Climate Change Mitigation: Understanding *Comparability* (of Targets and Efforts)

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INSTITUTE OF POLICY STUDIES
WORKING PAPER 09/06

July 2009

Institute of policy studies

INSTITUTE OF POLICY STUDIES WORKING PAPER 08/07

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MONTH/YEAR July 2009

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ACKNOWLEDGE-MENTS
Prepared for the Institute of Policy Studies as part of the Post-2012 Climate Treaty project under the auspices of the Chief Executives' Emerging Issues Programme.

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EXECUTIVE SUMMARY

A critical issue facing international negotiations of a post-2012 climate change agreement is the respective contributions of individual countries to the needed overall mitigation effort by developed countries. This was given clearer framing in the *Bali Action Plan* which called for (bolding added)

> *Measurable, reportable and verifiable nationally appropriate mitigation commitments or actions, including quantified emission limitation and reduction objectives, by all developed country Parties, while ensuring the* ***comparability of efforts*** *among them, taking into account differences in their national circumstances.*

Since Bali, the topic of "comparability" has become central to the UNFCCC post-2012 negotiations. Prior means under the UNFCCC by which countries have been compared and treated differently do not provide much precedent or guidance. So this topic is mostly 'new territory' for negotiators.

There are a large number of ways that countries can be compared against each other. This is generally unhelpful in negotiations, as countries can be expected to pick the indicators and metrics[1] that best present their individual case – with a result that the negotiations are pulled in many directions. What seems needed is a few core indicators plus the ability for countries to present other data that helps the negotiations assess the fairness of numerical outcomes using these core indicators and associated metrics – and make adjustments as is deemed fit and acceptable.

In general, indicators can be grouped under three classes: emissions-based, mitigation-cost based and 'other'. Within these classes some can also be described as of a change type and others of an end-point type.

By themselves, current or projected emissions data are of little use in drawing comparisons between countries, or making judgements about possible future targets. Other parameters are needed to help normalise, or make sense of, emissions data. One common, and simple, form of metric is the percentage change of current (or future) emissions from a prior base year. But these results depend critically on the base year. It is also instructive to incorporate other key indicators in such change-type metrics, such as the change in population and GDP over the same period. However, even these may need further information to get a proper understanding, e.g. on structural changes in economies involving shifts of the location of emissions intensive production.

Metrics of the costs of mitigation (whether average costs, total costs or marginal abatement costs) necessarily involve the use of a *reference case* from which the costs of the *mitigation case* are derived. Assumptions about the reference case can therefore be as critical to the mitigation cost results as the abatement cost curves involved in any cost analyses. Debates about assumptions being used in models (as well as the models themselves) can be expected to present a key challenge to negotiators. This raises questions about the viability of mitigation cost-based metrics being used as core metrics – as compared with their use just as secondary 'testing' metrics. Moreover, many analyses of costs are just 'first round' direct costs of the abatement actions and do not take into account macroeconomic impacts (due to sectoral changes and trade impacts).

For all of marginal, average and total costs it is also important to distinguish between costs 'with and without' (or 'before and after') international emissions trading (which is intended to equalise marginal abatement costs across countries). More broadly with respect to the use by countries of emissions trading and other flexibilities provided for in the Kyoto Protocol, is what judgements about comparability should be carried forward into subsequent commitment periods, given the effects on domestic emission from the use of such flexibilities (i.e. higher emissions for 'buyers' and lower emissions for 'sellers').

[1] The distinction between indicators and metrics used in this paper is that metrics are a finer definition, or units, of an indicator. For example, metrics for the indicator "national wealth" could include GDP or GNI or GDP per capita, etc.

Endpoint metrics (such as emissions per capita at a future point in time, or 'efficiency' of given sectors e.g. emissions per MWh or per tonne of production of major energy intensive commodities) have the simplicity of not having a comparative 'reference' (i.e. as change metrics do, such as base years or future 'BAU' emission trends), thereby avoiding the issues that arise with such reference points (or lines). But endpoint metrics on their own may not fully reflect the national circumstances, e.g. access to renewable energy resources. Also, the lack of a reference means there is no detail about the mitigation path that countries may have followed or will follow.

There are already a range of analyses by independent research groups, as well as by the European Commission, that show how the use of different indicators and metrics can produce suggested targets for developed countries (or groups of countries). These targets are also calculated for different overall levels of reductions by developed countries, i.e. for different stabilisation pathways.

Targets are usually first calculated in 'allowed tonnes' of emissions. Typically, they are then presented in percentage terms by comparison with some prior base year. Depending on the prior year chosen, the percentage reductions (for the same allowed tonnes) can vary widely. Using a more recent year such as 2005 can help the percentage reductions appear more uniform (so comparable) – which may be very helpful in the communicating of the outcomes of negotiations to domestic constituencies.

Most discussion thus far in the post-2012 literature related to indicators and metrics has been about the differentiation of countries' emission reduction targets within some overall emissions reduction commitment by developed countries. This raises the question about "commitments or actions" that are other than targets (noting that the Bali language implied these might be different things[2]). A key issue will likely be how to compare emission reduction targets with 'lesser' targets plus financial (or other, e.g. technology) contributions. It is feasible that these could be compared on the basis of some equivalence of costs or projected emissions outcomes. Again, these could be normalised across developed country Parties by considering factors such as population or GDP.

The process by which comparability indicators and metrics get taken up and used in the negotiations is, as yet, unknown. A total emissions envelope (or budget) for developed countries over a given period of time could first be set. The use of indicators and metrics would then be to assist negotiators to agree countries' shares of this total amount of emissions such that their mitigation efforts are considered to be *comparable*. An alternative approach to negotiations is that developed countries might present proposals of what emission reductions (and other "commitments or actions") they can contribute to the overall effort (and perhaps what they expect of others). Proposals could include the indicators and metrics that underpin the numerical targets suggested. A third approach to kickstart serious numerical negotiations might be a *Chairman's Proposal* of targets for developed countries, which includes the indicators and metrics that underpin this proposal.

[2] The phrase *quantified emission limitation and reduction objectives* (or QELROs) was the term used in the Kyoto negotiations for "targets".

1 INTRODUCTION AND CONTEXT

Why is "comparability" a word of interest?

At a simple level *comparability* indicates that differences exist in 'something' and there is a desire to understand these and treat like for like or determine that different things can have equal value, or different outcomes be seen as equitable.

The term *comparability* has taken on greater significance in the lexicon of climate change policy following its use in the *Bali Action Plan* in paragraph 1 b (i), under a chapeau about "enhanced national/international action on mitigation of climate change":

> Measurable, reportable and verifiable nationally appropriate mitigation commitments or actions, including quantified emission limitation and reduction objectives, by all developed country Parties, while ensuring the **comparability of efforts** among them, taking into account differences in their national circumstances

With respect to negotiations of a post-2012 climate change agreement, the formal use of the term *comparability* is, therefore, focused on the efforts of developed country Parties.

"Comparability": Is its usage and meaning clear?

Already from the UNFCCC and Kyoto Protocol?

There are already ways in the UNFCCC that developed countries are seen and treated as being different. First, developed countries are in the group *Annex I Parties* which includes industrialised countries and the "economies in transition" countries of the former Soviet Union (EITs). Second, there are Annex II Parties, which is the industrialised countries subset of Annex I that have additional responsibilities with respect to providing financial, technology and capacity building assistance for developing countries (non-Annex I Parties).

From these divisions, some common measures of differences among countries have been seen as:

- *responsibility*: which countries' anthropogenic emissions of greenhouse gases have, thus far, mostly caused the climate change problem
- *capability*: which countries have the technological ability to mitigate their emissions
- *capacity*: which countries have the economic and governance system wherewithal to mitigate their emissions (and help others to do so)

Beyond these broad distinctions, however, the Convention provides little guidance on how *comparability* might be elaborated in finer detail. This said, most metrics can probably be seen to fall under these three broad categories.

Under the Kyoto Protocol, the *quantified emission limitation and reduction commitments* (QELRCs or targets) of developed countries, as listed in Annex B, are *differentiated* through varying percentage reductions, mostly relative to a 1990 base-year. Also, under Article 4 of the Protocol (the so called "EU Bubble" provision), a group of countries can agree to meet their commitments jointly as a group, with a single numerical target, rather than being 'tested' at the individual country level.[3] So it may be feasible that *comparability* is assessed at a collective level rather than just for individual countries.

