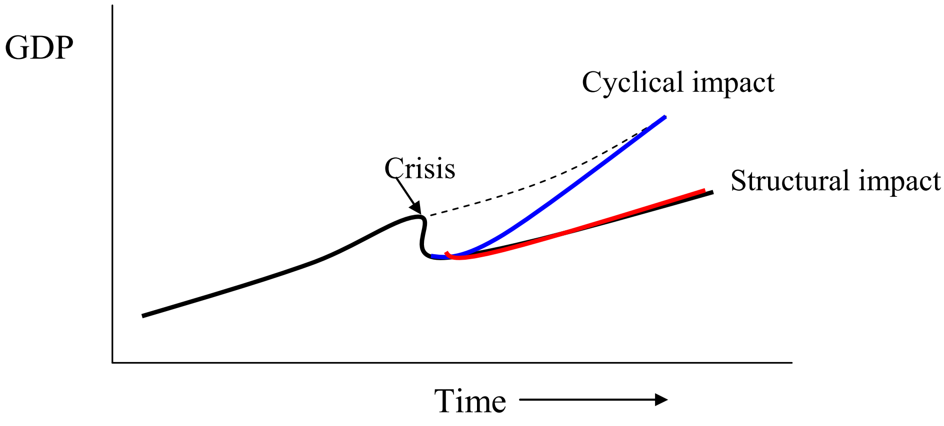
In this chapter we investigate the impact of the economic crisis on the costs of meeting a more stringent target. First in paragraph 3.2 we will investigate the total costs of meeting the 20% target and how the economic crisis has impacted on these costs, and then we subsequently we investigate how much additional packages would cost taking into account the impacts of the economic crisis (paragraph 3.3). Finally, in paragraph 3.4 we will investigate the question whether capital for large scale investments has become scarcer after the economic crisis and how this impacts on the desirability of more stringent targets.

3.2 Impact on costs of meeting fixed reduction targets

3.2.1 Structural or cyclical adjustments?

Economic crises have been frequent in the economic system since the earliest record of economic data. An economic crisis can have a temporary or permanent impact on the level of GDP. For a temporary (or cyclical) crisis, the negative growth in a specific year is in later years catched up by accelerated growth so that the total impact of the crisis on the income levels of the future is negligible. Structural impacts, on the contrary, tend to have a permanent effect on the economy by lowering future GDP levels.

Figure 7 The difference between both types of crisis



The present economic crisis is by large considered to have a structural impact on future levels of GDP. This implies that future income levels will be structurally lower than they would have been without economic crisis.

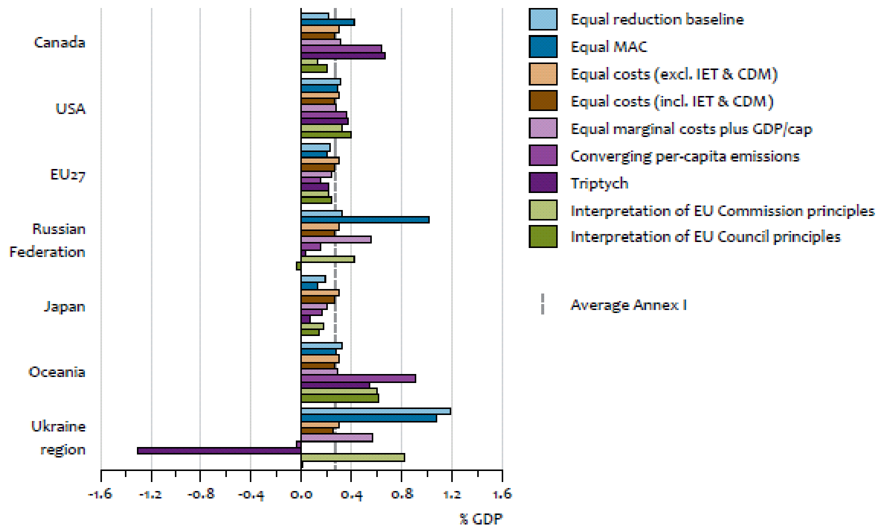
With respect to climate policies, the crisis has some different impacts. Emissions of CO_2, which are highly correlated with the growth of the economy, will be lower as well. As a consequence, the costs of meeting absolute targets, like in Annex I countries, will be lower. Compared to business as usual, the economic crisis has the impact that fewer emissions have to be reduced to achieve the targets. This lowers the costs of complying with those targets. Finally, the economic crisis will impact on the effectiveness of environmental policies, as various targets are set in relative terms (see below for more explanation).

3.2.2 Overall costs Annex I about half lower

Average abatement costs in the 30% Annex I reduction scenario have been estimated in PBL (2008) at the level of 0.55% of GDP. However these estimates have been updated in PBL (2009), where account is taken of the impact of the economic crisis. According to the updated report, the average abatement costs for Annex I countries would amount to about 0.27% if GDP, so they would be almost 50% lower than expected without the economic crisis.[12] For the EU this percentage is slightly lower than average for all approaches, with the exception of equal total costs scheme excluding trading. Figure 8 gives an overview of abatement costs as a percentage of GDP in Annex I countries.

[12] Also IIASA (2009) show that the total GHG abatement costs in Annex I countries for the scenario of 30% reduction amount to approximately 0.5% of GDP in the scenario without the crisis and to approximately 0.2% of GDP in post-crisis situation, which is in accordance with the PBL estimates.

Figure 8 Abatement costs as percentage of GDP, 30% reduction target, Annex I countries according to various effort-sharing approaches



Source: PBL (2009), see for description of the scenarios Annex A.

3.3 Impacts for the EU

In December 2008, the European Union agreed upon the Integrated Energy and Climate Change package which underlines the objective of limiting the rise in global temperature to maximum 2° C as compared to the pre-industrial level[13]. To achieve this goal, Member States agreed to reduce total EU GHG emissions by 20% in 2020 as compared to 1990. Minimising overall reduction costs implies a 21% reduction in emissions from EU ETS sectors by 2020 as compared to 2005 and a reduction of approximately 10% of emissions in 2020 as compared to 2005 from non EU ETS sectors. The coverage of the non-trading sectors (including households, services, transport, waste and agriculture) currently represents about 60% of total GHG emissions of the EU (EEA, 2009). How did the economic crisis impact on this climate package?

3.3.1 Impacts compared to business as usual

The economic crisis is to have a profound impact on the European economies. Some models estimate that overall GDP will be 13% lower in the EU in 2020 (IIASA, 2009, based on analysis from the IEA, 2008 and 2009)[14]. This fall down in economic activities results, according to IIASA (2009), in a decrease of GHG emissions of 12%[15]. This seems a reasonable assumption here that due to the economic crisis, GHG emissions will be about 12% lower in 2020 compared to a business as usual scenario.

13 On 6 April 2009, the European Council adopted the Integrated Energy and Climate Change package.

14 This figure can be perceived a bit higher than expected, as the economic crisis so far has resulted in a 4.5% lower GDP between 2007 and 2009. Given the fact that in the business of usual scenario of IEA (2008) the economy of the EU-27 is expected to grow at 2.5% per annum, the fall down of the economy is at present about 9.5%.

15 However, IEA (2008) and (2009) may not be entirely comparable, as has been done by IIASA (2009), as the baseline of the World Energy Outlook in 2008 and 2009 includes for the EU-27 a different mix of policy scenarios.

As the economic crisis does have a more profound influence on the EU than for other Annex I countries, the costs will also decline more considerably. In order to quantitatively assess the impacts of the economic crisis, we adopt data used by Ecofys (2009c). Ecofys (2009c) describes a forecast of the EU policies aimed at GHG reduction with the perspective of meeting the 20% reduction target in 2020 as compared to the level of emissions in 1990. The baseline scenario is based on Capros et al. (2008) and uses the PRIMES model. This is the scenario underlying the 2008 climate package of the European Commission (European Commission, 2008b). The PRIMES baseline takes into account implemented policies up to 2006 and an average growth of GDP of 2.3% per year for the period 2005-2020. Overall, the PRIMES baseline predicts an increase of total greenhouse gas emissions in the EU-27 of 5.5% between 2005 and 2020.

