Analysis of possible quantified emission reduction commitments by individual Annex I Parties

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1. Introduction

Article 3.9 of the Kyoto Protocol mandates that

> "commitments for subsequent periods for Parties included in Annex I shall be established in amendments to Annex B to this Protocol, which shall be adopted in accordance with the provisions of Article 21, paragraph 7. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall initiate the consideration of such commitments at least seven years before the end of the first commitment period referred to in paragraph 1 above."

At CMP1 in Montréal 2005, Parties agreed to establish an *Ad Hoc Working Group on further Commitments for Annex I Parties under the Kyoto Protocol* (AWG-KP).[1] The AWG-KP spent a large part of the first year on negotiating a work plan, which included three main elements: (a) Analysis of mitigation potentials and ranges of emission reduction objectives of Annex I Parties; (b) Analysis of possible means to achieve mitigation objectives; and (c) consideration of further commitments by Annex I Parties.[2] It also agreed that "legal matters arising from its mandate pursuant to Article 3. paragraph 9 [will be addressed] … in due course." Each of these issues has been further sub-divided, as the work programme has been kept under review and Annex I Parties have insisted on an iterative approach. Some observers have commented that the AWG-KP has been in 'analysis-paralysis' for three years.

Part of this paralysis has been political, in particular the sense that Annex I Parties were waiting to see what happened in the other track – for two years the Convention Dialogue and since 2007,[3] the *Adhoc Working Group on Long-Term Cooperative Action under the Convention* (AWGLCA). In particular, the question has been what non-Kyoto Annex I Parties (the USA) might do on mitigation, and what further mitigation actions might be implemented by developing countries.

There has been particular reluctance by Annex I Parties to put forward specific numbers, that is percentages to be inscribed in Annex B for the 2nd (and / or subsequent) commitment period. The G77&China has consistently argued that the mandate of the AWG-KP is focused on this issue – numbers and amendments for Annex B.

The work of the AWG-KP has included "identification of possible ranges of emission reductions by Annex I Parties". In this process, the range identified by the IPCC's Fourth Assessment Report (IPCC 2007) consistent with the lowest stabilization levels of GHG concentrations in the atmosphere (lowest assessed by AR4) has been referenced – the range for Annex I Parties of -25% to -40% from 1990 levels by 2020. Including such a range provides an objective basis for identifying individual Annex I commitments, which is an important departure from a pure pledge-and-review approach taken in Kyoto (which amounted to -5.2% from 1990 levels for the 1st commitment period, including hot air). The AR4 range, however, was relegated to a footnote over the last two years. It is further discussed in section 2 below.

The political context has changed considerably since the Bali Action Plan makes provision for mitigation "commitments or actions, including quantified emission limitation and reduction objectives, by all developed country Parties" (i.e. a space for the US) and "nationally appropriate mitigation actions by developing country Parties", supported by technology,

[1] Decision 1/CMP.1

[2] AWG-KP 2 report in FCCC/KP/AWG/2006/4, para 17 and 18 (legal).

[3] Decision 1/CP.13, the Bali Action Plan.

finance and capacity-building, both in a measurable, reportable and verifiable manner.[4] The change from the Bush to Obama administrations in the US at a minimum means that the largest contributor to historical cumulative emissions will be more engaged in the AWGLCA.

Nonetheless, progress in the AWG-KP remained slow in 2008. At CMP4 in Poznań (December 2008), the AWG-KP agreed to focus on emission reductions, both for Annex I as a group, and for individual Annex I Parties:

> "The AWG-KP concluded, noting the iterative nature of its work programme, that in 2009 it will focus on agreeing on further commitments for Annex I Parties under the Kyoto Protocol. In this context, it recognized the need for work to be conducted on the following issues:
>
> (a) Consideration of the scale of emission reductions to be achieved by Annex I Parties in aggregate;
>
> (b) Consideration of the contribution of Annex I Parties, individually or jointly, consistent with Article 4 of the Kyoto Protocol, to the scale of emission reductions to be achieved by Annex I Parties in aggregate;"[5]

It further agreed to consider a range of other issues, including legal matters pursuant to Article 3.9 (para 49(c)(viii)). Parties agreed to adopt conclusions aggregate emission reductions and reach conclusion on a draft amendment text at the seventh session of the AWG-KP (para 60).

This paper draws on research in the public domain, in order to provide an analytical basis for a proposal on possible quantified emission reduction commitments for Annex 1 countries under the Kyoto Protocol.

2. Ranges for Annex I as a group in IPCC AR4

The Intergovernmental Panel on Climate Change's Fourth Assessment Report (IPCC AR4) clearly establishes what is needed for various stabilisation levels. Equally clearly, the lower the stabilisation level, the better chance of avoiding the worst impacts of climate change, to which developing countries are particularly vulnerable. The lowest stabilisation level assessed by IPCC AR4 in the Working Group III report is 450 ppmv.

Figure 1: Ranges of emission reductions required for various stabilisation levels

Source: (IPCC 2007: Box 13.7, page 776)

[4] Bali Action Plan, decision 1/CP.13, paragraphs 1.b(i) and 1.b(ii)

[5] Report of AWGKP 6.2 in FCCC/KP/AWG/2008/8, para 49.

Box 13.7 The range of the difference between emissions in 1990 and emission allowances in 2020/2050 for various GHG concentration levels for Annex I and non-Annex I countries as a group[a]

Scenario category	Region	2020	2050
A-450 ppm CO_2 –eq[b]	Annex I	–25% to –40%	–80% to –95%
	Non-Annex I	Substantial deviation from baseline in Latin America, Middle East, East Asia and Centrally-Planned Asia	Substantial deviation from baseline in all regions
B-550 ppm CO_2 -eq	Annex I	–10% to –30%	–40% to –90%
	Non-Annex I	Deviation from baseline in Latin America and Middle East, East Asia	Deviation from baseline in most regions, especially in Latin America and Middle East
C-650 ppm CO_2 -eq	Annex I	0% to –25%	–30% to –80%
	Non-Annex I	Baseline	Deviation from baseline in Latin America and Middle East, East Asia

[a] The aggregate range is based on multiple approaches to apportion emissions between regions (contraction and convergence, multistage, Triptych and intensity targets, among others). Each approach makes different assumptions about the pathway, specific national efforts and other variables. Additional extreme cases – in which Annex I undertakes all reductions, or non-Annex I undertakes all reductions – are not included. The ranges presented here do not imply political feasibility, nor do the results reflect cost variances.
[b] Only the studies aiming at stabilization at 450 ppm CO_2-eq assume a (temporary) overshoot of about 50 ppm (See Den Elzen and Meinshausen, 2006).
Source: See references listed in first paragraph of Section 13.3.3.3

IPCC AR4 thus suggests that pursuing the lowest stablisation level assessed would require absolute emission reductions by Annex I and relative emission reductions for developed countries. For Annex I Parties, these reductions need to be in the range of 25% to 40% below 1990 levels by 2020, and 80% oto 95% below 1990 levels by 2050. The chapter in IPCC AR4 indicates that "substantial deviations from baseline" will be needed in some developing country regions by 2020 and in all regions by 2050. [6]

The ranges are important for the AWG-KP in two ways. Firstly, the range provides a fixed point against which to assess individual Annex I commitments. The experience in Kyoto was that in a pledge-based negotiations, Annex I reverts to the lowest common denominator. Secondly, developing countries have clear interests in Annex I countries commiting to at the top of the IPCC ranges. Aggregate emission reductions by Annex I countries must be consistent with the lowest stabilization levels assessed by IPCC AR4. If Annex I countries do less than required by science, there are only two possible implications. Either more must be done in developing countries, or higher stabilization levels will result with even worse impacts of climate change, to which developing countries are particularly vulnerable. Neither implication is likley to be acceptable to developing countries.

3. Possible approaches

The discussion thus far has focused on a top-down approach, developing individual Annex I country commitments based on the IPCC range. This involves applying a set of criteria of an index to share the burden *within* the Annex I group. This has the merit of avoiding a race to the bottom in a pledge-based negotiations, as motivated above (section 2).

Based on that motivation, the recommendation above is to call for Annex I commitments at the top of the range (-40% from 1990 levels by 2020), if not even beyond. These ranges are

[6] No numbers are put to this deviation are reported. However, they were of course implicit in the calculation, but not included in the chapter, and hence not reviewed by governments in the IPCC process. The EU has since proposed -15% to -30%, based on a single journal article. (den Elzen & Höhne 2008) Since these negotiations take place in the AWG-LCA, this issue is not elaborated further here.

well above anything proposed by Annex I Parites themselves. To date, only the EU has put forward a mid-term target within the range, -30% from 1990 levels by 2020. Even then, it is towards the lower end of the range and conditional on the US making comparable efforts and "economically more advanced developing countries" contributing through deviation below baseline. The January 2009 communication from the Commission again specified a range for developing countries of "15 to 30% below business as usual" (CEC 2009b). Unilaterally, the EU still only commits to -20%, that is a target outside of the range. The Obama team has indicated a long-term goal of -80% by 2050. The campaign pledge of a return to 1990 levels of emissions by 2020 seems to have disappeared from the White House web-site since inauguration. [7] And it is 0% below 1990 levels by 2020. Australia announced a -5% to -15% target immediately after the Poznań meeting – but against 2000 levels, which converts to *increases* of +15% or +2% against 1990 levels. Canada seems to believe that -9% is ambitious. Japan complains that it is a 'dry towel' – saying that its economy is so efficient that further increases are too costly.