[3] In practice, given the emissions trading provisions of the Protocol, this mostly just means a reallocation of their initial "assigned amounts" depending on the group's internal burden sharing agreement.

In addition, at a finer point of detail, some of the land use, land-use change and forestry (LULUCF) provisions allow for a differentiation between countries, e.g. the caps on emissions and removals of Article 3.4 activities.[4]

But the key contribution of the Protocol to the notion of *comparability* seems to be that countries' commitments can be numerically different, and that this can be accepted as *fair and reasonable* (i.e. equitable) to the other countries in the negotiations.[5] Indeed, most analyses about possible country contributions to a future post-2012 agreement are framed around different targets, or shares of an overall emissions target.

From the language in the Bali Action Plan?

However, the language of paragraph 1 (b) (i) in the Bali Action Plan might be seen as opening up the discussion of *comparability* to well beyond just differences in numerical targets. For example, it refers to:

- "commitments or actions". How are these different? The following term "quantified emission limitation and reduction objectives" (QELROs) was the term used for "targets" in the AGBM[6] negotiations leading to the Kyoto Protocol.[7] So the "commitments" here may also be targets. But might there be commitments that aren't targets? And what about "actions"? What is the scope here?

- "measurable, reportable and verifiable". This does appear to put some bounds around "commitments or actions", and thus usefully constrains the options set. It suggests that they will be tested in a quantitative manner, and that there might be meaningful consequences of such measurements.

- "comparability of efforts" ....."taking into account differences in their national circumstances". What are *efforts*? How do they relate to "commitments or actions"? Are they measured as outcomes or just activities seeking to achieve an outcome? And what does the "taking into account...." phrase mean in practice? Does this connect to "measurable, reportable and verifiable" or did that phrase just relate to "commitments or actions"? So could "taking into account...." mean judgements that, in nature, are more qualitative than quantitative?

In short, as is common with negotiated texts in politically charged circumstances, the language of 1 (b) (i) perhaps was selected precisely because of its perceived 'constructive ambiguities'. It is then left to subsequent process to sort out what things mean so as to enable eventual agreement.

[4] But this LULUCF example of differentiated 'minor' provisions may not be seen as an enduring or useful precedent, as this was seen at the time as an 'ex-post' adjustment of targets to allow some key countries to ratify the Protocol so that it could enter into force.

[5] However the means by which the Kyoto targets were differentiated is not a useful example for the post-2012 negotiations. These targets primarily emerged from a last minute political 'horse trading' process among major countries, not from any transparent analytically-based process.

[6] Ad-hoc Group on the Berlin Mandate

[7] The word "objectives" became "commitments" in the final text (so QELRCs).

2 COMPARABILITY INDICATORS AND METRICS – NATURE AND USE

There is already a broad menu of possible metrics that could be employed in assessments of comparability[8] – noting, however, that the 'post-2012' literature thus far on potential developed countries' efforts (and how they may differ from each other) has primarily been around different targets[9]:

centred around emissions

- change in emissions relative to a previous point in time
- change in emissions relative to projected (without measures) reference emissions at a future point in time
- aggregate emissions from a historical point in time to the present or a future point in time
- emissions per capita – present and at a future point in time
- change in emissions relative to change in population
- emissions per GDP – present and at a future point in time
- % of world emissions
- emissions abatement potential
- % of emissions associated with exports
- % of 'embodied' emissions of domestic consumption relative to national production emissions

centred around 'dollars'

- total mitigation costs, $
- average or marginal costs relative to emissions, $/tonne
- total mitigation costs relative to GDP, $/GDP
- total mitigation costs relative to population, $/capita
- economy and trends in economy, GDP and rate of change of GDP
- national 'wealth' and trends in wealth, GDP per capita
- payments into international climate change funds, including to support activities in developing countries (e.g. technology, adaptation, REDD)

other

- population and trends in population
- 'efficiency' (of given sectors), e.g. emissions per MWh or per tonne production of major energy intensive commodities
- domestic energy resources available – fossil relative to renewable

In sum, there seems to be many possible ways to define how 'things' might be comparable. That they may also be equitable is a further consideration. All this is generally unhelpful to negotiators. The purpose of the use of indicators and metrics is to assist negotiators to reach an agreement, not present them with a dizzying array of information pulling in different directions. Some grouping and rationalising of the attributes of the metrics is needed to simplify the key messages. What also seems obvious given the 'richness' of this menu of possible metrics is that it is highly unlikely that the outcome will just fall out from some simple formulaic mathematical exercise.

[8] Most analyses look at results on an economy wide basis, but some sectoral discrimination is also evident (e.g. Triptych approach).

[9] This work has used these metrics in 'effort sharing' analyses and translated the results back into targets.

The following sections provide a sense of how some key comparability metrics may inform the negotiations. They start with simple, more one-dimensional metrics and work up to more complex, multi-dimensional metrics. A number of numeric examples are provided in figures. However the purpose of providing these is not for focussing on the data per se, but to illustrate specific characteristics of the metrics with a view to suggesting how they might be used, or not.

In practice, negotiators are likely to look at three broad classes of metrics, centring around (1) emissions, (2) mitigation costs and (3) other financial/resource contributions. Additional factors – population, GDP etc – can then be used to help in assessing the comparability of the core metrics by helping to normalise the data given differences in national circumstances.

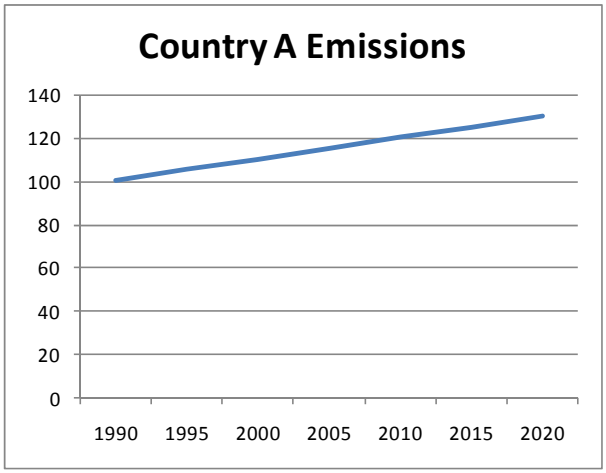
2.1 Some basic concepts

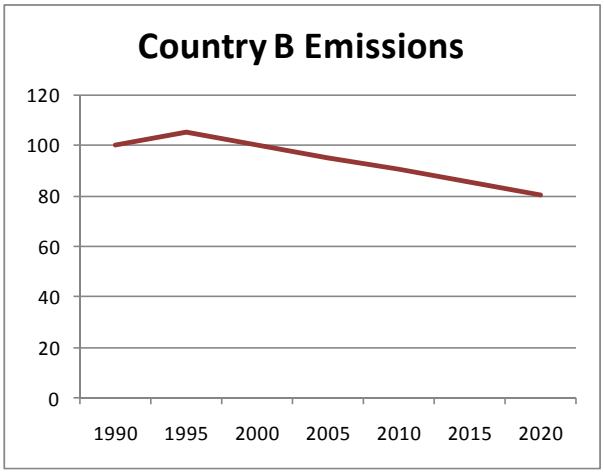
Initial perceptions about what may constitute a 'tough' or 'easy' target can often be misplaced. The following '101' exercise is intended to set out some basic concepts such that later sections which get into examples of possible targets for specific countries might be better understood. The exercise is about how greenhouse gas emission targets in 2020 for two developed countries ('A' and 'B') can be calculated and expressed based on four simple indicators:

- Reductions compared with two different base years (1990 and 2005)
- Equal marginal abatement costs
- Equal costs

This is a deliberately simplified analysis. For example, the treatment of costs is based on simple and static marginal abatement cost (MAC) curves. The purpose of this analysis is to explain some of the beginning issues when you consider 'comparability'.