Total greenhouse gas emissions in the EU in 2005 (baseline) were equal to 5,211 Mton of CO_2 eq. and are projected to grow to 5 496 Mton in the baseline scenario. The target of 20% reduction of GHG emissions in comparison to 1990 would lead to a reduction of emissions to 4,458 Mton in 2020 (or -20%). This is divided by Ecofys (2009c) to corresponding targets of ETS and non-ETS emissions where ETS typically has the more stringent targets procentually. In these figures we roughly estimated the impacts of the crisis on the amount of emissions that have to be reduced to reach the target. As the PRIMES model seem to have a less higher correlation between economic growth and CO_2 emissions than the model used in the World Energy Outlook (IEA, 2008 and 2009), we calibrate here the reduction due to the crisis to be in the range of 9%. For reasons of simplicity we assumed that the additional reduction in baseline emissions of 9% according to IIASA (2009) applies equally between ETS and non-ETS sectors. This gives the following results.

Table 3 Overview of baseline emissions and reduction targets in 2020 as compared to 2005 (Mton of CO_2 eq.)

	2005 emissions	2020 baseline before crisis	*2020 baseline after crisis*	2020 target emissions	Target 2020 c.t. 2005	Target 2005 c.t. baseline	Target 2005 c.t. baseline after crisis
EU ETS	2,340	2,557	2,330	1,872	-20%	-27%	-19%
Non-ETS	2,871	2,940	2,670	2,584	-10%	-12%	-3%
Total GHGs	5,211	5,496	5,000	4,458	-14%	-19%	-10%

Source: Own calculations based on Ecofys (2009c). Targets refer to targets excluding international aviation.

In Table 4 the total percentual change in 2020 emissions is compared to:
a The 2005 emissions.
b The 2020 baseline from PRIMES.
c The 2020 baseline when corrected for impact from the economic crisis.

From these comparisons, we see that the economic crisis almost covers up for the required reduction in non-EU ETS sectors. They will have to reduce a meagre 3% compared to business as usual in 2020. EU ETS sectors still must reduce their emissions with about 19% compared to business as usual implying that positive prices will still prevail on the ETS markets (there is scarcity).

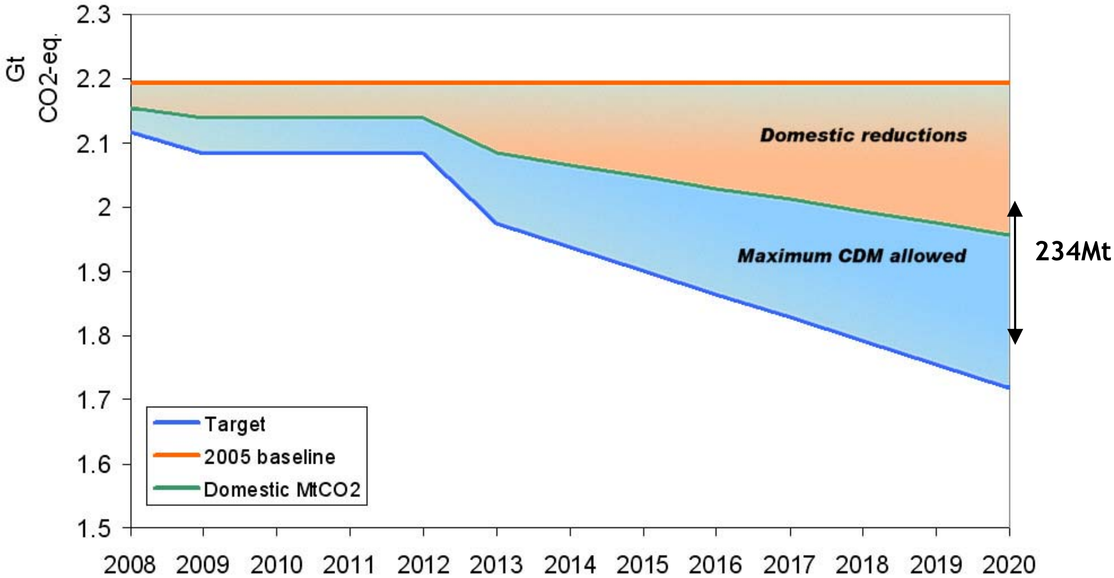
However, a substantial part of these reductions will be covered by CDM/JI/AAU credits (see below for an analysis).

3.3.2 The role of CDMs in reaching the targets

One important question is to what extent this 20% reduction compared to the crisis adjusted business as usual levels is going to be reached. This is, amongst others, depended on the amount of CDM/JI that is going to be used in reaching these targets. During the second trading period, Member States allowed their operators to use significant quantities of credits generated by emission-saving projects undertaken in third countries to cover part of their emissions in the same way as they use ETS allowances. The use of these credits is extended for Phase III (2013-2020) in such a way that the overall use of credits is limited to 50% of the EU-wide reductions over the period 2008-2020 compared to 2005.

Ecofys (2009c) estimated that, before the recession, about 36% of the reduction compared to 2005 will be achieved by using flexible mechanisms. The volume of carbon credits available annually for CDM has been estimated at the level of 122 Mt, which results from dividing the overall volume of 1,584 Mton for the period 2008-2020 by 13 years thus assuming equal spread over the whole period. However, this does not necessarily reflect the situation in 2020 but rather an average in the period 2008-2020. Using the 50% maximum set by the Commission for every year individually, one can re-estimate the amount of CDM to cover emissions can slowly grow over the years mounting to 234 Mtons in 2020.

Figure 9 **Total amount of CDM and domestic reductions against the 2005 baseline in EU ETS sectors (aviation excluded)**



Note: The total amount of CDM (the blue area) amounts to 1.6 Gt CO_2, similar to the estimate by Ecofys.

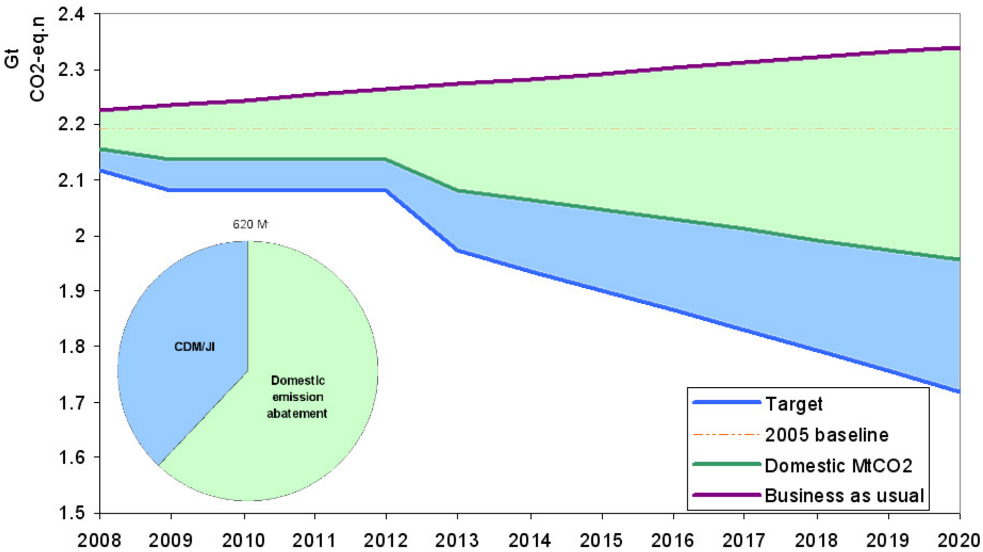
Figure 9 of 234 Mton of CO_2 is then to be added to the 98.5 Mton that is estimated to be used in 2020 in the non-ETS sectors.[16]

3.3.3 Impact of the economic crisis on EU ETS

The economic crisis will have a severe impact on EU ETS: in fact there is the thread that the functioning of EU ETS will be fundamentally changed compared to the situation before the economic crisis.