In short, existing pledges from Annex I fall well short of the range required to meet the lowest stabilization level assessed by IPCC AR4. The argument to counter, however, will be that they may claim that targets calculated are beyond their *capability*.

Analytically, a bottom-up approach is included as well, based on studies of Annex I mitigation targets that support greater ambition. Ideally, such studies would be from researchers in the countries concerned. Apart from the numbers, national studies should provide information on how emission reductions can be achieved. That would address the issue of capability from a different angle.

A 'hard floor' for the bottom up analysis would be figures reported in Annex I national communications by countries themselves. However, as shown in section 3.3.1, few countries have projected reductions, even with additional measures, that are within the range. These countries are either economies in transition or in the EU and part of the broader target.

3.1 Burden-sharing amongst Annex I based on objective criteria

Starting with objective criteria, such as aggregate scales of emission reductions based on the IPCC ranges, provides a firm reference point for negotiation. It avoid purely pledge-based negotiations, in which commitments by Annex I countries would be determined in a 'pick-and-choose' manner.

3.1.1 Greenhouse development rights

The approach which has been used in this section to allocate reduction requirements amongst AI countries is based on the Greenhouse Development Rights framework (Baer *et al.* 2007), which allocates burden-sharing amongst all countries via a Responsibility-Capacity Index (RCI), a multi-criteria approach based on historical responsibility and ability to pay for mitigation, but with the important proviso that only citizens of a particular country above a certain income threshold should be required either to pay for mitigation or to be held responsible for their emissions. Rather than using the World Bank figures of $ 1 or $ 2 per day, GDR suggests a more defensible definition of a global poverty line would be at a level where Millenium Development Goals have been met. The figure used is $ 16 per day or $ 6,000 per year, and while the exact value is open to debate, the higher level is important. Emissions and income below this poverty line are considered to be required for subsistence purposes, and this excluded from the burden-sharing calculations on equity grounds. The result of taking this approach is twofold: first, wealthy countries have a much higher burden of mitigation, which in many cases requires them to mitigate all their own emissions and a

[7] http://www.whitehouse.gov/agenda/energy_and_environment/

significant proportion of poorer country emissions (mainly on account of their historical responsibility and higher proportion of non-poor citizens); and second, non-Annex I countries are required to take on binding reduction targets. A fuller discussion of the GDP framework is available in this report (Baer *et al.* 2007).

In this instance, we have taken the indices used by the GDR for responsibility and capacity for Annex I countries only, and applied them to the problem of differentiating commitments between AI countries in achieving a common AI reduction target of between 25% and 40% of 1990 emissions (including LULCF and other gases, but excluding international ships' bunkers and international flights) by 2020. The calculation of the RCI is follows, and is described in more detail in the above report. The indices used here are the output of a piece of software distributed free on the GDR website (Baer *et al.* 2007):

- The basic data used in calculating the indices are as follows: per capita income (PPP); 2005 population; the Gini coefficient (a measure of the equality or inequality of income distribution); and the cumulative per capita emissions from 1990 to 2005. The latter figures are calculated by summing fossil fuel emissions only from 1990 to 2005, and dividing by the 2005 population.
- Capacity to mitigate is based on the portion of the GDP (using PPP to compare countries) which is earned by individuals above a poverty threshold (individuals who earn below the poverty threshold are excluded entirely)
- Responsibility to mitigate is based on historical responsibility to mitigate (per capita cumulative emissions from 1990), minus 'survival emissions; which are those emissions which correlate to income earned below the poverty line.
- The indices are combined into one RCI using the formula $R^a \times C^b$ where a+b must equal 1. This in effect gives different weightings to responsibility and capacity.

We have applied these indicators to a different purpose to GDR's use of them: 1) we have assumed an AI reduction obligation for 2020, which might well be larger in the GDP framework, and 2) we have applied them to only one year, whereas the GDR allocates mitigation obligations for the whole period until 2050.

We have applied three different indices: a) capacity only, b) responsibility only and c) a weighted average of both (capacity = 0.4, responsibility = 0.6). As a result, the percentage contribution to meeting an AI target (in other words, the percentage that individual countries would have to contribute to meeting a collective AI mitigation target) is contained in the table below:

Table 1: Burden sharing between Annex I countries based on the GDR framework

Source: adapted from Baer et al *(2007)*

	Responsibility	Capacity	0.4 Capacity, 0.6 Responsibility
Australia	2.7%	2.1%	2.4%
Austria	0.5%	0.9%	0.6%
Belarus	0.2%	0.1%	0.2%
Belgium	0.9%	1.0%	0.9%
Bulgaria	0.2%	0.1%	0.2%
Canada	4.2%	3.5%	3.9%
Croatia	0.1%	0.1%	0.1%
Czech Republic	0.8%	0.5%	0.7%
Denmark	0.4%	0.5%	0.5%
Estonia	0.1%	0.1%	0.1%
Finland	0.4%	0.5%	0.4%

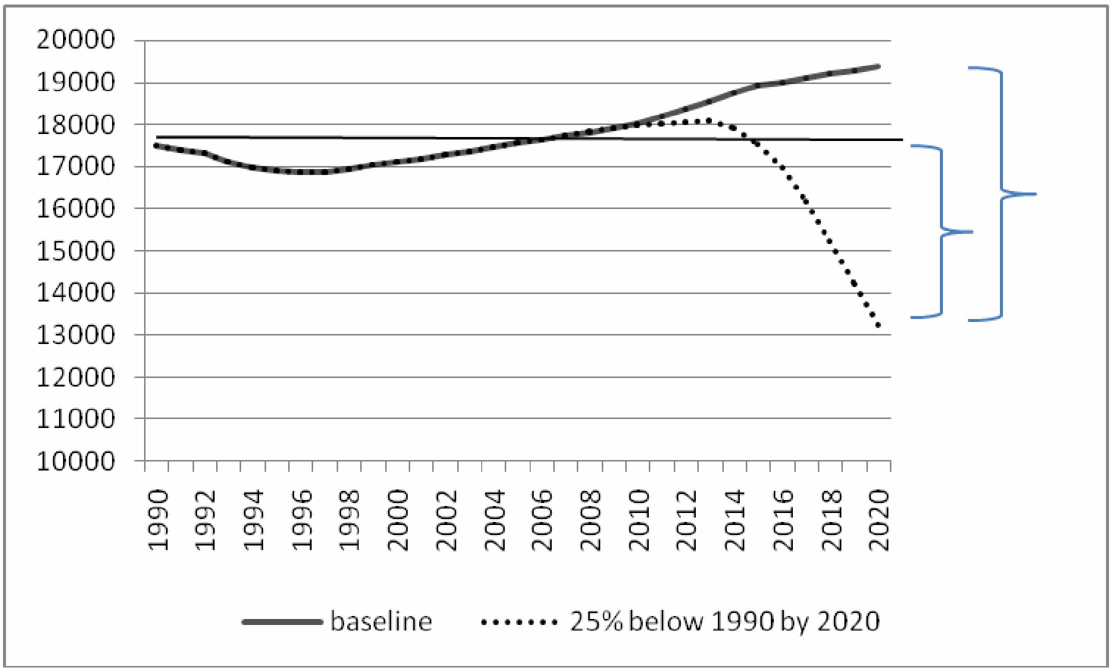
France	2.9%	5.4%	3.8%
Germany	6.2%	7.4%	6.8%
Greece	0.7%	1.0%	0.8%
Hungary	0.3%	0.4%	0.4%
Iceland	0.0%	0.0%	0.0%
Ireland	0.3%	0.5%	0.4%
Italy	3.1%	4.6%	3.7%
Japan	8.5%	10.8%	9.5%
Latvia	0.0%	0.1%	0.1%
Lithuania	0.1%	0.1%	0.1%
Luxembourg	0.1%	0.1%	0.1%
Netherlands	1.3%	1.7%	1.4%
New Zealand	0.2%	0.3%	0.2%
Norway	0.3%	0.7%	0.4%
Poland	1.7%	1.1%	1.5%
Portugal	0.4%	0.5%	0.4%
Romania	0.4%	0.4%	0.4%
Russian Federation	8.0%	3.9%	6.1%
Slovakia	0.2%	0.2%	0.2%
Slovenia	0.1%	0.1%	0.1%
Spain	2.2%	3.4%	2.6%
Sweden	0.4%	0.9%	0.6%
Switzerland	0.3%	0.8%	0.5%
Turkey	0.8%	0.8%	0.8%
Ukraine	0.6%	0.2%	0.4%
United Kingdom	4.0%	5.6%	4.6%
United States of America	46.3%	39.6%	44.0%

Countries highlighted in orange have greater shares as a result of capacity than responsibility, whereas those which are not have a greater responsibility than their capacity to mitigate.

There are two approaches to allocating the collective AI emissions burden to individual countries: the first would be to conceive of the burden as being the difference between 1990 emissions levels for all A1 countries and 2020 levels (reduced from 1990 levels by 25-40%), and to then allocate this burden to individual countries according to the above percentages. The second would be to conceive the burden to be the difference between the AI business-as-usual emissions pathway in 2020 and the same reduced emissions level in relation to 1990.