The emissions history from 1990 and projected reference (unmitigated) emissions to 2020 for Country A and Country B are:





Targets based on two different base years

Given these emissions profiles (and underlying data) the calculations of targets in 2020 for a **25% reduction** compared with the two base years are:

Country A	Country B
Emissions in 1990 = 100 tonnes	Emissions in 1990 = 100 tonnes
Emissions in 2005 = 115	Emissions in 2005 = 95
Reference Emissions in 2020 = 130	Reference Emissions in 2020 = 80
25% reduction target cf 1990 = 75 - Needed reductions cf reference = 55	**25% reduction target cf 1990 = 75 tonnes** - Needed reductions cf reference = 5
25% reduction target cf 2005 = 86 tonnes - Needed reductions cf reference = 44	**25% reduction target cf 2005 = 71 tonnes** - Needed reductions cf reference = 9

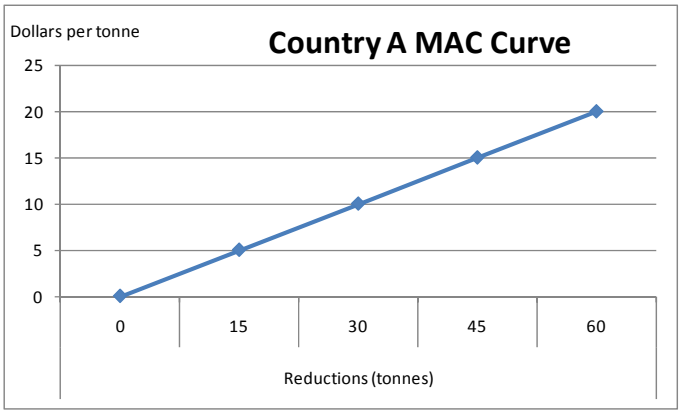
Some simple insights that can be drawn from this data are:

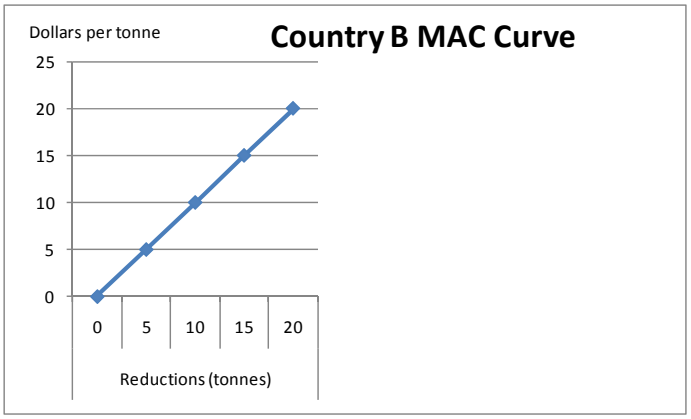
- Differences in base year is important. But the greater influence on results can be the emissions path since 1990 and on to 2020, i.e. the reference emissions in 2020 is a key data point.
- The question "Who has the tougher target (for a given base year), Country A or B?", or alternatively "How comparable are A and B's targets?", does not have a single simple answer. Looking, for example, at the data using 2005 as the base year, it might seem that B has the tougher target at 71 tonnes (A is allowed 86). But A has to reduce 44 tonnes and B only 9.

It is likely that one question to help sort out this 'tougher target' question will be "What are the costs for A and B to achieve these targets?" The underlying thought may be that it is likely that A has a relatively lower abatement cost curve because B seems to have made more efforts to reduce their emissions, so already may have taken up all their 'low hanging fruit'. Costs are explored in the next section, again with a deliberately simplified data set and analysis.

Targets based on equal marginal abatement costs and equal costs.

The MAC curves for Country A and B are:





The following analysis is for the case where the collective target (of A plus B) in 2020 is a **25% reduction compared with 1990 levels**. So the target is 150 tonnes versus the reference 'A plus B' emissions in 2020 of 210 tonnes. The collective reduction, therefore, is 60 tonnes.

The two calculations here are:

- For equal MAC: What is the target (allowed emissions) for A and B when the reductions at an equal MAC value for A and B total 60 tonnes

- For equal cost: What is the target (allowed emissions) for A and B when the reductions at an equal cost (the area under the MAC curves) for A and B total 60 tonnes

The results of these calculations are provided below.

Equal MAC

The equal MAC that results in a total of 60 tonnes reduction by A plus B is $15 per tonne. Key results for A and B are:

Country A	Country B
Reduction required at $15/tonne = 45 tonnes	Reduction required at $15/tonne = 15 tonnes
Target (ref of 130 in 2020 minus 45 reduction) **= 85** - this target cf 1990 = -15% - this target cf 2005 = -26%	**Target** (ref of 80 in 2020 minus 15 reduction) **= 65** - this target cf 1990 = -35% - this target cf 2005 = -32%
Cost for these reductions = $338	Cost for these reductions = $113

Equal Cost

The equal cost that results in a total of 60 tonnes reduction by A plus B is $241. Results for A and B are:

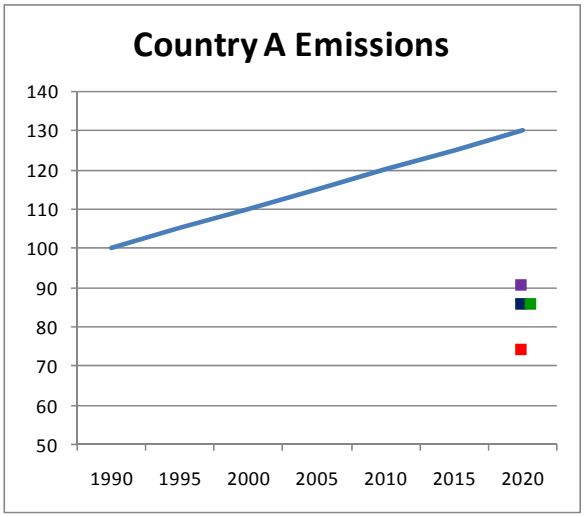
Country A	Country B
Reduction required at $241 = 38 tonnes	Reduction required at $241 = 22 tonnes
Target (ref of 130 in 2020 minus 38 reduction) **= 92** - this target cf 1990 = -8% - this target cf 2005 = -20%	**Target** (ref of 80 in 2020 minus 22 reduction) **= 58** - this target cf 1990 = -42% - this target cf 2005 = -39%
Marginal cost at these reductions = $13/tonne	Marginal cost at these reductions = $22/tonne

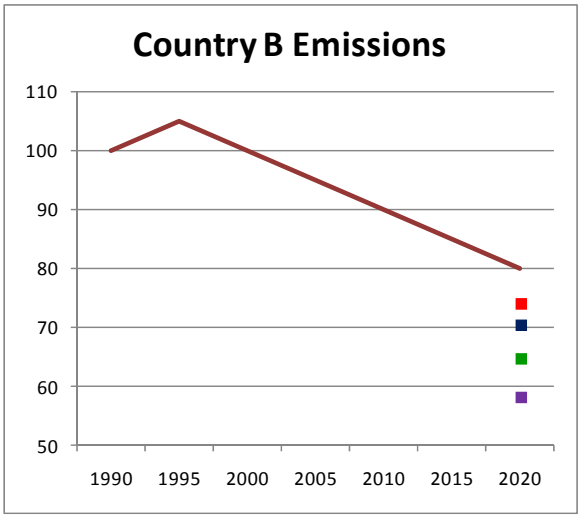
Insights that can be drawn from these costs related assessments are:

- Targets based on equal costs can be significantly different than targets based on equal marginal costs. And these cost related targets can be significantly different than targets based just on percentage reductions from a base year. (See summary figure below.)
- A country with a relatively steeper MAC curve would prefer a target based on equal MAC (it stops earlier having to do more). Conversely, a country with a relatively less steep MAC curve would prefer a target based on equal costs (it doesn't have to do more just because it still has lower cost abatement to do). Note, however, these results are likely to be influenced by the assumed simple emission paths and cost curves of A and B used here. These results may not hold for other more complex cases.
- Total costs (with the emission pathways and MAC curves in this 'thought experiment' anyway) are cheaper in the equal marginal cost case ($452) than in the equal cost case ($482). This result might hold generally, as equal marginal abatement costs is an accepted 'least cost' efficiency proposition.
- For a given target, calculated in tonnes, the values for A and B are closer (so seemingly more comparable) when then expressed as reductions compared with a 2005 base year than when compared with a 1990 base year.