Figure 10 depicts the situation as was apparent before the economic crisis. The green area gives the emission reductions that have to be achieved within the EU compared to the business as usual scenario and the blue area gives the CDM credits. The pie chart depicts the situation in 2020: about 2/3 of the required reductions compared to the business as usual are to be realized by domestic emission reductions.

Figure 10 Development of EU ETS (excl. aviation) and ways of meeting the target before the economic crisis (2008-2020)

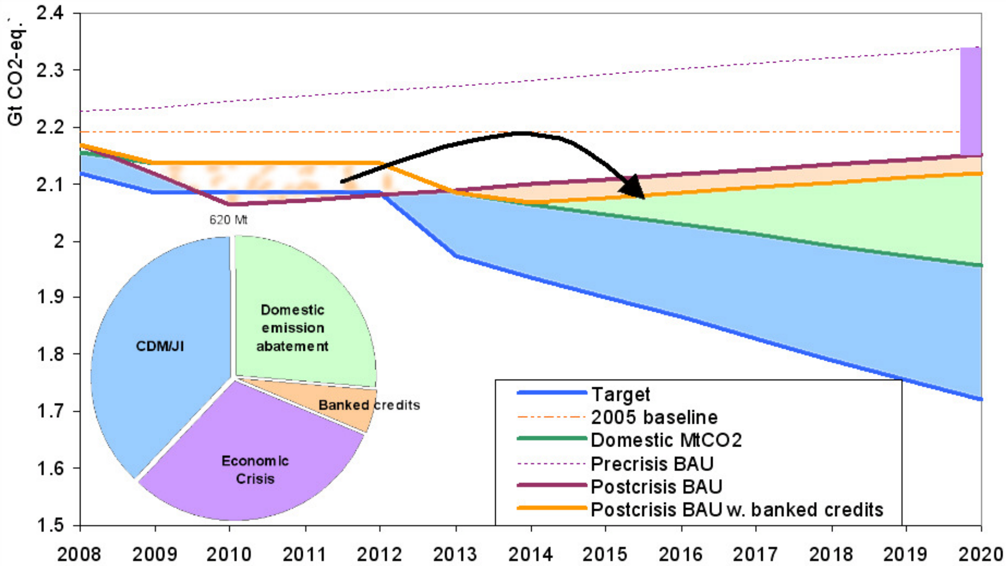


However, the economic crisis has a severe impact on this 'business as usual' scenario. Between 2009 and 2013, domestic emissions under the revised business as usual are now slightly below the target. However, CDM credits could be used to cover present day emissions so that banked EUAs could be transferred to the next period (Ecofys, 2009c). This generates a cumulative surplus of credits amounting to 220 Mton by 2013. Banking allows these to be used in Phase III of the EU ETS, from 2013 onwards, such that in 2020 domestic can be higher. As can be seen from Figure 11, the green area representing the domestic efforts to reduce emissions under EU ETS is now considerably lower. The amount of emissions that is to be reduced over the period 2008-2020 reduces from to 2,800 Mton to less than 600 Mton: a reduction of almost 80%.

[16] Also here one could argue that the use of CDM in non-ETS sectors will be growing over time as more CDM projects may become available and a proportional share of reductions in non-ETS sectors is to be realized by flexible mechanisms. However, we did not take that effect into account.

The pie charts indicate the mechanisms that are responsible for the reduction in 2020 before and after the economic crisis. They show that the domestic reductions shrink from about 2/3rd of reduction efforts in the original situation to about 1/4th in the present situation with taking into account the impacts from the economic crisis.

Figure 11 Impact of economic crisis on EU ETS (excl. aviation) 2008-2020 and pie chart 2020



This has, in addition to the lack of ambition, three important side-consequences:

1. The costs of meeting the climate package will now be drastically reduced. The average costs of meeting the EU ETS cap from 2008-2020 will be more than a factor 5 lower due to the fact that the marginal cost curve for CO_2 emissions is not linear. As we will outline in the next Section, we estimate the present costs to be lower than 0.05% of GDP – almost a tenfold reduction compared to earlier estimates.
2. The development of emission abatement technologies will be much slower in the EU. Literature has supported the view that environmental policies do stimulate innovation and lower the costs of future environmental policies (see paragraph 5.4).
3. The market in EU ETS will now entirely be driven by other policy fields. The renewable energy directive will reduce domestic emissions at an estimated 9% compared to the 1990 emissions of the whole EU-27 (Ecofys, 2008). That is equivalent to about 500 Mton CO_2. A large part of these emissions will fall under EU ETS creating a supply of 300-400 Mton CO_2 in 2020. At the same time, demand is only 160 Mton of CO_2 in 2020 after the economic crisis. Hence, there is an oversupply of credits on the market. Moreover, since supply is fixed by other policies and demand is fixed by the cap, the price of CO_2 may go down to zero if no banking is allowed in an eventual fourth period post 2020. This means that under a target of -20%, EU ETS has the risk of failing to deliver any abatement incentive, just as has happened after Phase 1 when prices collapsed.[17]

[17] One should notice that this does not change if aviation is included in EU ETS. Aviation will demand a maximum of about 80 Mton according to Primes estimates before the economic crisis (Ecofys, 2009c). After economic crisis, demand from aviation will also be lower.

3.4 Conclusions

The economic crisis will have a larger impact on EU than on other Annex I countries. For the Annex I countries as a whole it implies that the costs of meeting a 30% reduction target in 2020 is reduced by about half. Some of the analyses on the EU level suggest also that EU-wide costs will be reduced to a similar level. However, the analysis in this chapter suggests that chances are high that the impacts of the economic crisis alone will be enough to achieve the majority of emissions reductions compared to business as usual. For non-EU ETS sectors, the impact of the economic crisis may almost be enough to reduce emissions to the target (-10% compared to 2005). The remaining 70 Mton can be completely reduced by using CDM.[18]

Emissions in the EU ETS sectors in 2020 must still be 20% lower compared to business as usual. However, the possibility to bank CDM/JI credits in Phase 2 for using in Phase 3, and the possibility to have 50% of the reductions covered by CDM, suggests that the total amount of domestic reductions is most likely to be much lower. Only 25% of the reductions in 2020 compared to the original business as usual will be covered by domestic reductions. This would create a demand for 160 Mton of credits in 2020. However, as the domestic supply is much larger due to the renewable energy directive, the price of EU ETS will presumably fall to nearby zero if no banking is allowed into an eventual fourth trading period post 2020.

Table 5 gives information on the final division of the 20% goal in the EU over ETS and non-ETS sectors. We see here that the 20% goal of EU ETS can almost completely be covered through the input of flexible mechanisms. The true virtue of the climate change package is now revealed: in total only 4% domestic emission reduction is being achieved with the climate package compared to the 2005 emissions.

Table 5 Emission developments and the Climate Change Package of the Commission in CO_2 emissions (Mton/yr) in 2020

	2005 emissions	2020BAU_crisis	2020Target	Reduction compared to BAU	Input of CDM/JI and BC*	Domestic reductions	Domestic reductions % compared to 2005
EU ETS	2,340	2,330	1,872	458	266	192	8%
Non-ETS	2,871	2,670	2,584	87	87	0	0%
Total GHGs	5,211	5,000	4,458	547	353	192	4%

Note: * Under the assumption that the price of CERs is lower than the price of EU ETS and assuming maximum transferability of Phase 2 ERU/CERs into Phase 3. BC= Banked credits from Phase 2. Only influence from EU ETS and non-EU ETS policies have been taken into account. No impacts from renewable energy directive and energy efficiency programs have been estimated.