The difference is indicated in the figure below:

Figure 2: Conceptual diagram showing difference between reduction from baseline versus reduction from fixed base year



The choice of approach has an impact on the distribution of the burden. Countries which have much higher projected baselines by 2020 have lower commitments in relation to 1990. The figures below portray the allocation of AI mitigation for the 20 largest AI emitters (in 1990) using both methods. The bars represent ranges – the lower reduction corresponds to a 25% target and the upper reduction corresponds to a 40% target. Predictably, the 1990 approach renders a more even spread. The positive ranges in the baseline approach represent reductions from a baseline which do not lower emissions below the 1990 level.

Figure 3: Ranges of emission reductions for individual Annex I countries, based on GDR index and using baseline method

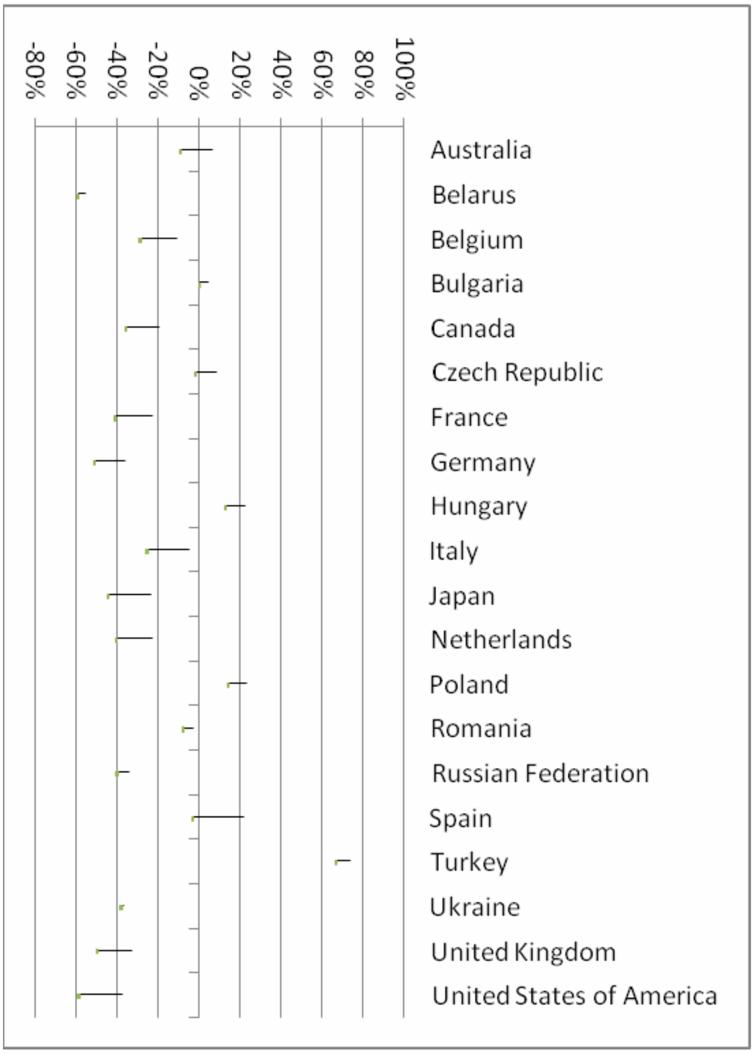
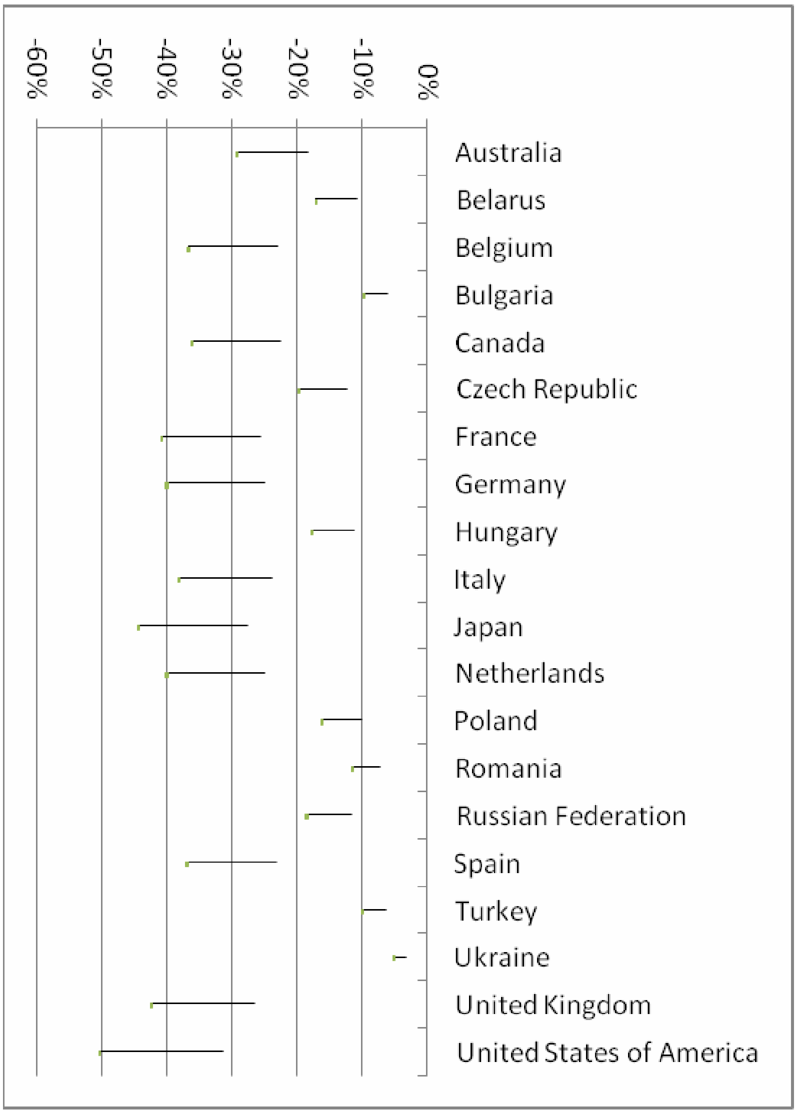


Figure 4: Ranges of emission reductions for individual Annex I countries, based on GDR index versus 1990 base year



The data in Figure 3 and Figure 4 are reported in Table 2 below.

Table 2: Ranges of emission reductions for individual Annex I countries, based on GDR index for both baseline and fixed base year methods

	Baseline method		*Fixed base year method - 1990*	
	25%	*40%*	*25%*	*40%*
Australia	7%	-9%	-18%	-29%
Austria	-8%	-30%	-26%	-41%
Belarus	-55%	-58%	-11%	-17%
Belgium	-10%	-28%	-23%	-37%
Bulgaria	5%	1%	-6%	-10%
Canada	-20%	-35%	-23%	-36%
Croatia	55%	44%	-11%	-17%

Czech Republic	8%	-1%	-12%	-20%
Denmark	-27%	-45%	-27%	-42%
Estonia	-63%	-71%	-23%	-37%
Finland	-6%	-23%	-22%	-35%
France	-22%	-41%	-25%	-41%
Germany	-36%	-51%	-25%	-40%
Greece	9%	-13%	-23%	-37%
Hungary	22%	13%	-11%	-18%
Iceland	-30%	-53%	-31%	-50%
Ireland	-5%	-25%	-24%	-38%
Italy	-5%	-25%	-24%	-38%
Japan	-24%	-44%	-28%	-44%
Latvia	-118%	-124%	386%	618%
Lithuania	-75%	-83%	-31%	-50%
Luxembourg	-33%	-58%	-33%	-53%
Netherlands	-22%	-40%	-25%	-40%
New Zealand	2%	-8%	-13%	-21%
Norway	-24%	-52%	-33%	-53%
Poland	23%	14%	-10%	-16%
Portugal	16%	-5%	-21%	-34%
Romania	-3%	-8%	-7%	-12%
Russian Federation	-34%	-40%	-12%	-19%
Slovakia	53%	44%	-8%	-14%
Slovenia	124%	105%	-12%	-19%
Spain	22%	-3%	-23%	-37%
Sweden	-34%	-55%	-31%	-49%
Switzerland	-37%	-61%	-34%	-54%
Turkey	74%	66%	-6%	-10%
Ukraine	-36%	-38%	-3%	-5%
United Kingdom	-32%	-49%	-26%	-42%
United States of America	-37%	-58%	-31%	-50%

3.1.2 Post-2012 climate targets for the North

This approach was adapted from a study by the Wuppertal Institute for Climate, Environment and Energy (Brouns & Ott 2005). Based on the modified South North framework, the approach seeks to provide a method for differentiating among the different annex i countries that is both fair and reflective of national circumstances. The approach is based on the following two criteria (Brouns & Ott 2005).

1. **Responsibility** – This reflects the country's contribution to the climate problem through historic and ongoing greenhouse gas emissions. Here Brouns and Ott only analyse emissions between 1990 and 2000 because the former marks the period from which the IPCC's first Assessment report was available to every party.
2. **Potential to mitigate** – This reflects the opportunities within the country's economy to either reduce or avoid the growth of greenhouse gas emissions without endangering a basic level of development.