Summary Depiction

The following figures superimpose the 2020 targets discussed above on the original emissions path curves (note different 'y axis' scales when comparing data points across countries A and B).





Legend ■ -25% cf 1990 ■ -25% cf 2005 ■ Equal MAC (A&B -25% cf 1990) ■ Equal cost (A&B -25% cf 1990)

What do these comparisons have to do with 'equity'?

The simple cases set out in this analysis show that:

- For targets in a future year set as a percentage reduction against a historical base year, it can matter a lot what base year is used and what the emissions path has been and is expected to be. Such a simple test for comparing across countries, in fact, provides little insight about *comparability*. Indeed, without the light of the detail about historical and future emissions, such targets can give a misleading sense of how "tough" a target is to meet.
- If cost indicators are considered as the next step to consider what targets might be comparable, results can be substantially different if based on *equal marginal costs* or *equal costs*. (Note that this 'simple case' statement will hold less if emissions trading across countries is considered.)

However, comparability analyses of targets based on cost indicators may still only provide an initial sense of what might be perceived as *equitable*. Taking the simple cases set out in this 'tale', it might be seen that Country B has been more responsible than Country A with respect to its mitigation actions – so this should be recognised in any future target setting. It may be seen as entirely equitable for Country A to have a tougher target than Country B.

But such judgements may not be adequately informed. Other indicators such as percentage growths over the same periods in population or GDP, or changes in the structure of economies (e.g. the outsourcing or insourcing of production of energy-intensive internationally traded commodities) may be highly relevant to such equity judgements.

In short, with respect to target setting, comparability and equity may well be seen as two different and separable concepts. It can be imagined that what is being strived for in the first instance are targets that are equitable – probably also in the light of other commitments and actions. How these targets (tonnes of allowed emissions) are subsequently expressed (e.g. what percentage reduction and what base year) may then play an important role in communicating what is equitable (through a sense of what seems comparable) to observing international and domestic audiences.

2.2 Comparability and use of mechanisms

Another aspect of comparability is how targets in a following commitment period should be influenced by how countries have used flexibility mechanisms in meeting their commitments in the previous period. A simple three country 'thought experiment' is provided here to set this out for consideration.

Initial settings:

- Each country's starting emissions are 100.
- The primary equity rule applied is equal emission reductions in the first commitment period (CP1) – in this case of 20 per country, so 60 in total.
- A secondary equity rule is that marginal abatements costs can (and ideally should) be equalised, so emissions trading is enabled.

As it plays out in CP1, Country A hits the overall marginal abatement cost at reductions of 10 so chooses to buy 10 units which it gets from Country C which has low abatement costs. Country B achieves its 20 reductions exactly at the overall marginal abatement cost so does not participate in trading and achieves all its reductions domestically.

The results for CP1 are therefore:

Country	CP1 Starting Emissions	Required Reductions	Domestic Reductions	Emissions Trading	CP1 Ending Emissions
A	100	20	10	Buy 10	90
B	100	20	20	None	80
C	100	20	30	Sell 10	70
Totals:	**300**	**60**	**60**	**-**	**240**

While there is not information provided for this simple case to be able to identify the relative costs of the three countries in meeting their commitments, it may be reasonable to assume that:

- Country A had the highest costs because it had to buy 10 units that may all have been at (or slightly above) the price of the overall marginal abatement cost.
- Country B had the middle costs.
- Country C had the lowest costs, not only because its required 20 reductions were at lower abatement costs, but also because of the profit it made on the next 10 reductions that it sold to Country A.

An important result of CP1 is that the countries have met their commitments, collectively and individually – and at least cost. This outcome is exactly what the international rules set intended.

These three countries are now negotiating targets for the next commitment period (CP2) and want these targets to be "comparable". The sought aggregate reductions compared with emissions at the start of CP1 are now 120, i.e. double the reductions of CP1.

Three options for setting the targets of these countries are:

i. As in CP1, equal reductions in absolute terms and percent of starting CP1 emissions (40%)

ii. Equal percent reductions based on ending CP1 emissions (so requires 25% reductions)

iii. Equal percent emissions based on ending CP1 emissions adjusted for trading in CP1 (meaning, for the purposes of this calculation, Country A's CP1 ending emissions are reduced by 10 and Country C's CP1 ending emissions are increased by 10).

The calculations for these three options are:

Country	CP1 Ending (CP2 Starting) Emissions	**Option 1** Target of 40% reductions cf starting CP1 emissions		**Option 2** Target of 25% reductions cf starting CP2 emissions		**Option 3** Target of 25% reductions cf starting CP2 emissions adjusted for CP1 trading	
		Req'd End Emissions (CP2 Target)	Hence Req'd CP2 Reductions	Req'd End Emissions (CP2 Target)	Hence Req'd CP2 Reductions	Req'd End Emissions (CP2 Target)	Hence Req'd CP2 Reductions
A	90	60	30	67.5	22.5	70	20
B	80	60	20	60.0	20	60	20
C	70	60	10	52.5	17.5	50	20
Totals:	**240**	**180**	**60**	**180**	**60**	**180**	**60**

Given these calculations, the question becomes "Which of these three options is more equitable and required efforts more comparable?".

On the first of these points, equity, the original primary equity rule was "equal reductions". Because of the simple starting case (i.e. all countries with starting emissions of 100) it was not clear whether this was intended in percentage or absolute terms. This becomes an issue only in CP2 when the starting emissions are different. But it may be seen as more likely that it was meant in an absolute sense. Applying this interpretation for CP2 would suggest that Option 3 gives the intended outcomes for CP2.

This view might be reinforced by again considering possible cost implications. Would it be fair to Country A which probably had the highest cost to meet its commitments in CP1 to also then be set a greater absolute target than those for countries B and C, additionally in the circumstance where its ongoing abatement cost curve may again be higher than for these other two countries?

This thought experiment, of course, is abstracted from the real world, so care is needed to apply the apparent lessons to other cases, including those that have more complex "effort sharing" equity rules. But it does add an important new consideration, beyond just those around percentages, base years and costs. Namely, in the setting of targets for a next commitment period, how should you take into account the use of flexibility mechanisms by countries that have met their commitments in the previous period partially by utilising these mechanisms – which the rules encouraged them to do in the interests of achieving commitments at "least cost"? This seems an important general consideration in any debate on effort sharing and comparability.