[18] About 3% of the emissions in 2005 can be covered by using CDM (Ecofys, 2009c).

This conclusion only holds if the price of CERs will be lower than the price of EU ETS. If the price of EU ETS will be lower, firms may find it more profitable to reduce emissions internally and more domestic reductions will be achieved at the expense of CDM. Secondly, this conclusion only holds if one does not take into account eventual influences from other EU policies, like the renewable energy directive or energy efficiency programs.

4 More ambitious policy packages

4.1 Introduction

The analysis in chapter 2 showed that a 20% overall target is not enough to keep the world within the 2° C threshold. Chapter 3 showed that the economic crisis has resulted in the possibility that the EU climate goals will be attained without much domestic reduction in the EU. Therefore the 20-20-20 policy package not only lacks ambition but is also difficult to sell in the international climate change negotiations.

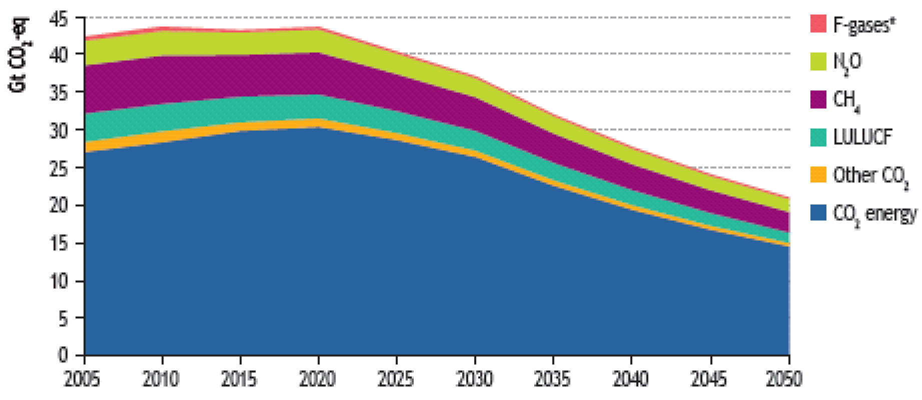
In this chapter we will investigate alternative packages of EU targets and investigate the domestic reduction efforts that may stem from these packages. We will also investigate potential costs and benefits from such packages. First, in paragraph 4.2, we will investigate the IEA scenario that aims to stay within the 2° C threshold. This scenario will be sketched both for the world and for the EU. Then, in paragraph 4.3, we will, based on this IEA scenario, present 3 packages for the EU that accept an overall target of -30 to -40% for the year 2020 and investigate the distribution of direct costs of such packages. Finally, in paragraph 4.4 we will investigate some auxiliary costs and benefits of an enhanced climate change program within the EU.

4.2 IEA policy scenarios

4.2.1 World

In order to reach a further decline in greenhouse gases and mitigate climate change to a maximum temperature rise of 2°C, a more strict policy plan is needed than the reference scenario. It is estimated that for reaching this goal, CO_2 emissions need to fall 50 to 80% below 2000 levels by 2050. In the IEA (2009) scenario, global energy-related CO_2 emissions peak just before 2020, at the level of 30.9 Gt and decline thereafter to 26.4 Gt in 2030. The emission reduction in this scenario would amount to almost 4 Gt in 2020 and 14 Gt in 2030 as compared to the reference scenario. The forecasted trend of GHG emissions is depicted in Figure 12.

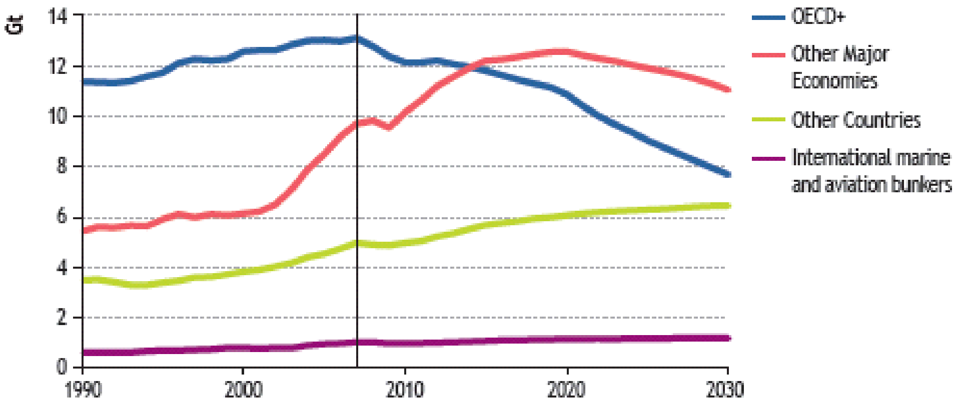
Figure 12 Global anthropogenic GHG emissions in the 450 ppm scenario



Source: IEA, 2009.

In this scenario, emissions of OECD+ countries[19] decline steadily, from 13.1 Gt in 2007 to 7.7 Gt in 2030. Emissions in Other Major Economies (including China and Brazil) peak at 12.6 Gt in 2020 and then decline to 11.1 Gt in 2030, still 14% above the level of 2007. Emissions in other countries increase steadily. These trends are shown in Figure 13.

Figure 13 Energy related emissions by region in the 450 ppm scenario



Source: IEA, 2009.

In this scenario, world primary energy demand grows 20% between 2007 and 2030. Except for coal, demand for all fuels is higher in 2030 than in 2007. Fossil fuels comprise 68% of global primary demand in 2030 as compared to 80% in 2007. The share of zero-carbon energy carriers increases from 19% in 2007 to 32% in 2030.

Policy framework in this scenario assumes a combination of policy instruments, namely carbon markets, sectoral approaches and national policies and measures. Carbon market for power generation and industry sectors is assumed to be introduced in OECD+ countries in 2013, with a total cap of 5.2 Gt in 2020 and 2.7 Gt in 2030. According to IEA (2009) the estimated price of CO_2 with such caps would amount to US$ 50 per tonne in 2020 and US$ 110 in 2030.

In 2021, a separate cap-and-trade system would be introduced in Other Major Economies (including China, Russia and Middle East). The two schemes are not assumed to be linked. Other Major Economies (through 2020) and Other Countries (through 2030) would have the opportunity to generate and trade emissions credits through carbon-market mechanisms. In case if domestic emissions in OECD+ countries exceed the imposed emission limits, they would be able to buy a limited amount of emission credits from non-OECD regions to achieve compliance. If, in 2020, OECD+ countries were to purchase additional credits amounting to 600 Mt, the credit price of CO_2 in the Other Countries Market would be around US$ 30 per tonne.

National policies and measures, and sectoral agreements in transport and industry are expected to generate 2.1 GT reductions, and the remaining 1.8 reductions in 2020 as compared to the reference scenario could be achieved through a combination of domestic reductions in the power and industry

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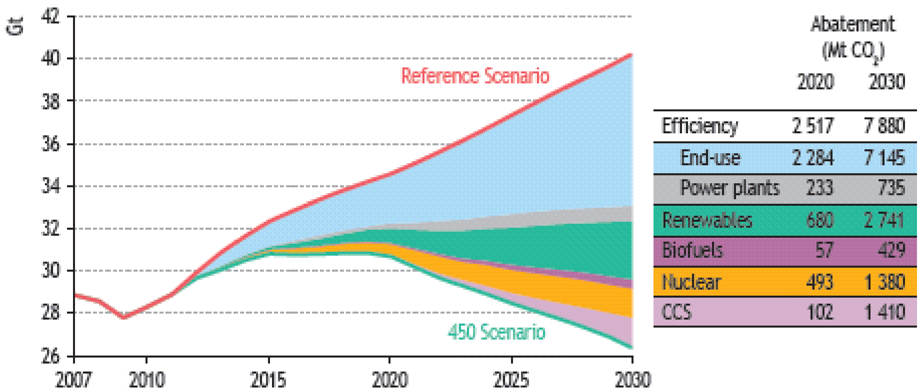
19 OECD members plus EU Member States not being OECD members.

sectors in OECD+ countries and through carbon-market mechanisms in non-OECD countries.