These criteria are translated into appropriate national parameters which are then aggregated into a single-score index. The index is derived from the following parameters, chosen to represent the above criteria:

a. **Responsibility** – Cumulative 1990-2000 CO2 emissions/capita [tCO2 equivalent]

b. **Potential to mitigate** – 2000 CO2 emissions/GDPppp [tCO2/GDP] and
– 2000 GHG emissions/capita [tCO2 equivalent]

To determine the index for each country, the indicators were indexed to a scale of 0 to 100, where 0 represents the minimum value in the data set and 100 represents the maximum value (WRI, 2004). The formula for the index is as follows;

*Index value = 100 * (actual value – minimum value) / (maximum value – minimum value)*

The final aggregate index equally weighs responsibility and potential to mitigate, with the two parameters of the potential to mitigate also weighted equally. Hence, for the potential index (where there are two parameters) and the aggregate index, the two feeding indices were simply added and divided by two (Brouns and Ott, 2005).

Using this final aggregate index, the Annex I countries were then divided into three groups:

- High emitters: Those whose index value is one standard deviation or more above the mean
- Medium emitters: Those countries whose aggregate index is within one standard deviation from the mean (between -1 and +1 of mean)
- Low emitters: Those countries whose index is one standard deviation or more below the mean

Our Application: Aiming at the mitigation targets on the upper end of the -25% to -40% range for all annex I countries (as discussed in section 2 above), we assigned three levels of reduction targets by 2020 below 1990 levels for the three different emitters: -30% for Low emitters, -35% for Medium emitters and -40% for High emitters.

Table 3: Emission reductions for Annex I countries grouped into three categories, based on Wuppertal index

Australia	-42%
Austria	-37%
Belarus	-37%
Belgium	-37%
Bulgaria	-37%
Canada	-42%
Croatia	-32%
Czech Republic	-42%
Denmark	-37%
Estonia	-42%
Finland	-37%
France	-37%

Germany	-37%
Greece	-37%
Hungary	-37%
Iceland	-37%
Ireland	-37%
Italy	-37%
Japan	-37%
Latvia	-32%
Lithuania	-32%
Luxembourg	-42%
Netherlands	-37%
New Zealand	-37%
Norway	-37%
Poland	-37%
Portugal	-37%
Romania	-37%
Russian Federation	-42%
Slovakia	-37%
Slovenia	-37%
Spain	-37%
Sweden	-32%
Switzerland	-32%
Turkey	-32%
Ukraine	-42%
United Kingdom	-37%
United States of America	-42%
Annex I	-40%

The percentages for the groups have been scaled so that the combined reduction target for Annex I countries is **-40%** from 1990 levels by 2020.

3.2 Four factor analysis by European Commission

The European Commission has done analysis of burden-sharing between Annex I Parties. 'Staff working documents' have been prepared to underpin the Copenhagen communication (CEC 2009b), as issues of competitiveness and comparable effort by the US in particular are a key concern.

In particular, Annex 9 of the second part of the third Staff Working Document contains extensive analysis. It uses the Triptych approach long favoured by the EU (Den Elzen *et al.* 2008; Phylipsen *et al.* 1998; Groenenberg *et al.* 2001) and modifies it to generate its differentiation proposals for (current) Annex B, including an 'early action' indicator.

Four criteria are used to differentiate amongst Annex I Parties. The results in the right-hand column, 'targets relative to 1990' work well for the EU.

Table 4: EC analysis of burden-sharing between Annex I countries

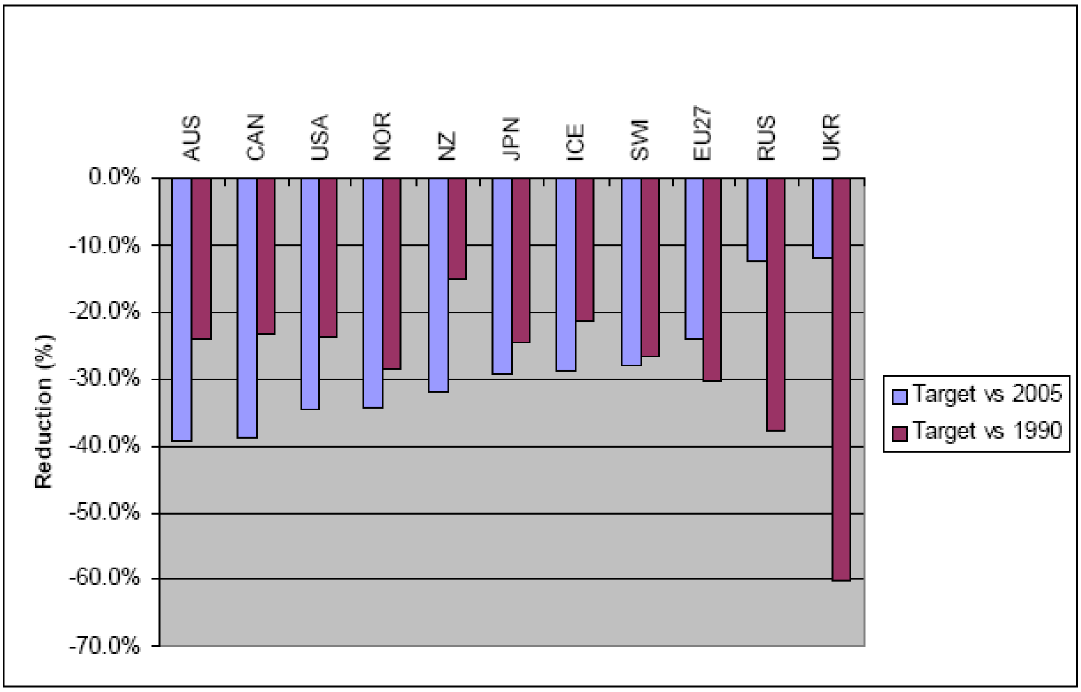
Source: (CEC 2009a: Annex 9)

	Share according to GDP/cap	Share according to GHG/GDP	Share according to GHG '90-'05	Share according to Population '90-'05	Target relative to 2005	**Target relative to 1990**
	(a)	(b)	(c)	(d)	(e) = (a+b+c+d)	
EU27	-10.2%	-10.1%	-5.2%	1.7%	-24%	**-30%**
Australia	-12.6%	-16.7%	-20.0%	10.0%	-39%	**-24%**[38]
Canada	-12.6%	-14.6%	-19.3%	7.8%	-39%	**-23%**
Iceland	-17.3%	-4.9%	-14.0%	7.6%	-29%	**-21%**
Japan	-12.8%	-5.6%	-12.5%	1.7%	-29%	**-24%**
New Zealand	-9.6%	-12.8%	-19.3%	9.8%	-32%	**-15%**
Norway	-20.0%	-4.7%	-13.3%	3.9%	-34%	**-28%**
Russia	-1.4%	-20.0%	8.0%	0.8%	-13%	**-38%**
Switzerland	-16.5%	-4.0%	-10.7%	3.4%	-28%	**-27%**
Ukraine	0.0%	-20.0%	8.0%	0.0%	-12%	**-60%**
USA	-14.3%	-12.3%	-15.9%	8.2%	-34%	**-24%**

The EC staff document also analyses how these targets would translate if the 1990 level were moved to a 2005 base year. In other words, they are proposing that the target can be expressed in a different base year, as long as it does not "water down" the level of effort (CEC 2009b).

Figure 5: EC analysis of Annex I targets from 1990 levels, expressed as 2005 base year

Source: (CEC 2009a)



The targets proposed by the EU, as reported in Table 4, conveniently add up to -30% below 1990 levels by 2020 for the EU itself. In this, the Commission may be making a point to member states that -30% is possible, but it is still towards the lower end of the range. A

Table 5: Adjusted targets for Annex I countries, based on EC criteria but resulting in -40%

Source: J Richards, personal communication

	Share according to GDP/cap	Share according to GHG/GDP	Share according to GHG '90-'05	Share according to Population '90-'05	40% recast Target relative to 2005	40% recast Target relative to 1990	2020 outcome
EU27	-10	-10	-5	2	**-32**	**-40**	3237
Australia	-13	-17	-20	10	**-52**	**-32**	274
Canada	-13	-15	-19	8	**-52**	**-31**	401
Iceland	-17	-5	-14	8	**-39**	**-28**	2
Japan	-13	-6	-13	2	**-39**	**-32**	802
New Zealand	-10	-13	-19	10	**-43**	**-20**	47
Norway	-20	-5	-13	4	**-45**	**-37**	29
Russia	-1	-20	8	1	**-17**	**-51**	1451
Switzerland	-17	-4	-11	3	**-37**	**-36**	33
Ukraine	0	-20	8	0	**-16**	**-80**	187
USA	-14	-12	-16	8	**-45**	**-32**	4063
							10527
							59.92%

3.3 Studies on mitigation potential

The approaches in sections 3.1 and 3.2 were based on objective criteria. Mitigation potential can also be determined in a bottom-up manner. This section focuses on numbers reported in Annex I national communication and in-country assessments.

3.3.1 Mitigation potential in Annex I national communications

Projections in their own national communications represented a 'hard floor' of minimum levels of Annex I country targets. However, few of these projections provide numbers in the range required. Submissions made by Annex I countries on their mitigation potentials were synthesised in a technical paper for the AWG-KP in 2007.[8] Section V of the paper summarises the information, and Table 3 of that document is reproduced as Table 6 below.