2.3 Elaborating concepts with specific country results

2.3.1 Emissions-based metrics

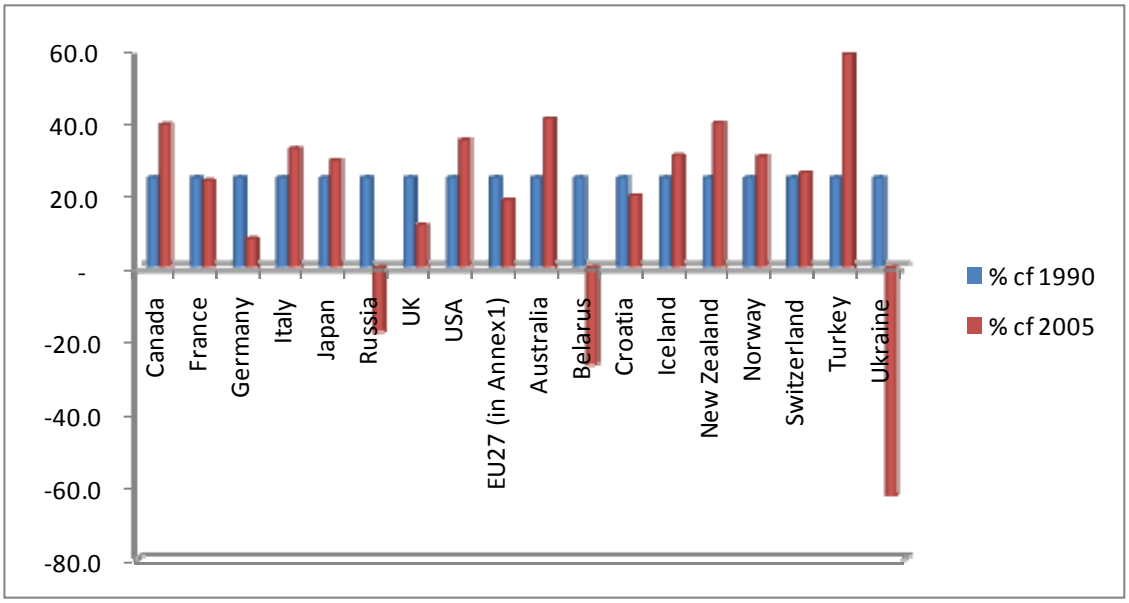
Importance of base year

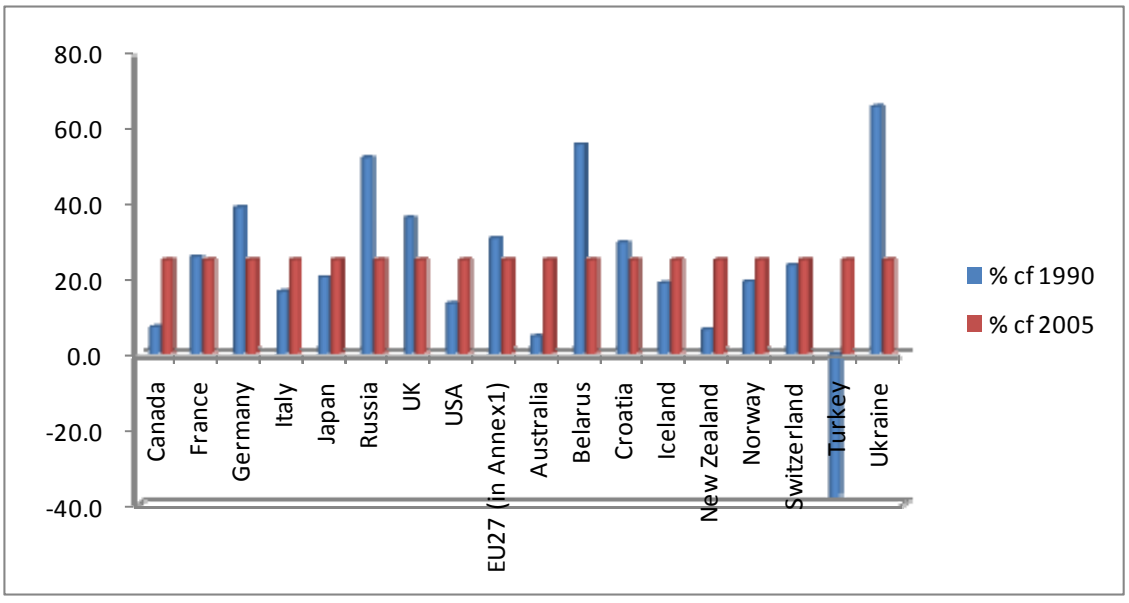
While emissions in a given year or period ultimately is the basic metric of *quantified emission limitation and reduction objectives* (QELROs), otherwise known as targets or allowed emissions, emissions in a given year

or period, by itself, is generally of limited use to draw comparisons across countries. Instead, emissions data is normally presented as changes in emissions relative to a given base year or period. The simplest version of 'comparable targets' is that at some future time emissions represent the same percent reductions compared with a given base year. Even this simple metric, however, depends critically on what base year is used.

To illustrate this point, Figures 1a and 1b demonstrate for Annex I Parties (G8 countries, aggregate EU27 member states and others) the effect of picking 1990 or 2005 as the base year. It shows how a common percentage of 25% reductions (of CO_2 equivalent greenhouse gas emissions excluding LULUCF) would change if the 'other' base year was used. In Figure 1a the 25% reduction is based from 1990 levels, in Figure 1b from 2005 levels.

Figures 1a and 1b. % Emission Reductions against Different Base Years





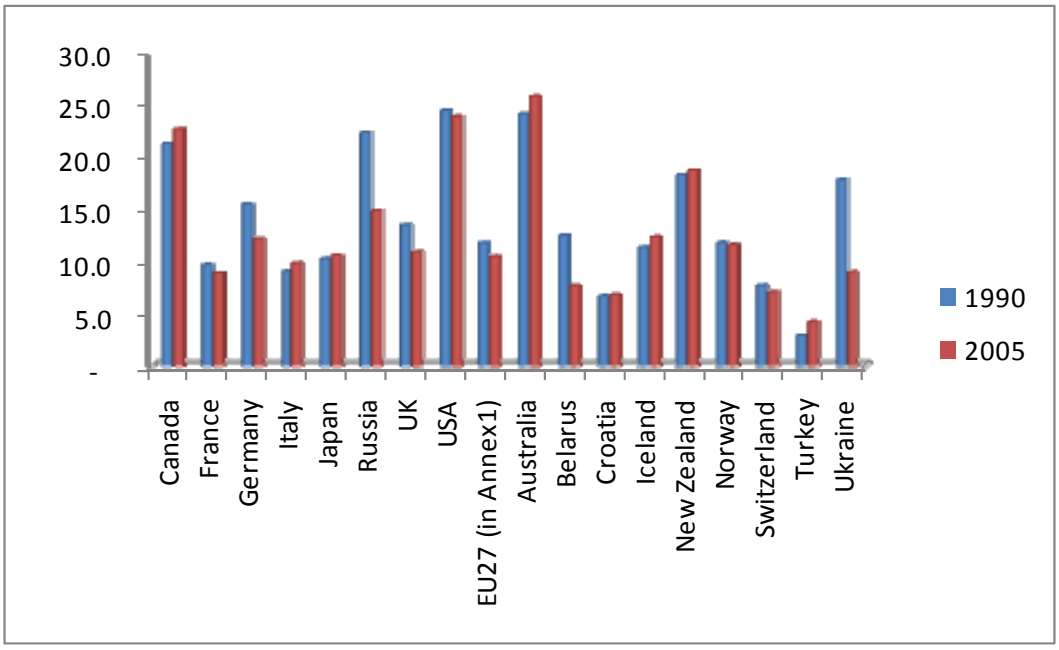
Source of emissions data (in Figures 1-4) : Developed from UNFCCC/GHG Data/Time Series-Annex 1/1990-2006

A key issue here is whether and how past emission reduction efforts are recognised in the next targets. Using a base year that is prior to such efforts will tend to mean a relative lowering of the effort needed to achieve the next target. Using a later base year means earlier reductions are not recognised and a relative increasing of the effort needed to achieve the next target.

Other circumstances matter

However, passed emission reduction efforts can also be influenced by other circumstances such as changes in population or changes in GDP. Figures 2 and 3 below compare data for emissions per capita and emissions per GDP in 1990 and 2005 for the same Annex I countries. These are examples of *hybrid metrics* involving different type data elements.

Figure 2. Emissions per capita, T CO_2e per person



Source of emissions data in Figures 1-4: Developed from UNFCCC/GHG Data/Time Series-Annex 1/1990-2006
Source of population and GDP data in Figures 2-4: IEA Statistics

Figure 3. Emissions per GDP, T CO_2e per $10000 GDP (PPP, 2000$)