Figure 14 shows share of various measures in achieving CO_2 reductions in 450 ppm scenario as compared to the reference scenario.

Figure 14 Global energy related CO_2 reductions in 450 ppm scenario as compared to the reference scenario



Source: IEA, 2009.

Energy efficiency measures would contribute the most to CO_2 emissions abatement as compared to the reference scenario (they constitute more than half of the reductions). Early retirement of old, inefficient coal plants and their replacement by more efficient ones, mainly in China, accounts for an additional 5% of the global emissions reduction. Increased use of renewables in power and heat generation account for 20% of reductions and increased use of bio fuels in transport – for 3%. Additional nuclear power generation and CCS in power and industry each represent about 10% CO_2 reductions in 2030 as compared to the reference scenario.

4.2.2 EU policy scenario 450 ppm

The scenarios presented in the World Energy Outlook are also modelled separately for the specific regions and countries. Table 6 gives a summary of changes in demand for energy coming from the specific sources in the reference and 450 ppm scenarios together with the projected energy-related CO_2 emissions in the EU.

Table 6 **EU-27 energy demand per source in Mton and the energy related CO_2 emissions (in Gt per year) for the reference and 450 ppm scenario**

Energy demand in Mote	Reference year	Reference year	Reference scenario		% change		450 ppm scenario		% change	
	1990	2007	2020	2030	1990-2020	2007-2030	2020	2030	1990-2020	2007-2030
Coal	455	330	260	233	-43%	-29%	204	103	-55%	-69%
Oil	603	607	557	545	-8%	-10%	512	448	-15%	-26%
Gas	295	432	463	508	+57%	+18%	429	418	+45%	-3%
Nuclear	207	244	202	192	-2%	-21%	257	297	+24%	+22%
Renewables	74	144	241	302	+226%	+110%	267	415	+261%	+188%
TPED in Mt	1,633	1,757	1,723	1,781	+6%	+14%	1,668	1,682	+2%	-4%
Energy-related CO_2 emissions	4.0	3.9	3.6	3.5	-10%	-10%	3.1	2.3	-23%	-41%

Source: IEA, 2009.

As can be seen from the table, in the reference scenario, CO_2 emissions in the EU-27 are expected to be only 10% lower than in 1990. The rest can (and will) be covered with flexible mechanisms in order to obtain the 20% target in the reference scenario.[20] In the 450 ppm scenario, the decline in emissions between 1990 and 2020 would amount to 23% from domestic measures.

Energy efficiency is assumed to offer the largest scope in order to cut emissions towards 2030. According to IEA (2009), the largest contribution should be done by end-use efficiency due to investments in buildings, industry and transport. More power plant efficiency can be reached by investing in techniques that result in less energy loss during electricity generation, by add-ons that decarbonise the emissions or by switching from coal to gas plants.

The huge increase in the use of renewable energy sources has to evolve in a shift in energy fuel mix. For electricity generation this means the share of nuclear energy and renewables must increase, while the share of coal and gas should decrease. Furthermore, big investments are needed in carbon capture and storage (CCS) at present coal and gas power plants. In the transport sector (road transport and aviation) the amount of consumed oil must be reduced. In order to reach that, the expansion of bio fuels and the uptake of new vehicle technologies, such as the electric, hydrogen and hybrid car, should be promoted. In this scenario only 40% of the cars on the market are allowed to be a conventional combustion vehicle in 2030 (IEA, 2009).

[20] Not all policies currently in place at the EU may be properly reflected in the base case scenario.

4.3 Policy packages and costs

The above section showed that the IEA (2009) sketches a pathway so that the world can stay within the 2° C threshold. Although this is important, we cannot continue our analysis on this route as we lack the underlying databases and models that have been used in the IEA (2009) study. Therefore we will below give account of three possible policy packages of the EU. The costs of these will be roughly estimated using the measures from the SERPECC study (Ecofys et al., 2009) and CE (2007).

This will only give a back-of-the envelop calculation as the various models and studies that have been used here are not aligned and have not been synchronized. The aim is here merely to indicate that more stringent policy packages are possible and to give a first assessment of the costs involved.

4.3.1 Formulation of three policy packages

As the present 20% reduction goal is far from ambitious given the impact from the economic crisis and the large possibilities to cover the reductions with flexible mechanisms (CDM/JI), we formulate here three possible policy packages that differ with the reduction percentages (-30 and -40%) and the amount of CDM that is allowed to cover these reductions. The packages are described as follows:

1. An overall target of -30% compared to 1990 with the same provisions with respect to input of CDM/JI as in the present proposal.
2. An overall target of -30% with restricted input of CDM/JI so that the *absolute* amount of CDM is restricted to be the same as under the -20% proposal.
3. An overall target of -30% with no input of CDM after 2012.
4. An overall target of -40% where the input of CDM is restricted to 1/3 of the total reductions 2008-2020.

Table 7 gives the outcome of these four policy packages and compares them to the present target of -20%.

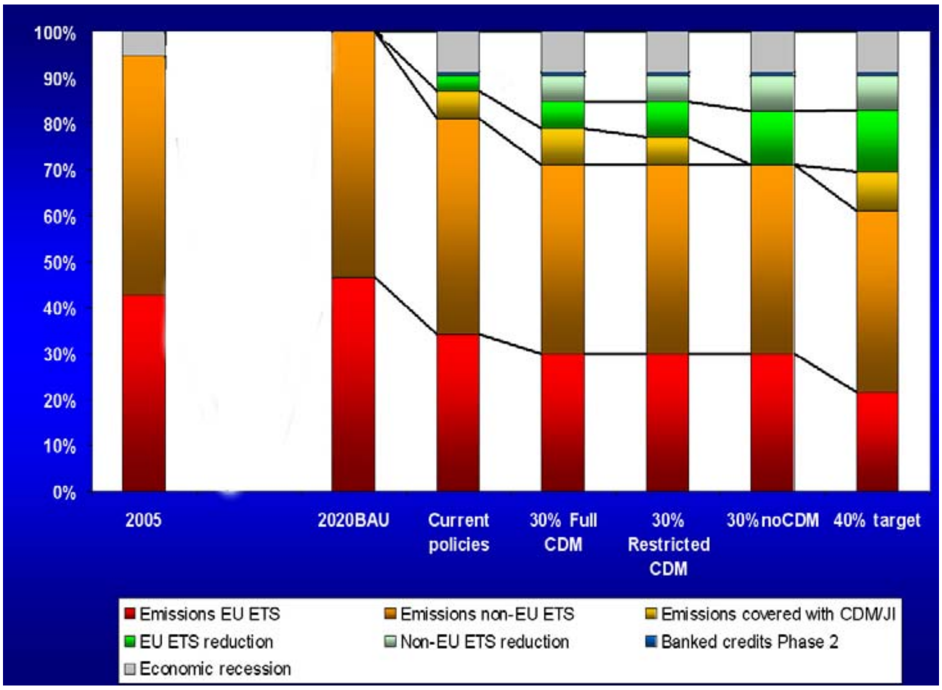
Table 7 Four policy packages with CO_2 emissions in Mton in 2020 in comparison with current policy

	20% Current policy*	30% Full CDM	30% Restricted CDM	30% No CDM	40% target
Domestic emissions 2020	4,816	4,374	4,266	3,933	3,853
Reduction compared to BAU	4%	13%	15%	21%	23%
Reduction compared to 2005	8%	16%	18%	25%	26%
EU ETS domestic reduction	192	310	418	652	737
EU ETS CDM (incl. banked)**	266	374	266	32	411
Non-EU ETS domestic reduction	0	321	321	420	415
Non EU ETS CDM	92	99	99	0	99

Note: * Only EU ETS and non-EU ETS reduction targets have been used as policy baseline scenario; ** includes banked EUAs from second phase.