It "summarizes data on projections submitted by Annex I Parties contained in their latest national communications. Column 1 contains GHG emissions in 1990 as reported in the chapter on projections within national communications; these may be slightly different from the information contained within national GHG inventories because they may have been prepared at a different date or they may have used different base year data. Most Parties provide a 'with measures' projection until 2010 and until 2020 (columns 2–4). The 'with additional measures' projection is provided by some Parties for 2010 and only by a few for 2020 (columns 5 and 6)." (*ibid*) Other tables in the technical paper provide a break-down on a sectoral basis.

In other words, negative numbers are reductions below 1990 levels, positive numbers are increases. A percentage in a column headed "1990-2020" means x% from 1990 levels by 2020, i.e. the same metric as the IPCC ranges discussed in section 2 above.

[8] FCCC/TP/2007/1, *Synthesis of information relevant to the determination of the mitigation potential and to the identification of possible ranges of emission reduction objectives of Annex I Parties*, 26 July 2007.

Developing countries could consider using the percentages in column 6 (with additional measures), or where these are not available, column 4 (with measures, 2020).

Table 6: Annex 1 countries' own projections of emissions and reductions with (additional) measures

Table 3. Projections reported by Annex I Parties in their national communications

Party	National total GHG emissions in Convention base year (Mt CO_2 eq)[a]	Percentage change 'with measures' (%)			Percentage change 'with additional measures' (%)		Effect of additional measures (% of 1990)	
		1990–2005	1990–2010[b]	1990–2020	1990–2010[c]	1990–2020	2010[d]	2020[e]
Australia	417	28	35	54				
Austria	79		17		-1		18	
Belarus	105	-34	-25	-16				
Belgium	146	3	2	6	0		2	
Bulgaria	138	-51	-35	-24	-40	-33	6	8
Canada	599	24	38	50				
Croatia	34	-12	0	15	-12	-7	12	22
Czech Republic	192	-23	-24	-37	-27	-38	2	1
Denmark	69	1	5	-2				
Estonia	38		-56		-56		0	
Finland	71	11	10	15	-2	-3	12	18
France	567		6	12	0	-2	6	14
Germany	1,275		-21	-21	-29	-41	8	20
Greece	109	31	37	52	28		10	
Hungary	122	-28	-28	-20	-29	-23	0	3
Iceland	3		0	38				
Ireland	56	28	30	39				
Italy	521	5	11	27	4		8	
Japan	1,188		10		4		7	
Latvia	25	-51	-46	-35	-49	-45	3	10
Liechtenstein	0		4					
Lithuania	41	-57	-40	-34				
Luxembourg								
Monaco								
Netherlands	212	2	2	5	-1	2	3	3
New Zealand	62	24	34	48				
Norway	50		23	37				
Poland	569		-26	-16				
Portugal	60		47	60	43	57	4	3
Romania	262	-39	-27	-11	-31	-15	4	4
Russian Federation	2,961		-21	-4				
Slovakia	72	-32	-22	-3	-25	-8	2	4
Slovenia	20	4	5	1	-1	-6	6	7
Spain	286	47	52	85				
Sweden	72	-2	-1	6				
Switzerland	52	-2	-3	-6	-6		2	
Turkey	132	86	158	308				
Ukraine	925	-53	-48	-38				
United Kingdom	763		-18	-19	-24		6	
United States								
High		86	158	308	43	57	18	22
Low		-57	-56	-38	-56	-45	0	1

Abbreviations : GHG = greenhouse gas, Mt CO_2 eq = million tonnes of CO_2 equivalent.

Note: Data has been extracted from the latest national communication (NC). Exceptions: Belarus (second NC), Finland (report on demonstrable progress), Italy (third NC), Turkey (First NC) and Ukraine (second NC).

[a] Excluding land use, land-use change and forestry and excluding international transport, base year is 1990 except for Bulgaria (1988), Hungary (average of the years 1985 to 1987), Poland (1988), Romania (1989) and Slovenia (1986).

[b] The Russian Federation provided two equivalent scenarios. 'Scenario II' is included here, which is the only one that included non-CO_2 gases.

[c] United Kingdom provided several scenarios. Here the 'with additional measures - high ETS' scenario is shown.

[d] Calculated as the difference between the percentage change 'with measures' for the period 1990–2010 and the percentage change 'with additional measures' for the same period.

[e] Calculated as the difference between the percentage change 'with measures' for the period 1990–2020 and the percentage change 'with additional measures' for the same period.

The numbers may be of limited usefulness, however, since many of them indicated *increases* in emissions, or decreases below the range that developing countries might want to suggest. Politically, they can be used to argue that Annex I Parties must adopt additional measures, and report these.

The percentages within the range of -25% to -40% from 1990 levels by 2020 are summarised in Table 7 below (a sub-set of Table 6).

Table 7: Emission reductions reported in AI national communications, within the range

Country	*Percentage below 1990 levels by 2020, with measures*	*Percentage below 1990 levels by 2020, with additional measures*
Bulgaria		-33%
Czech Republic		-37%
Germany		-41%
Latvia		-45%
Lithuania	-34%	
Ukraine		-38%

It can be seen that the reductions are mainly for Economies in Transition, where the reason is likely to be hot air rather than climate policy, with the exception of Germany. Germany's reduction would form part of the EU's target already. Given this lack of ambition in numbers reported in Annex I national communications, it is useful to also consider in-country assessments.

3.3.2 In-country assessments

In-country assessments are studies conducted in individual Annex I countries by government agencies or independent researchers in the country concerned. Such studies typically conduct analysis of how particular levels of emission reductions could be achieved, including particular policies and measures that would be implemented pursuant to a target. In several cases, they are more ambitious than the numbers reported in national communications.

This section reflects both on numbers reported in the national communications (section 3.3.1 above) and in-country assessments.

3.3.2.1 Australia

The projections reported in their most recent national communication indicate that 'with measures', Australia's GHG emissions would increase by **54%** by 2020 compared to 1990 levels (see Table 6). No percentage with *additional* measures was reported.

3.3.2.2 Canada

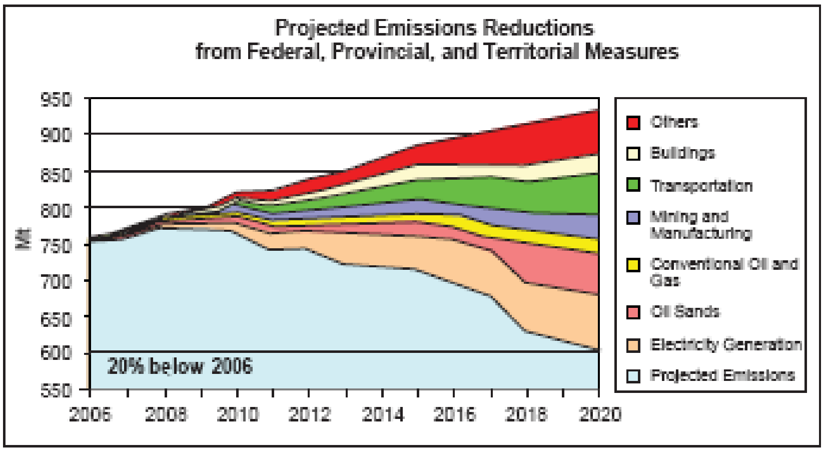
Canada has published a document in which it announced its mid-term goal as being

> "Canada will move from rapid growth to achieve absolute reductions of 20% from 2006 levels – a reduction of 330 megatonnes from projected levels in 2020" (Environment Canada 2008)

The document outlines a range of measures, which can be seen graphically in Figure 6.

Figure 6: Projected emission reductions in Canada by policies and measures

Source: (Environment Canada 2008)



Canada's emissions, including LULUCF and all gases, were 656 Mt CO_2-eq in 1990 (WRI 2005). If these emissions of 600 Mt CO_2-eq above are for the same sources and gases, then the Canadian target is -9% below 1990 levels.

A 2008 study by a Canadian environmental NGO concluded that Canada could reach a 25% reduction in relation to 1990 levels via an economy-wide carbon tax of around $250/ton.

> "even with the most stringent of the possible mitigation targets [40% below 1990 in 2020] there is likely to be continued growth in Canada. Further, there are opportunities to minimize compliance costs through either efficient policies, such as economy wide carbon pricing, but also through using carbon price proceeds to recycle revenue." (Drexhage *et al.* 2008)

The projections reported in their most recent national communication indicate that 'with measures', Canada's GHG emissions would increase by +14% by 2020 compared to 1990 levels (see Table 6), but *decrease* to **-2%** with *additional* measures. Based on the IISD study, substantially more is possible.

3.3.2.3 EU

The European Union has put forward a mid-term target of -20% from 1990 from 1990 levels by 2020 unilaterally, and -30% based on conditions (see section 3). The January 2009 communication from the Commission again specified a range for developing countries of "15 to 30% below business as usual" (CEC 2009b).

Developing countries could push for a higher range from the EU as a group, e.g. -40% from 1990 levels by 2020. Information on individual EU countries may be helpful.

3.3.2.3.1 France

The projections reported in their most recent national communication indicate that 'with measures', France's GHG emissions would increase by +**54%** by 2020 compared to 1990 levels (see Table 6). No percentage with *additional* measures was reported. France has proposed a 'Factor Four', i.e. reducing its GHG emissions to one quarter.