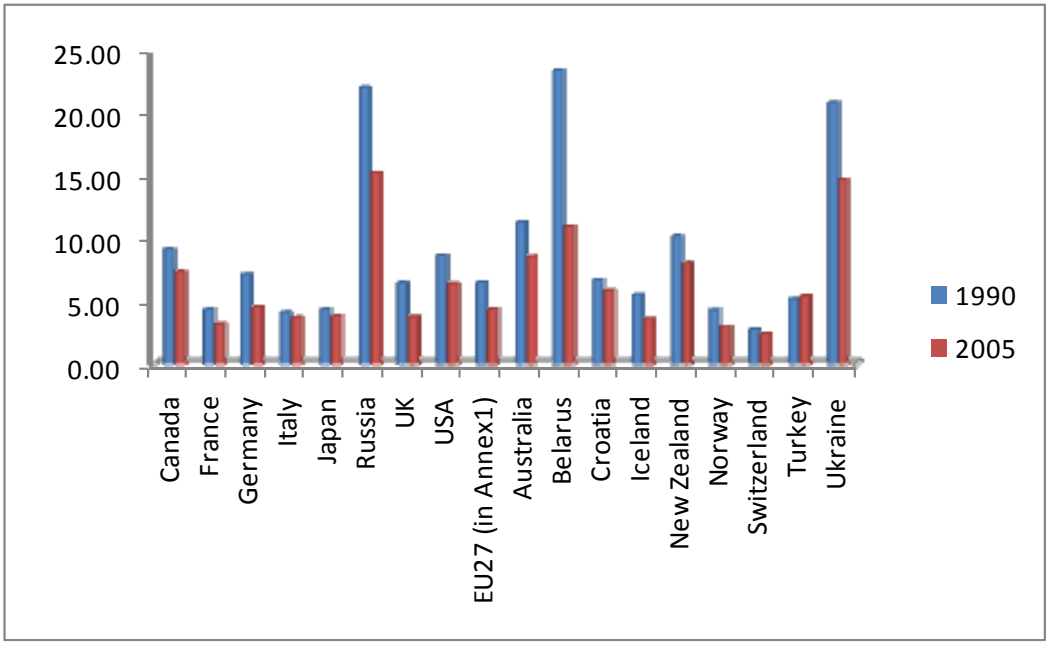
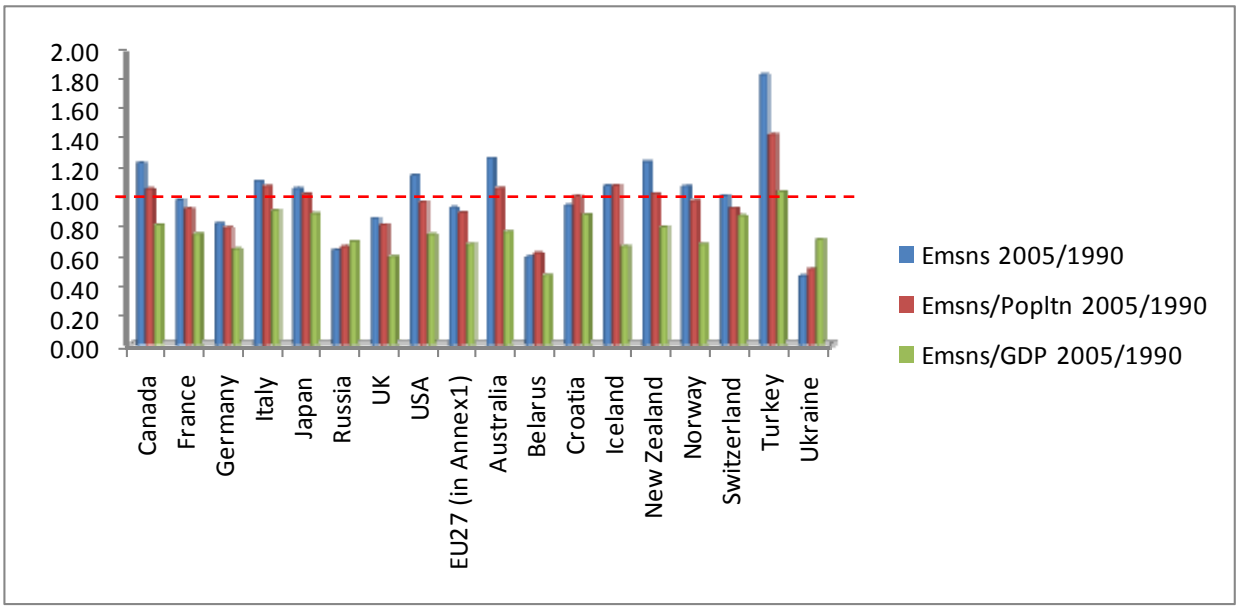


Figure 4 below presents the same data but in 'ratio' metrics, comparing the change in emissions over 1990 to 2005, and this divided by the change in population and change in GDP.

Figure 4. Ratios of change of emissions compared with changes in population and GDP



Source of emissions data (in Figures 1-4) : Developed from UNFCCC/GHG Data/Time Series-Annex 1/1990-2006

Source of population and GDP data in Figures 2-4: IEA Statistics

The presentation of data in Figure 4 helps to show the extent to which countries are decoupling changes in emissions from changes in population and changes in GDP. For example, looking at the first country Canada, its emissions grew by about 24% between 1990 and 2005 (factor 1.24). This growth in emissions was greater than its growth in population (so the factor for change in emissions divided by change in population is 1.06). But its growth in emissions was not greater than its growth in GDP (so the factor for change in emissions divided by change in GDP is 0.81). This data is supported by that in Figures 2 and 3 which show that its emissions per capita grew but its emissions per GDP fell.

While hybrid metrics can provide additional insights, they too are subject to the individual elements chosen and may neglect other important aspects of what is behind changes in emissions. For example, the favourable GDP adjusted metric for the US occurred over a period when there was a significant shift of emissions intensive production of the goods that the US consumes to developing countries such as China – so called "emissions outsourcing".

Also, as with simple 'change' metrics (meaning looking at how results change over time), hybrid change metrics can be significantly influenced by the timing of the base year from which comparisons are being made. So, for example, the ratio results in Figure 4 for countries in eastern Europe in particular would be quite different if they were instead comparing the years 2005 and 1995, given the considerable drop in their economies (and in some cases drops in population) between 1990 and 1995.

2.3.2 Mitigation cost-based metrics

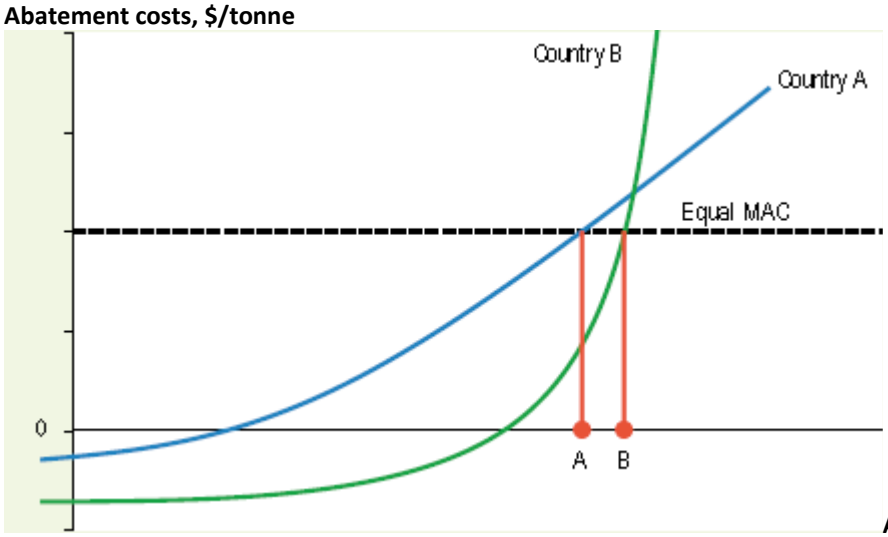
It is feasible that countries targets are based on some comparability of what their mitigation costs would be. Like emissions, costs could be normalised across developed country Parties by considering factors such as population or GDP.

Metrics involving mitigation costs require some care in their interpretation and use. By their nature, analyses of costs are not absolute, but instead involve a reference case and then look at the difference in

costs between this and with the level of mitigation action undertaken. Assumptions behind the reference case are therefore critical to any calculations.

In practice such analyses also involve the use of modelled abatement cost curves which are a measure of what mitigation is available at different abatement costs, working up from the lowest abatement costs (which can be negative). (see Figure 5 below).