In terms of domestic efforts, these policy packages reduce between 16-26% of domestic emissions in the EU between 2005 and 2020. Therefore, such reduction efforts can be perceived as relatively moderate. Part of these reductions will be realized because of the economic crisis. Figure 15 gives the result from these policy packages in terms of the original predicted business as usual in 2020. This figure shows that the current policies result in very little domestic reductions (the green bars) due to the impact of the economic crisis. Domestic reduction in the other policy plans is subsequently increased,

Figure 15 Four policy scenarios in the year 2020 compared to 2005 emissions, current policies and 2020 emissions according to business as usual (BAU) before the economic crisis



4.3.2 Costs

The costs of meeting such packages have been estimated using the cost-curves from the SERPECC study (Ecofys et al., 2009) and CE Delft (2007). Table 8 gives an estimate of the costs within EU ETS sectors.

Table 8 Estimate of the costs within EU ETS sectors

	20% Target	30% Full CDM	30% Restricted CDM	30% No CDM	40% Target
Estimated EU ETS price (2009)*	18	33	42	-	-
Estimated EU ETS price (2007)**	21	29	40	65	85
Estimated CDM price	17	23	30	30	30
Costs compared to GDP	0.0%	0.1%	0.1%	0.1%	0.3%

* Estimated price range based on CE, 2009.

** Estimated price range estimated on the basis of CE, 2007.

From previous studies at CE (2007, 2009) we have estimated two price ranges.[21] These show that in the first two packages, prices of EUAs will remain below the € 40/t CO_2 under a reduction target of -30%. Only if CDM is to be abandoned completely, marginal costs will rise and even more if the target is set at -40%. Despite these rising marginal costs, the total average costs of complying with EU ETS will remain very low. The direct net costs of investments in GHG reducing technologies mount to 0.1% annually in all 30% reduction packages and only in the case of a -40% reduction target this will increase to 0.3% of GDP.
This is not entirely surprising. The recent and extensive SERPEC-CC project (Sectoral Emission Reduction Potentials and Economic Costs for Climate Change, (Ecofys et al., 2009) in commission of the DG Environment and DG Research, Technology and Development) has mapped out the potential represented by 650 relevant technologies for reducing the emissions of greenhouse gases in the European Union across ten major sectors. The SERPEC-CC project concludes that greenhouse gas emissions in the EU-27 can be reduced to 30% below 1990 levels by 2020 and to 45% lower by 2030. The key to realising this potential is to replace all energy-related equipment in the EU at the end of its economic life with energy-efficient and low-carbon technologies. The resulting lower energy bills are expected to largely repay the costs of such a transition.

The costs for non-EU ETS sectors have been assessed in the present study using SERPEC-CC results. The domestic CO_2 abatement in the non-EU ETS sectors can up to an estimated 363 Mton be reduced at zero costs. Most of the reductions come from the buildings sector.

Table 9 Available measures within the buildings sector.

	Reduction (Mton CO_2)	Estimated total energy savings (billion Euro)	Average benefits (€/t CO_2)
Buildings	297	35	-120
Agriculture	43	1.6	-38
Transport	23	1.9	-83
Waste	3	0.5	-155
Total	363	39	-108

As mentioned earlier, the SERPEC-CC project concludes that most emission abatement can be achieved in a cost-effective way, i.e. that the resulting lower energy bills are expected to repay the investment costs. It should be noted, however, that the cost-effectiveness is assessed in the SERPEC-CC project from a 'technical-economic' perspective, i.e. on the basis of detailed information about investment costs and benefits of saved energy. Indeed, the 'technical-economic' perspective generally results in the conclusion that many cost-effective options are available. However, there is also a 'neoclassical' perspective on the determination of cost effectiveness, which results in much higher costs of emission abatement. More generally, from the 'neoclassical' perspective it is assumed that hardly any cost-effective (i.e. profitable) measures exist, since if they did they would already have been implemented without any governmental policy (see e.g. Nickell, 1978). There are various

[21] The 2007 study used data from Ecofys, the 2009 study used results from the Energy Centre Netherlands (ECN). We did not assess which of these estimates gives a better explanation.

reasons explaining the difference between the 'technical-economic' and 'neoclassical' perspective, but the most important are the following:

- Particularly when energy costs are only of minor influence on total production costs, companies may give priority in investments to other issues, which are more 'core business' (OECD/IEA, 2007). After all, there are efforts, time and money connected to taking decisions.
- Related to the previous issue is the issue of transaction costs. Gathering information about abatement options, supervision, or the interruption of the production process all have costs which are not included in cost calculations from a 'technical-economic' perspective (Sutherland, 1991).
- In the 'technical-economic' perspective generally a low social discount rate is used or a relatively long payback period. However, firms face additional risks of adopting new technologies that are not captured by the social discount rate because their assets are less diversified than those of society as a whole (Sutherland, 1991; Rivers and Jaccard, 2005). DeCanio (1993) showed that firms typically establish internal hurdle rates for energy efficiency investments that are higher than the cost of capital to the firm (OECD/IEA, 2007). Furthermore, there is a great deal of uncertainty around the potential outcomes of adopting new technologies. Early investors may be sceptical about the prospects of a technology and demand a premium on return in order to cover the risks of the investment (MMA, 2008). Apart from this uncertainty regarding the *reliability* of new technologies, there is uncertainty regarding economic trends (e.g. fuel prices) and governmental policy, and uncertainty regarding sector and company trends (SPRU, 2000).

In practice, the truth will lie somewhere between the extremes of the 'technical-economic' and 'neoclassical' perspective. An in-depth analysis can only be performed on a case by case basis, however, which lies outside the scope of this paper.

4.4 Indirect impacts of more ambitious policy plans

In climate change policy proposals the costs of achieving the targets are most widely communicated. However, the costs are always relatively small. Even the Sterm review (Stern et al., 2007) finds only moderate costs of safeguarding the planet. Eventual benefits of climate change policies have, however, been underscored. This is partly true because of the above elaborated dichotomy between top-down neoclassical economics that negate the possibility of a 'free lunch' and other points of view on the functioning of our economies.

In this section we present three possible benefits from a more ambitious climate change policy.

During economic crisis opportunity costs of climate change policies tend to be much lower offering business safe investment climate

In normal economic analysis the costs of climate change policies are presented. However, in economics not the costs matter so much but the opportunity costs. The central question is: what would our money yield if we did not invest it in climate change policies but in other, more profitable, activities?

During economic boom times the difference in profitability between climate change investments and other business investments is normally quite large. However, economic recession make most investments less profitable. Hence climate change policies become cheaper when compared to the alternative investments in business opportunities. If stimulated under the right policy perspectives, investments in energy savings can become even more profitable during economic recessions.

Creating some employment opportunities during times of increasing unemployment rates.

Not much is known about the connection between climate change and employment, however in the last few years a few studies have shed some light on this topic. A comprehensive study of a consortium led by ETUC (2007) includes case studies from 11 Member States of the EU and European sectoral analyses based on alternative scenarios of CO_2 emission reduction. The study aims to assess the impact on employment by 2030 of both climate change and policies to reduce GHG emissions. The general conclusion is that both the effects of climate change and measures adopted to reduce its impact have positive impact on employment and economic activities in Europe through a structural redistribution of employment.

According to the ETUC study, the overall impact of climate change on employment is expected to be slightly positive. Emission reduction options are predicted to have a similar effect, i.e. the overall balance of jobs in the branches that will expand and in those where activity will be reduced does not appear negative and may even be positive. Compared to the reference scenario based on the PRIMES model, the overall net gain in employment according to active GHG reduction policy scenario approximating 20% reduction goal by 2020 would be of the order of 1.5%.