3.3.2.3.2 Germany

The projections reported in their most recent national communication indicate that 'with measures', Germany's GHG emissions would decrease by -21% by 2020 compared to 1990 levels (see Table 6), and decrease further to **-41%** with *additional* measures.

3.3.2.3.3 Italy

The projections reported in their most recent national communication indicate that 'with measures', Germany's GHG emissions would increase to +27% by 2020 compared to 1990 levels (see Table 6). However, Italy also indicates that these measures would result in increase to 11% by 2010, but only **+4%** with *additional* measures.

3.3.2.3.4 Poland

The projections reported in their most recent national communication indicate that 'with measures', Poland's GHG emissions would decrease by -16% by 2020 compared to 1990 levels (see Table 6). In 2010, the decrease is projected at -26%, which seems to suggest Poland would gradually be using up its hot air.

3.3.2.4 UK

The projections reported in their most recent national communication indicate that 'with measures', the United Kingdom's GHG emissions would decrease by **-19%** by 2020 compared to 1990 levels (see Table 6). No percentage is given for decreases by 2020 with *additional* measures, but the 2010 numbers indicate that about an additional -6% would be possible.

3.3.2.5 Japan

Japan only reported projections in their most recent national communication for 2010, which indicate an increase 'with measures' of +10%, compared to 1990 levels (see Table 6), or +4% with *additional* measures.

Studies by NGO have suggested that much more ambitious levels are possible. It aggregated a set of reductions from specific policies (A to F below), and found:

> "it is clear that Japan's reduction potential will be more than 30% in 2020" (CAN-I 2008: 43)

The specific policies and measures are:

A. Electricity generation:
   - Energy efficiency, switching from oil/coal to gas and increasing Renewables to 20% including hydro in commercial power plants can result in a national reduction of -12% by 2020 below 1990
   - Emissions from onsite electricity generation can be reduced by energy efficiency, switching from oil/coal to gas to a total of -2% of national emissions by 2020 below 1990
   - Fuel switching from oil/coal to gas in the production of Industry steam can lead to -1.2% reductions
B. Industry sector: By improving energy efficiency, switching fuel for energy from oil/coal to gas for all major industries, and also switching all cement facilities to top-runner, this industry can contribute up to -3% reduction to the national emissions below 1990
C. Transport: Improving truck efficiency by 10% and turning 25% of passenger transportation to hybrid can result in this sector's emissions reduced by -20% from 1990 levels by 2020
D. Commercial Household: This sector's emissions can be reduced by -30% from 1990 levels by 2020 simply through energy efficiency

E. Limiting HFCs, PFCs and SF6: limiting the use of these gases to essential appliances and switching to not-in-kind technology can contribute -3.6% to national reduction by 2020 compared to 1990 levels

F. CH4 and N2O: A total contribution of -5% to the national reduction can be achieved by implementing existing policies

3.3.2.6 Norway

Norway has aligned itself with the EU target of -30%, although not stating a base year and extending the time-frame:

> "Annex I Parties have a responsibility to take a lead in reducing greenhouse gas emissions. To limit the temperature increase to 2 °C, these Parties must undertake emission cuts in the order of 20 to 30 percent in the period 2020-2030. However, strengthening the commitments for Annex B Parties alone will provide only a modest and clearly insufficient step towards the ultimate objective of the Convention."[9]

Norway has conducted its own analysis of the technical possibilities to reduce Norwegian emissions further in the long-term, by 2050. Government appointed the Norwegian Commission on Low Emissions in March 2005 to prepare scenarios describing how Norway can reduce its emissions of greenhouse gases by 50-80 percent by 2050. The Commission presented its final report in October 2006. It confirmed that Norway could meet this target, 50-80 percent by 2050, even though emissions in the reference path were projected to grow by 40% (in the projections in their most recent national communication, 'with measures', this figure is +37% from 1990 levels by 2020 (see Table 6). The Commission has identified 15 measures that together will ensure the necessary reduction in Norwegian emissions in a long-term perspective.

Examples of identified technologies are:

- Transportation: Phasing in of low- and zero-emission vehicles, phasing in of CO2-neutral fuels, reduction of transportation demands, and development and phasing in of low-emission ships.
- Heating: Increased energy efficiency in buildings e.g. through stricter building codes, transition to CO2-neutral heating through increased use of biomass, more effective use of solar heat, heat pumps, etc.
- Oil and gas activities: Electrification of the continental shelf and more facilities located on land. (Location on land will facilitate use of carbon capture and storage.)
- Electricity production: Expansion of renewable energy through construction of wind and small hydro-electric power stations, and implementation of carbon capture and storage from gas-fired and coal-fired power plants

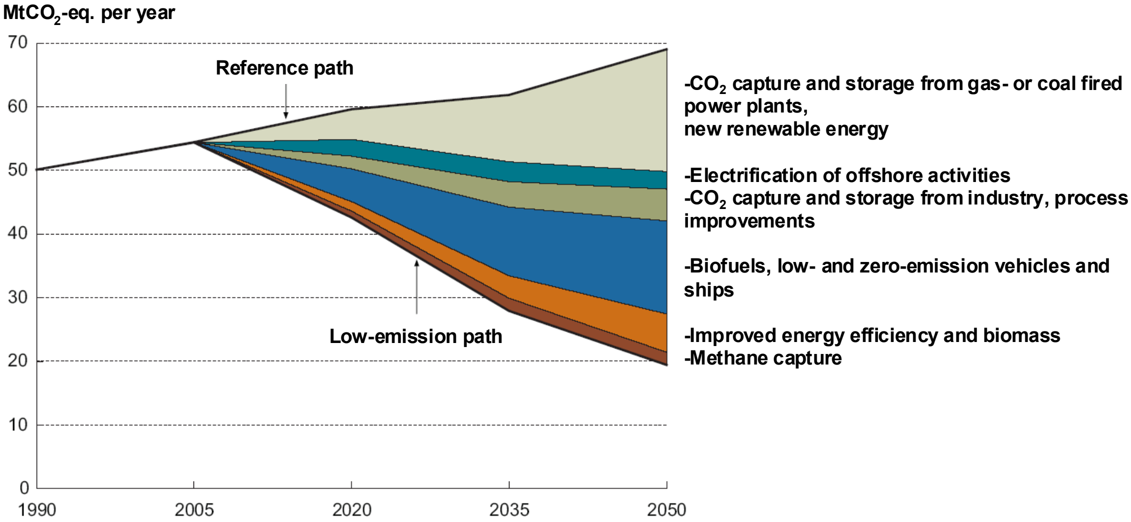
In addition, the Commission considers two basic measures as prerequisites – awareness and investment in climate-friendly technologies.

The Norwegian commission emphasized the 2050 goal, and this is reflected in submissions to the UNFCCC. However, in a presentation to an in-session workshop of the AWG-KP, the graph shown in Figure 7 was shown. It can be seen that the low-emissions path would bring Norway to roughly 40 Mt CO_2-eq or about -20% below 1990 levels by 2020. 1990 levels were of 50 Mt.

Figure 7: Greenhouse gas emissions in the past, in the reference path, and in the proposed low-emission path 1990–2050

[9] Submission by Norway, FCCC/KP/AWG/2007/MISC.1

Source: Presentation by Norway at AWG-KP [10]



3.3.2.7 Russia

Despite having reduced its energy intensity in the period 2000 – 2006, Russia remains a relatively inefficient energy economy and has large potential to reduce emissions through increased efficiency. One study suggests that Russia could save 45% of its primary energy consumption in 2005.

> "The assessment has shown, that the Russian energy efficiency potential amounts to 45% of primary energy consumption in 2005, or 282 mtoe (294 mtoe with the elimination of gas flaring), or 57% of 2005 oil production, or 54% of 2005 natural gas production" (Bashmako *et al.* 2007: 13).

Reduction in overall energy intensity of the economy translates fairly directly into reductions in GHG emissions, if the energy mix does not change and the composition of the economy does not move to sectors with a different energy intensity. On this basis, it could be argued that emission reductions of -45% **from 2005 levels** could be possible in Russia. Due to hot air, a later base year in Russia would be better.

The technical potential in the transportation sector is 38 Mtoe, 14 Mtoe in manufacturing and 68 Mtoe in public and commercial buildings. Industrial boilers in Russia have an average efficiency of 67%, compared to the 95% of best available technology. Supply-side efficiency could be improved by increasing the efficiency of coal-fired power stations from current 36% to 38% and gas from 41% to 57%(Bashmako *et al.* 2007).

Reductions in GHG emissions further reductions in energy intensity are reported in another study, at about 50% of its 2005 emission, or 793 Mt per year (Sargsyan & Gorbatenko 2008). The study was done by Russian researchers, building on the work of Bashmako *et al* (2007), for the World Bank and International Finance Corporation.

The projections reported in their most recent national communication indicate that 'with measures', Russia's GHG emissions would decrease by **-4% by 2020** compared to 1990 levels (see Table 6). In 2010, the decrease is projected at -21%, which suggests Russia is gradually be using up its hot air.

[10] unfccc.int/files/meetings/cop_12/in-session_workshops/application/vnd.ms-powerpoint/061107_3_awg_nor.pps

3.3.2.8 Ukraine

The projections reported in their most recent national communication indicate that 'with measures', Russia's GHG emissions would decrease by **-38%** by 2020 compared to 1990 levels (see Table 6). In 2010, the decrease is projected at -48%, which suggests Russia is gradually be using up its hot air.