Figure 5. Abatement cost curves



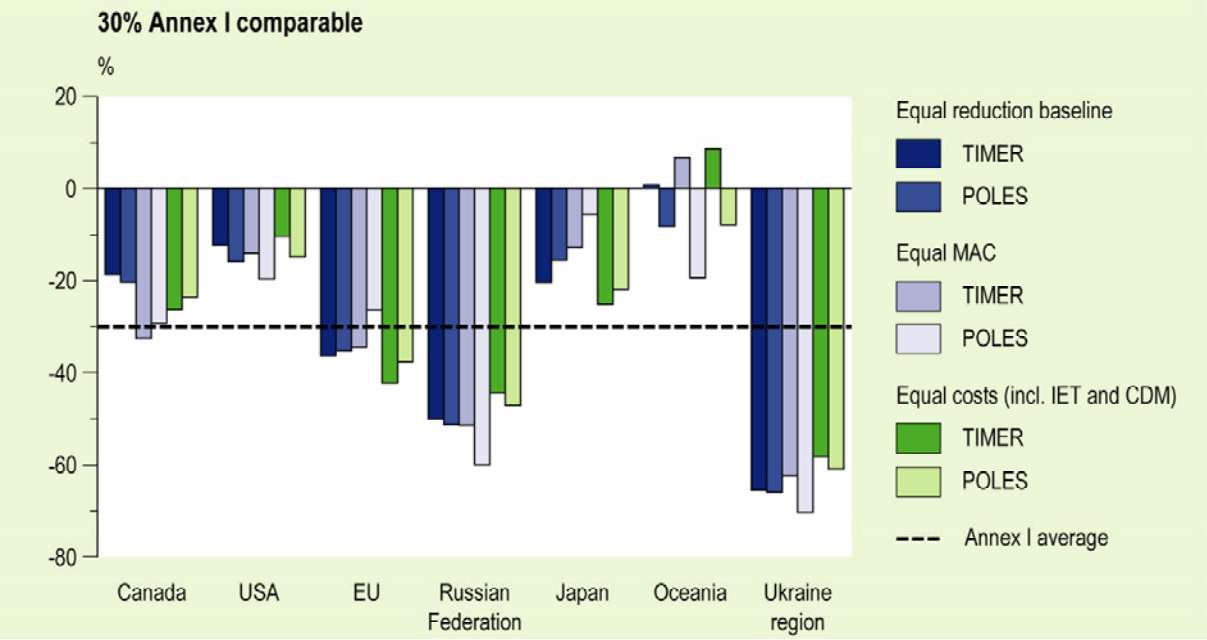
Marginal abatement costs are an estimate of the costs of the 'last' (most expensive) tonne being reduced (or sequestered) in countries to meet their commitments. In Figure 5's stylised depiction, the marginal abatement cost for Country A to achieve the level of emission reductions (denoted as point "A") is much higher than for Country B. Put another way, Country B could achieve a higher level of emission reductions (point "B") before the marginal cost is the same as Country A.

Marginal abatement costs do not provide information on the costs of all the previous tonnes of reduction. So these are quite different than average costs or estimating total costs. In Figure 5, the average and total costs incurred by Country A at the point when its marginal abatement costs are equal to those of Country B are much higher than Country B's average and total costs. This is because Country B has much greater emission reductions available at negative and low cost. Total costs are represented by the area under the graph. Country A has a large area of positive cost and just a small area of negative cost. For Country B the negative cost area is larger than the positive cost.

Another point about abatement cost curves is that bottom-up models typically only capture the direct costs of the abatement actions and do not take into account macroeconomic impacts (due to sectoral changes and trade impacts). Also, results are typically presented for a given year (i.e. the models are static in this sense).

Summarising key points, marginal abatement costs are a modelled 'construct', not something that is empirical and measurable. This then is true of projected estimates of average and total costs that are built up from modelled abatement cost curves. Modelling involves the development of both a reference case, which is bound by its assumptions as well as the development of abatement cost curves which are bound by their assumptions. In short, the results using different models can be quite different (see Figure 6 below).

Figure 6. Reduction compared to 1990 emissions in 2020 (POLES - TIMER MAC curves)



Source: den Elzen et al, *Exploring comparable post-2012 reduction efforts for Annex I countries*, Report by Netherlands Environmental Assessment Agency (December 2008)

Figure 6 looks at possible targets for an overall reduction by Annex I Parties of 30% in 2020 compared with 1990 levels based on different metrics – equal reduction baseline, equal marginal abatement costs (MAC) and equal costs (including IET and CDM) – using two different well respected Europe models (TIMER and POLES). This shows how the results can differ quite markedly, especially those for the equal MAC case. A key point for negotiations with respect to the use of any mitigation cost-based metrics is what is the source of the data (i.e. whose model), what are key assumptions used in the models and how complete is the data across all developed country Parties[10].

Marginal abatement costs are what efficient emissions trading markets are intended to discover and equalise. It is also therefore important to distinguish between costs "with and without" (or "before and after") trading. This is true of marginal, average and total costs.

2.3.3 End point metrics

Some examples of *endpoint* metrics are

- emissions per capita at a future point in time
- 'efficiency' (of given sectors), e.g. emissions per MWh or per tonne production of major energy intensive commodities

In general, endpoint metrics have the simplicity of not having a reference (i.e. as 'change' metrics do), thereby avoiding the issues that arise with references. The contribution of prior mitigation efforts towards meeting endpoints should be recognised. But endpoint metrics on their own may not fully reflect the national circumstances, e.g. access to renewable energy resources. Also, the lack of a reference means there is no detail about the mitigation path that countries may have followed or will follow.

[10] The challenges and uncertainties associated with mitigation cost model results have led some researchers to suggest that mitigation cost-based metrics score "low" on technical feasibility, so are not practical primary metrics for negotiations around "comparability".

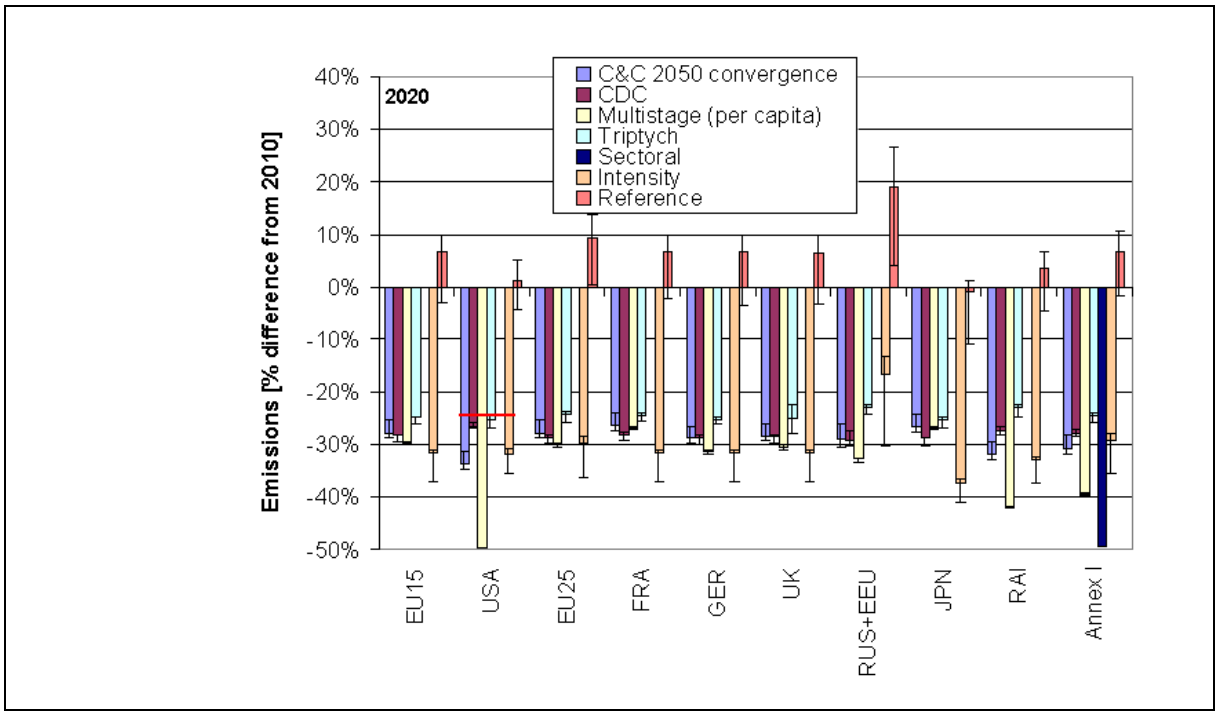
One example of a hybrid using endpoint-type metrics is referred to as the *Triptych approach*. This allocates future reductions among countries based on converging technological standards or targets at the sector level, accounting for structural differences. This approach was used successfully as a basis for negotiating the differentiation of the EU's single -8% Kyoto target at an EU15 member state level. However, it is complex and has comparatively high data requirements.