Large-scale redistribution of jobs that will result from the implementation of climate change policies will occur within rather than between sectors. Jobs will be created in companies that can take advantage of opportunities created by climate policies, and jobs will be lost in companies that cannot adapt. Climate policies should contribute to rising demand for increasingly educated and qualified workers, for instance in the field of innovation. This is a general evolution of the economy but it can be boosted through the activities related to combating climate change.

The following sectors can potentially win in terms of providing new attractive jobs:

- Building/construction. New jobs can be created in thermal renovation. According to ETUC (2007), the extension of the directive on energy performance of buildings would create 120-180 thousands man-years in the EU until 2030.
- Renewable energy. The number of jobs related directly to renewable energy is estimated to grow by about 50%. In spite of the fact that because of lower demand for energy some jobs in power generation will be lost, the net impact of energy savings on employment is expected to be positive. If jobs generated indirectly are considered, a growth of 23% in jobs in this sector could be observed, which is superior to the reference scenario.
- Transport. The report estimates that it is possible to stabilize transport emissions in 2030 while creating overall 20% more jobs than in the reference scenario. The employment dynamic in road transport would fall but the number of jobs in rail and public transport would increase about fourfold as compared to the reference scenario.

These findings are in line with the conclusions of the study of Greenpeace International (2009). This report outlines two scenarios: the reference scenario based on the World Energy Outlook 2007 projections and the energy (R)evolution scenario which shows how the world could, technically and

financially, increase the production of energy from renewable sources by nine times. It is estimated that in the (R)evolution scenario, by 2020 about 10.5 million new jobs would be created, which would be 2 million more than in the reference scenario. In both scenarios jobs would be lost in traditional energy sectors because jobs per MW decreases as labor productivity increases, and this trend is expected especially in developing countries. However in the (R)evolution scenario job growth in renewable energy sector would be so strong that the net effect would be positive. In OECD Europe region, the number of jobs in the (R)evolution scenario in 2020 would reach 1.2 million in the (R)evolution scenario and 854,000 in the reference scenario. It should be noted, however, that the differences between the scenarios would probably be lower after including the impact of the economic crisis in the reference scenario.
The overall conclusion of these findings is that the climate crisis and the financial crisis are not two competing issues and the solution to one may help to combat the other. Investments in energy efficiency and renewable energy help the economy by increasing employment, reducing energy costs and decreasing over-use of natural resources. However, the impacts are not very large as the positive effects are to some extent counterbalanced by employment losses in energy intensive sectors that face a deterioration of their competitive position. However, such a structural redistribution of employment can in the long run create better opportunities for sustainable growth.

Stimulating innovation

The hypothesis that environmental regulations, through providing right signals on how to use energy and natural resources more efficiently, increases profitability and competitiveness, has been formulated by Harvard professor Michael Porter (Porter, 1991). According to conventional wisdom, environmental regulation imposes costs on companies, which affects their competitiveness and in the end may have negative socio-economic effects such as lower employment and welfare. However according to Porter, more stringent environmental policies, if they are implemented correctly, can in fact lead to the opposite outcome: higher productivity, or a new comparative advantage, which can lead to improved competitiveness. In other words, environmental policy can lead to a win-win situation, or an extra profit of environmental regulation (in addition to net benefits related to less pollution).

Two variants of the Porter hypothesis exist. The ‘weak’ version says that environmental regulation stimulates environmental innovations. The ‘strong’ version of the hypothesis asserts that properly designed regulation may induce cost-saving innovation which more than compensates for the costs of compliance to the regulations (Lanoie et al., 2009)[22] Empirical evidence has been especially convincing for the weak version of the Porter hypothesis. This suggests that innovation in clean technologies will lower the costs of present and future climate change policies. Empirical support for the strong version of the hypothesis, leading to general improvements in competitiveness has been mixed. Based on a review of a broad empirical literature, Brannlund and Lundgren (2009) conclude that there is lack of strong evidence for the existence of a strong Porter effect; however the literature does not provide strong evidence against the hypothesis either

22 There is also a ‘narrow’ version of the Porter hypothesis that states that flexible environmental policies (such as market-based instruments) give firms greater incentive to innovate than prescriptive regulations.

5 Conclusions

Should the EU adopt more ambitious greenhouse gas reduction targets? Recently, from different perspectives, a large number of studies concluded that such higher emission reduction targets are desirable, feasible or necessary. This study reviews recent research and tries to answer the question how to make the EU's GHG reduction target consistent with its goal of limiting the increase in global temperature to below 2° C above pre-industrial levels.

Summarizing, this study finds six compelling reasons why the EU should be willing to adopt a more ambitious emissions reduction target:
1. To take its share of the global responsibility for delivering emissions reductions, which implies that Annex I countries are responsible for a greater share of the effort for reducing global emissions compared to business as usual.
2. To take its share of the responsibility among those Annex I countries that are willing to commit to a collective emissions reduction of 30% by 2020 compared to 1990 levels. This share would imply the EU adopting a 30-40% reduction target.
3. To distance itself from the insufficient pledges that have been made by countries like Russia the United States and Canada in the UN climate negotiations and align itself with those countries that have made more ambitious pledges, such as Australia, Japan, Norway and Switzerland.
4. Because the impact of the current economic recession, combined with the large possibility to offset emissions reductions (through use of flexibility mechanisms like CDM/JI) in the EU's current climate legislation, will result in the phenomenon that 2020 emissions will only be about 4% *below* their expected level in a business as usual scenario. The impact of the economic recession therefore risks making the EU climate policies and instruments like EU ETS void of content if not accompanied by more ambitious reduction targets. Within EU ETS there is a serious risk that supply of credits will outweigh demand undermining the functioning of EU ETS.
5. Because the costs of meeting more ambitious targets are smaller due to the economic crisis. Direct costs of meeting a -30 to -40% reduction target lay between a very moderate 0.1-0.3% of GDP.
6. Investments in emission reductions can have additional benefits, like fostering innovation and creating employment in eco-industries. Such benefits are higher during times of economic crisis underlying the urgency to invest now in more ambitious climate change reduction efforts.

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Annex A Conceptual approaches towards comparability

A.1 Approaches

What constitutes a 'comparable effort'? In general, the approaches to comparability may be divided into two categories:

1. Approaches based on equal future burden, where the burden of emission reduction has to be divided among countries. A country's effort relates to the needed change as compared to the current state, so the most obvious way is to assign to each country a certain percentage of emission reduction in relation to some baseline. The major advantage of this approach is that it aims to quantify each country's effort. Each country is supposed to carry the same burden while making a contribution to solving the common problem. The major disadvantage is that the reference scenario is hypothetical and if actual developments differ, the outcomes will also be different than expected. Reference scenario is based on assumptions on production patterns and lifestyles – over time these patterns may converge but some differences exist and will remain, which may create an unfair situation. Another disadvantage of this approach is that typically, it does not credit actions from the past. Within this category, the following approaches can be distinguished:
   a Equal percentage reduction below a base year. Equal reduction below a based year is considered to be too simplistic by not taking into account national differences in future emission developments, base year emissions and past efforts. Choosing the same base year would be very difficult because it would put some countries in a disadvantageous position as compared to other countries (e.g. the countries which reduced already a lot of emissions up to the base year, or countries which experienced an economic downturn in a given year). Therefore this approach does not represent well a concept of comparable effort.
   b Equal percentage reduction below a reference scenario. A reference (business-as-usual, BAU) scenario is calculated for each country, individually, and equal percentage reduction is applied. An underlying assumption in this approach is that the baseline scenario represents an equitable development and that equal percentage reduction from this baseline is equitable. The results are highly dependent on the assumed BAU scenario, and countries need to agree on the reference scenario. The parties have an incentive to inflate the BAU scenario so as to diminish the reduction effort. Therefore, reaching the agreement may be difficult. However once the agreement is reached, the approach is relatively simple to implement.
   c Multi-criteria formula. In this approach, various indicators can be used to differentiate percentage reductions below a baseline. For example, the higher the GDP per capita, the more stringent the required reduction percentage. European Commission (2009) proposed four factors as a basis of a multi-criteria indicator: (1) GDP per capita, (2) reduction potential – initially greenhouse gas emissions per GDP and after discussions greenhouse gas emission reduction potential calculated by models, (3) percentage change in emissions (1990-2006), population growth (2006-2020). This approach accounts for some factors but ignores others, such like access to renewable energy sources, climatic differences and sectoral spreads. The outcome depends highly on the selected factors and weighting.