It has been suggested that Ukraine could take on a target of at least -55% below 1990 levels by 2020.

> "It is technically and economically feasible for Ukraine to adopt the target of stabilization of greenhouse gas emissions by 2020 or 0% growth from the current level of emissions. Ukraine can take international commitment to reduce GHG emissions by at least 55% by 2020 from the level 1990. Such target could be achieved through both energy efficiency programs both in supply and demand side and from increasing the use of renewable sources in the energy mix." (CAN-I 2008)

According to the same source, Ukraine has economically feasible potential for renewable energy sources that could make renewables 14% of total primary energy sources in 2030, which is 2.25 times higher than the official government energy strategy.

3.3.2.9 USA

The US has not ratified the Kyoto Protocol and the likelihood of it inscribing a percentage in Annex B for the 2nd commitment period is low. Hence, detailed analysis is not directly related to the negotiations under the AWG-KP. As a contextual matter, however, the quantified emission reduction commitments that the US might agree to through the AWG-LCA negotiations are highly relevant.

In this initial draft, reference is made to existing studies. (Laitner *et al.* 2006; Laitner & Hanson 2006; Hanson & Laitner 2004; Pew Center 2008; Keohane & Goldmark 2008). Some summaries have been provided in these and other studies, which are reflected in the tables below.

Table 8: Modeling results for innovative policy solutions in the US (2020)

Source: (Pew Center 2008)

2020	EIA Core Case	CATF	ACCF/NAM Low Cost	ACCF/NAM High Cost	MIT Offsets + CCS	EPA ADAGE Scenario 2	EPA ADAGE Scenario 10	CRA Scenario w/ Banking
S. 2191 Cap ($MtCO_2e$)	4,992	4,968	4,992	4,992	4,924	4,924	4,924	4,924
Total GHG Emissions ($MtCO_2e$)	6,770	6,910	5,593	5,385	6,325	6,388	6,256	5,748[3]
Allowance Price ($/$tCO_2e$, 2005$)	$ 28.96	$22	$52	$61	$58	$37	$28	$58
GDP Impact (% chg from BAU)	-0.27%	-0.5%	-0.8%	-1.1%	-0.8%	-0.7%	-0.5%	-1.5%
Consumption Impact (% chg from BAU)	-0.41%	-0.7%	-0.7%	-2.6%	-0.7%	-0.4%	-0.2%	-2.5%
Consumption Impact per household (2005$)	$ (316.9)	$ (743)	$ (701)	$ (2,778)	$ (747)	$ (446)	$ (239)	$ (1,940)
Coal Prices (% change)	163%	118%	322%	389%	402%	224%	188%	200%
Electricity Prices (% change)	3%	5%	28%	33%	30%	32%	26%	32%
Natural Gas Prices (% change)	18%	8%	26%	36%	14%	25%	19%	43%
Total CCS (GW)	18.5	8.0	12.7	22.0	37.3	25.0	25.0	17.0
Total Nuclear (GW)	126.3	119.7	102.7	102.7	109.2	126.2	125.2	119.0
Total Renewables (GW)	178.5	188.4	140.3	134.0	137.3	138.1	138.1	83.0
Total Natural Gas Consumption (Quads)	21.8	23.8	24.3	24.2	26.4	26.5	25.5	25.5

CALCULATIONS

For MIT data, we have adjusted the prices to include their reported allowance prices, according to the following formulas:

Price (coal or natural gas) under S.2191 = Price Index relative to 2005 * Price in 2005 + Carbon Content * Allowance Price in $MtCO_2e$

Price in Reference Case = Price Index relative to 2005 * Price in 2005

Thus: Percent change in price from BAU = (Price under S.2191 / Price in Reference) – 1

Coal Price in 2005 ($ per short ton of coal)............................$26.70
Natural Gas Price in 2005 ($ per tCf)....................................$11.05
Carbon Content of Coal ($MtCO_2e$ per short ton)......................2.048
Carbon Content of Gas ($MtCO_2e$ per tCf)...............................0.055

For comparison purposes, we converted electricity generation reported in the MIT analysis (exajoules) to electricity capacity (gigawatts).

Capacity in GW = Generation in EJ * (1/1.055056 Btu per EJ) * (1000/3.412 Watts per Btu) * 1000/(8760 Hours per year * Capacity conversion factor)

Capacity Conversion Factors:

Nuclear: 90% CCS: 85% Biomass: 83% Hydro: 40% Wind/Solar: 38%

The Pew report has tables for 2015, 2020 (reproduced in Table 8 above), 2030 and 2050.

Another study provides a useful comparison of the range of cap-and-trade proposals which are at various stages in the US Congress. It used the MIT Integrated Global System Model (IGSM) – and its economic component, the Emissions Prediction and Policy Analysis (EPPA) model –to assess these proposals. It found that for "more aggressive reductions, the economic cost measured in terms of changes in total welfare in the United States could range from 1.5% to almost 2% by the 2040–2050 period, with 2015 CO2-equivalent prices between $30 and $55, rising to between $120 and $210 by 2050. This level of cost would not seriously affect US GDP growth but would imply large-scale changes in its energy system." (Paltsev *et al.* 2008)

The same study compares several proposal to three notional levels. These amounts are 287 bmt (meaning 'billion metric tons' of CO_2-eq) with implies holding emission flat at 2008 levels; 203 bmt when allowance for -50% from 1990 by 2050, and 167 bmt for -80% from 1990 by 2050. While Obama has not stated the base year for 2050 recently, 167 bmt is consistent with the long-term goal put forward by his administration (see section 3, chapeau).

Table 9: GHG cumulative allowances available from 2012 to 2050 to the US

Source: (Paltsev et al. 2008: 406)

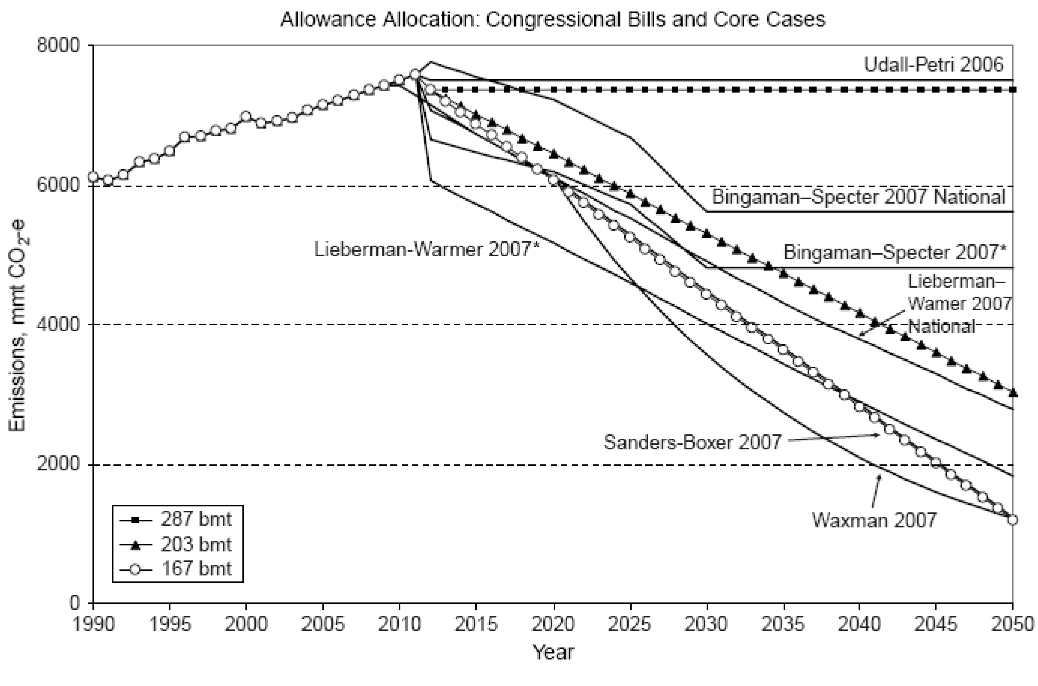
Allowance path	Cumulative allowances 2012–2050, bmt CO_2e
Udall-Petri 2006	293
287 bmt	287
Bingaman-Specter 2007	245 (210)[a]
203 bmt	203
Feinstein August 2006	195
Lieberman-Warner 2007	190 (153)[b]
Kerry-Snowe 2007	179
Sanders-Boxer 2007	167
167 bmt	167
Waxman 2007	148

[a] 210 are the allowances for covered sectors; 245 is the estimate of total emissions including uncovered sectors. The actual national emissions depend on growth in uncovered sectors. The allowances for covered sectors for 2030–2050 are kept constant as specified in the Bill. An additional provision can change these allowances based on actions at the international level.
[b] 153 are the allowances for covered sectors; 190 is the estimate of total emissions including uncovered sectors. The actual national emissions depend on growth in uncovered sectors. The Bill also has a provision for an increase in allowances for domestic projects and purchases from foreign trading systems, each limited to 15% of total covered emissions.