d Equal marginal abatement costs (MAC). This approach would require countries to reduce emissions until the level of equal marginal costs for reducing a unit of emissions (e.g. per tonne of CO_2) is reached. Sharing efforts on the basis of equal marginal costs would contribute towards implementing reductions where they are most cost-effective. However such a cost-effective distribution of mitigation efforts can result in unfair burden sharing, where the largest mitigation potential occurs in less affluent countries[23]. This approach requires a good knowledge of – and agreement on – the MAC curves for each country, which may be difficult in practice. Another disadvantage is that equal MACs indicate an equal effort only for the last saved tonne of GHGs but total costs of reduction may differ significantly. Only if the shape of the MAC curves is similar for all countries, this approach would provide a fair distribution of the burden from the point of view of total costs. This last point is dealt with in the next method proposed below.

e Equal total abatement costs per unit of GHG reduced. This approach is similar to the approach based on MACs only instead of marginal costs, total costs are taken into consideration – thus MAC curves have to be integrated to calculate total costs. A certain equal total abatement cost per unit GHG reduced can be set, and the reduction levels for countries can be calculated through optimisation. The main advantages and disadvantages of this approach are similar to the MAC-based approach.

f Equal total abatement costs as percentage of GDP. In this approach, countries would be required to spend a certain equal percentage of their GDP in a given year on the abatement of GHGs. This would lead to higher absolute costs for richer nations. It would be possible to extend this approach to a consideration of the net present values of total abatement costs and GDP over time period from a base year to a target year. The GDP can be measured in market exchange rates or in purchasing power parities. PBL (2008) uses market exchange rates because in international trade of emission credits the prises are paid in local currencies based on market exchange rates.

g Equal total abatement cost per capita. In this approach, the total abatement costs are applied in relation to the size of the population so that an equal cost per inhabitant is required. A big problem with this approach is that it does not consider differences in wealth between countries. Therefore, it is not considered to be a fair approach.

h Equal macroeconomic burden. General equilibrium models can be used to predict total macroeconomic changes related to mitigation efforts. Such approach would be more comprehensive than the approaches based on costs but it would also be much more uncertain. In addition, it is difficult to find a macroeconomic modelling framework consistent with the modelling of abatement costs.

i Equal marginal costs combined with GDP per capita. This is a new approach which emerged from discussions (European Climate Foundation, 2009). The effort is split in two parts. First, countries should implement domestically all low-cost reduction options, up to some level of costs per tonne of CO_2. Then, countries would be required to make additional reductions based on their ability to pay expressed as GDP per capita. In this way richer countries would have to reduce proportionally more. This approach has most of the advantages and disadvantages of the MAC-based option, however the pure MAC-based could imply that developing countries would have to pay

[23] A cost-effective allocation of mitigation measures can occur through trading, where equalisation of marginal costs is rather an output and not an input method to sharing efforts.

effectively more than the more developed countries, and this approach is trying to deal with this disadvantage.

2. Approaches based on equal endpoint. Here, countries are supposed to reach the same state in the future, defined for instance in terms of per capita emissions, in some target year. Thus in contrast to the previous category, here there is not assumption of equal future effort. The major advantage of this category is that it does not require calculations of a reference scenario. Critical element of these approaches is to agree on a current situation and on a common future endpoint, which is easier to agree on than defining a hypothetical future development. In addition, actions in the past are acknowledged. Countries that are already closer to the defined endpoint, also because of efforts already undertaken in the past, will have to make less of an effort. One disadvantage of this approach is that it may not be possible to adequately deal with different national circumstances such as access to renewable energy sources, historical sectoral spread and climatic differences. In addition, defining current efficiency levels can be difficult and data intensive. In this category, three methods can be distinguished:
   a Converging per capita emissions. Countries would need to reach equal level of per capita emissions in a predefined target year. Thus above average emitters would be required to undertake strong emission cuts. Cost minimisation can be achieved through trading credits (see the proposal of WBGU in WBGU (2009)). It is assumed that in the long term, living standards and technology availability will be more or less the same for all countries and therefore, the need for trading of allowances will decrease. This approach is simple, easy to communicate and does not require agreement on reference scenarios or MAC curves. However as indicated above in the description of the whole category, it does not reflect various national circumstances.
   b Equal efficiency levels per sector. Instead of equal per capita emissions, the requirement can be set with regard to sectoral efficiency levels which could be made more stringent than the current average. Thus, for example in the cement sector, a certain target expressed in tonnes of CO_2 per one tonne of cement would be introduced. In this approach, countries are rewarded for an early action while countries with low sectoral efficiency need to make an extra effort to reach the average level. Structural differences between countries are acknowledged and international competitive sectors are treated equally. However data requirements in this approach are relatively extensive as compared to other approaches.
   Cost-effectiveness might not be very good – sectoral targets might require high costs in some sectors and low costs in others. Efficiency loss could be however minimised by using cost-effectiveness criteria to guide the level of emission reductions. Besides, limiting the approach to a few sectors would ignore emissions from other sectors which might also contribute significantly to national emissions.
   c Triptych approach. This is a method of allocating future GHG emission reductions to countries based on converging criteria of meeting certain technological standards or targets at a sectoral level. Emission allowances are calculated for the various sectors, and then they are added to obtain a national target. Only the national target is binding. Sectoral targets may be defined in terms of energy efficiency. For the domestic sectors such as transport and building, convergence of per capita emissions is assumed. In this approach, the countries reach an equal state defined both in terms of per capita emissions and in terms of sectoral efficiency. Therefore, it is better suited than the simple per capita emissions approach to take into account differences in the

economic structure of a country. For example the country that is largely dependent on the energy-intensive exporting industry has to make this industry more efficient but is not penalized for the size of this industry, which would be the case in the approach based on per capita emissions. The major disadvantage of this approach is that data requirements are extensive and that countries need to agree on a set of scenarios including the expected growth in production of various sectors and on the targets providing the convergence level. This approach has been successfully applied as a basis for negotiating the Kyoto targets at the EU Member States level.

A.2 Assessment

Table 10 gives a summary of the approaches presented above. All approaches intend to represent comparable efforts but some may be considered to be more fair or equitable than others, and this evaluation is also included in the table. Technical feasibility reflects the level of difficulty in getting all data and calculating the comparable efforts. The last column gives the overall qualitative evaluation of the option, based on PBL (2008, 2009).

Table 10 Sharing approaches, strengths and weaknesses

Approach		Representation of comparable efforts	Technical feasibility
1a	Equal % reduction below base year	Low	High
1b	Equal % reduction below BAU	Medium	Medium
1c	Multi-criteria proportionality	Medium	Low
1d	Equal MAC	Medium	Low
1e	Equal total costs per unit GHG	Medium	Low
1f	Equal total costs per GDP	Medium	Low
1g	Equal total costs per capita	High	Low
1h	Equal macroeconomic burden	High	Low
1i	Equal MACs plus GDP	High	Low
2a	Equal per capita emissions	Medium	High
2b	Equal efficiency levels in sectors	Medium	Medium
2c	Triptych approach	High	Medium

Source: PBL (2008, 2009).