Table 9 shows that Sanders-Boxer is consistent with 167 bmt, and Waxman's proposal is below this. Graphically, this is shown in

Figure 8: Scenarios of allowance allocation over time

Source: (Paltsev et al. 2008: 406)



Finally, the results of a range of studies are usefully summarised in CAN-I (2008), reproduced in Table 10

Table 10: Key results of studies of US mitigation potential

Source: (CAN-I 2008)

Study (Lead organization/author)	Key Findings	Cost	Model used.
Adapting in Uncertain times: A Scenario Analysis of U.S. Energy and Technology Futures (Laitner, 2006)	Compared to a 2020 EIA forecast, policies are shown to reduce energy-related CO_2 emissions in the U. S. 28% by 2020, and 55% below the 2050 forecast by 2050.	While energy prices rise 17% and 8% by 2020 and 2050 respectively, efficiency measures reduce demand so that actual energy expenditures go up only 11% by 2020 and actually go down 30% by 2050.	The Argonne National Laboratory's AMIGA Modeling System
An Integrated Analysis of Policies that Increase Investments in Advanced Energy-Efficient/ Low-carbon Technologies (Hanson and Laitner, 2004)[224]	Using only what might be termed as moderate energy policies CO_2 emissions reached 2000 levels by 2020 and 1990 levels by 2050.	The carbon prices ranged from $18-25 with the nation's GDP slightly increased by 0.2% and 0.3 for 2020 and 2050, respectively	The Argonne National Laboratory's AMIGA Modeling System
Tackling Climate Change in the U.S. (ASES, 2007)	U.S. can reduce emissions 60-80 percent below 2005 levels by 2050 with renewable energy and energy efficiency.	N/A	Bottom up analysis
Energy Revolution (Greenpeace & EREC, 2007)	U.S. can reduce emissions nearly 75 percent below 2005 levels by 2050 without CCS or nuclear power.	Energy cost savings of about 40 percent compared with BAU	German Aerospace Center, MESAP/PlaNet

4. Possible QERCs in Annex B

4.1 Criteria

This methodology explains the core principles and key criteria used in calculating quantified emission reduction commitments for Annex I countries for the 2nd and 3rd commitment period under the Kyoto Protocol, as included in a proposed amendment.

The core criteria used are based on principles of the Convention:

- Responsibility, in particular historical responsibility for the cumulative emissions since the industrial revolution, which have caused the problem in the first place (Art 3.1)
- Capability, which should be assessed in broader terms of human development, not only income (Art 3.1)
- Development, which is based on the right to promote sustainable development (Art 3.4)

4.2 Methodology

The methodology uses a combination of responsibility and capability indicators to allocate emissions targets amongst Annex I countries. In this respect, and in other important respects discussed further below, it draws on the approach to emissions allocation outlined in the Greenhouse Development Rights (GDR) framework (see section 3.1.1 above), in which responsibility is conceptualized as responsibility for cumulative emissions per capita (cumulative emissions for a historical period, population for a base year), and capability conceptualized as GDP PPP per capita in the same base year. Data is taken from a consistent database (WRI 2005).

South Africa has used another factor – the Human Development Index (UNDP 2008) - as an additional indicator of capability, with higher development levels being indicative of higher capability to mitigate. Another aspect of considering development in relation to capability, we have used the method of excluding 'survival emissions' assumed to be incurred by the fraction of the population in each country living below a poverty line. This has been proposed in several places (for example, Agarwal & Narain 1991; Mwandosya 2000; Pan 2002). The GDR method operationalises this approach by reducing the capability and responsibility of each country proportionally to total income and the way in which income is distributed. The indicators are then combined to produce a final indicator which is used to allocate the required emissions reduction for the Annex I group as a whole for the specified emissions reduction target. Development considerations are thus integrated into the indicator for capability.

Mitigation effort is measured against 1990 emissions levels – thus, countries whose emissions levels have not grown significantly since 1990 benefit, and those whose emissions levels have grown significantly, are disadvantaged. On the other hand, those whose emissions declined immediatley prior to 1990 would be advantaged. Baseline emissions growth in 2020 is not taken into account; therefore Annex I countries which shift early to a low-carbon growth path are significantly advantaged. We will now outline the development of these components in more detail, before describing the input parameters of the spreadsheet.

4.2.1 Responsibility

Responsibility is calculated for each country based on cumulative emissions. Historical responsibility has been elaborated in detail in the Brazilian proposal (Brazil 1997; La Rovere et al 2002). In the present approach, the historical period over which emissions can be summed ranges from 1850-2005 to 1990-2005. The cumulative total is then divided by the population for 2005 to arrive at a cumulative per capita emissions indicator, which is taken as an indicator of historical responsibility. Following this, 'survival emissions' are excluded, which reduces the responsibility of countries in proportion to the fraction of their population below the poverty line.

4.2.2 Capability

Capability is measured in GDP PPP per capita in 2005, which is taken as a measure of mitigation capability. The GDR method is applied to capability as well, which excludes the income of the proportion of the population below the poverty line.

4.2.3 Taking the broader development context into account

We have assumed that in addition to wealth, broader human development is also an indicator of mitigation capability. We have used the UNDP's Human Development Index as an indicator of development on account of its wide acceptance, and applied this as a corrective factor to the GDP-based capacity indicator. Given that different components of the HDI are on logarithmic and linear scales respectively, the technique that has been used to link the HDI to a capability measure first involves the exclusion of the GDP indicator, since this is already expressed in the capability indicator; in addition, the logarithmic basis for the GDP component of the HDI would dramatically underplay income differences between countries at the higher end of the global income spectrum. The other two components of the HDI are included using the following technique:

- the average of the two remaining indicators is calculated
- the average, and upper and lower bounds, of the index are determined
- the GDP-derived capacity indicator is adjusted by a user-defined margin in proportion to the deviation from the average within the boundaries set by the upper and lower limits. For instance, if a specific country's GDP/cap is x, its indicator is 0.8, the mean is 0.85, and the lower limit is 0.75, and the user-defined margin is 67%. The country's indicator is halfway (50%) between the average and the lower limit, so the capability factor is reduced by 50% x 20% = 10%. Therefore the capability factor is adjusted by -10% to reflect the lower level of development of the country concerned.

The impact of the HDI indicators on the capability indicator is thus set by the user-defined margin.

4.2.4 Combining the indicators

The two indicators are combined using a technique borrowed from the GDR – if R = responsibility and C = capacity, the indicators are combined as follows: $I = R^m \times C^n$, where $m + n = 1$, $0 <= m,n <= 1$. Thus, if m=1 and n=0, the final indicator is comprised only of responsibility, and vice versa. Following this, the combined indicator (still expressed in per capita terms) is multiplied by the country's population, and divided by the population of the total country group (in this case Annex I), to calculate the share of the total mitigation burden for each country. In the analysis here, responsibility has been weighted 60%, capability at 40%.

4.2.5 Calculating the total mitigation burden

Calculating the total mitigation burden in this case is very simple and transparent, requiring only a calculation in relation to 1990 emissions. Thus, the mitigation burden for Annex I countries is the reduction in emissions for the group from 1990. Thus if the reduction target is 40%, the mitigation burden is 40% of 1990 emissions for Annex I as a whole.

4.2.6 Allocating emissions reductions for each country

The final step is very simple – the mitigation share for each country is multiplied by the mitigation burden to give the mitigation requirement for each country from their 1990s emission level, which can be easily converted into a reduction from 1990 levels.

4.3 Numbers for Annex B

Based on the above criteria and methodology, the quantified emission reduction commitments for Annex I countries can be derived. The table below indicates QERCs for two commitment periods of five years each, from 2013-2017 and 2018-2022.

Table 11: New numbers for Annex B

Party	***Quantified emission limitation or reduction commitment (2008-2012)*** ***(percentage of base year or period)***	***Quantified emission reduction commitment (2013-2017)*** ***(percentage of base year or period)***	***Quantified emission reduction commitment (2018-2022)*** ***(percentage of base year or period)***
Australia	108	82	61
Austria	92	69	32
Belarus		97	93
Belgium	92	70	34
Bulgaria*	92	96	92
Canada	94	79	53
Croatia*	95	92	83
Czech Republic*	92	87	72
Denmark	92	75	45
Estonia*	92	94	87
European Community	92	78	51
Finland	92	80	56
France	92	69	31
Germany	92	76	46
Greece	92	82	60
Hungary*	94	89	75
Iceland	110	77	48
Ireland	92	79	53
Italy	92	79	53
Japan	94	77	49
Latvia*	92	93	85
Liechtenstein	92	78	51
Lithuania*	92	93	85
Luxembourg	92	73	40
Monaco	92	78	51
Netherlands	92	77	49
New Zealand	100	84	64
Norway	101	67	27
Poland*	94	90	78

Portugal	92	84	64
Romania*	92	96	91
Russian Federation*	100	96	91
Slovakia*	92	91	79
Slovenia*	92	83	62
Spain	92	75	44
Sweden	92	65	23
Switzerland	92	69	31
Turkey		95	89
Ukraine*	100	99	98
United Kingdom of Great Britain and Northern Ireland	92	66	25
United States of America [c]	93	76	48

* Countries that are undergoing the process of transition to a market economy.

[c] Countries that have not yet ratified the Kyoto Protocol

The values for European Commission are calculated from the commitments for individual Annex I countries. Liechtenstein and Monaco are given the average for Europe. All base years are 1990; adjusting the base years for economies in transition to those in the Kyoto Protocol would result in different numbers.

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