2.3.4 Target calculations based on different (and hybrid) metrics

Some analyst groups have published results of modelling exercises that take specific levels of 'ambition' in terms of emission reductions (or ppm greenhouse gas concentration 'stabilisation' outcomes) and determine the shares of allowed emissions for countries based on the priority given to different metrics. For illustration purposes, one example is the work by Ecofys using their EVOC (evolution of commitments) model. This produces results such as provided below in Figure 7 below.

The source publication would need to be reviewed to understand the substance of this particular result example. Each of the cases represented in the legend (e.g. "C&C 2050 convergence" which is the per capita emissions-based contraction and convergence case with per capita emissions converging in 2050) is based on the use of specific 'comparability metrics'. For the purposes of this discussion, the key point is that the targets of individual countries (and groupings of countries) that are suggested by such analyses can be significantly different depending on the comparability metrics selected.

Figure 7. Change in emission allowances from 2010 to 2020 under the 450 ppmv CO_2eq. scenario for Annex I



Source: Höhne et al, *Factors underpinning future action - 2007 Update*, Report for UK DEFRA (May 2007)

Further recent work by Ecofys is presented in Figures 8a and 8b. These results are calculated using hybrid metrics following recent proposals of indicators by the EU and Japan. The point of these figures is to show how the same targets (in this case adding to a reduction by Annex I countries of 30% in 2020 compared with 1990) can be expressed as comparisons with 1990 levels or some other year (in this case 2006). A key point is that the results in Figure 8b are likely to be perceived as "more comparable" than those in Figure 8a, even though the underlying targets in tonnes of allowed emissions are exactly the same.

Figure 8a. Reduction targets, 2020 compared with 1990 levels (Annex I minus 30% cf 1990)

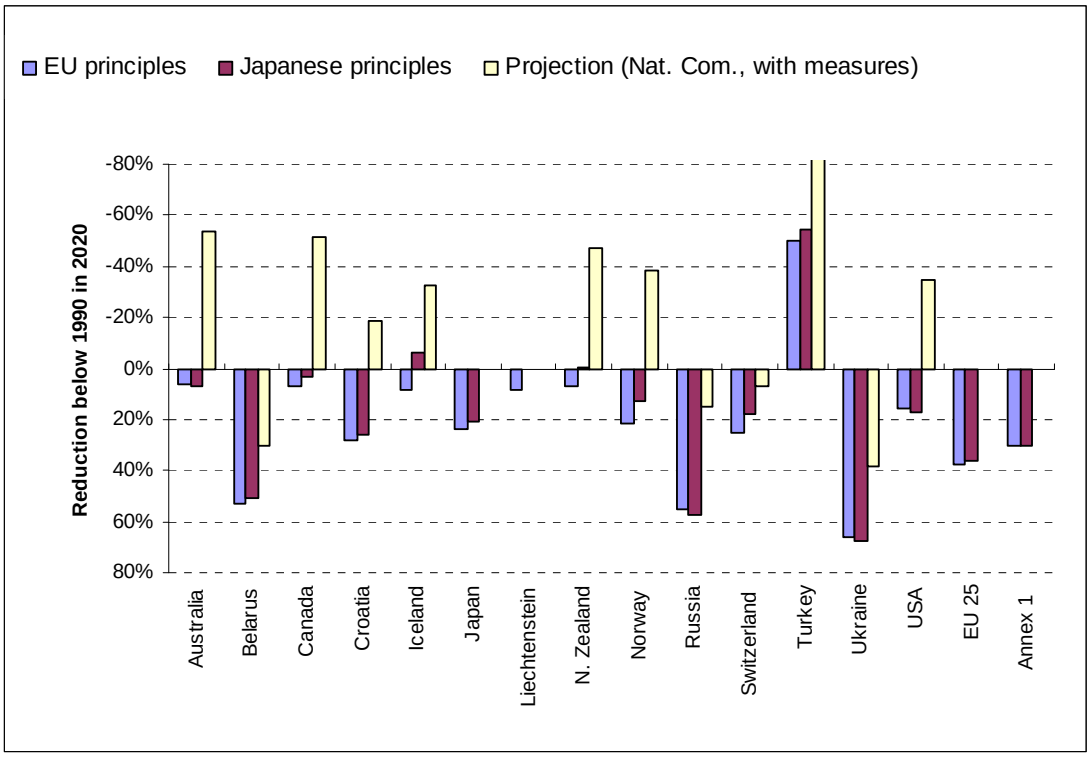
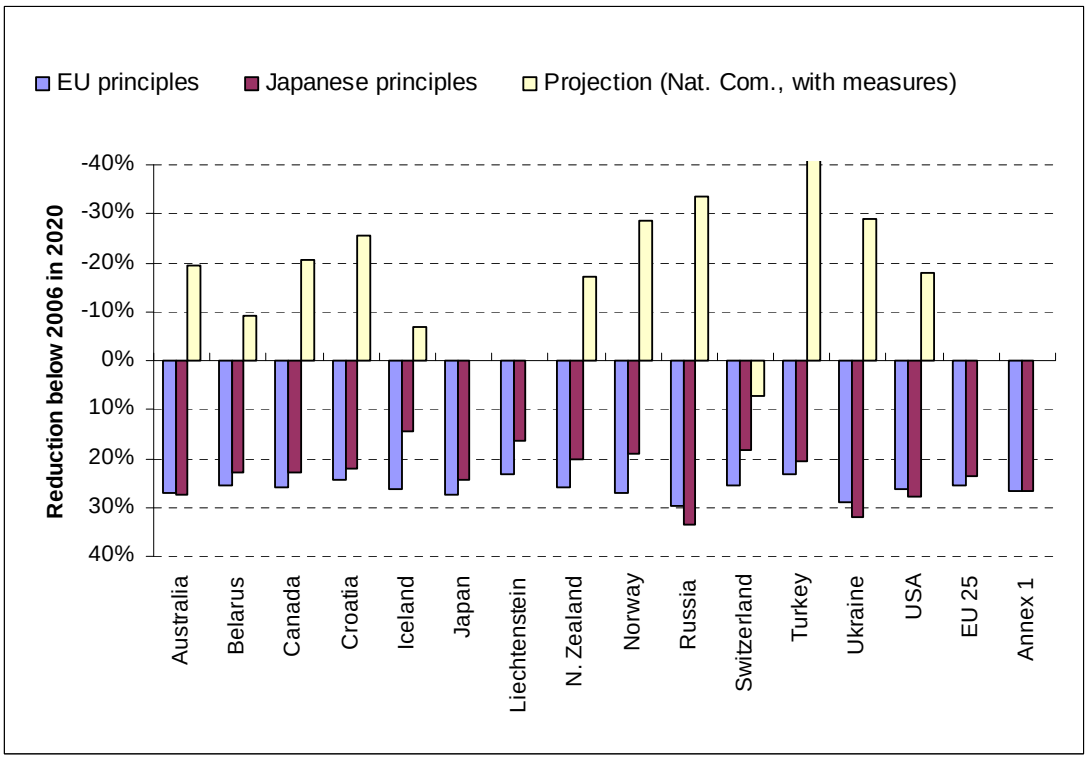


Figure 8b. Reduction targets, 2020 compared with 2006 levels (Annex I minus 30% cf 1990)



Source: Presentation by Niklas Höhne, Ecofys, at the CCAP *Future Actions Dialogue* in Wellington NZ, Feb 2009

On January 28, 2009 the European Commission (EC) released a Communication *Towards a comprehensive climate change agreement in Copenhagen.* Tables 1 and 2 are taken directly from this. The EC propose the use of four core metrics: GDP per capita, GHG emissions per GDP, GHG emission trend 1990 to 2005 and Population trend 1990 to 2005.

Table 1. Reduction targets, 2020 compared with 2005 levels, for four core metrics

	GDP/cap criterion		GHG/GDP criterion		Early action criterion		Population trends criterion	
	GDP per capita in 1000€, 2005	2020 Target compared to 2005	GHG/GDP, 2005, in kg of CO2 per US$(2000)	2020 Target compared to 2005	GHG trend 1990 to 2005 in %	2020 Target compared to 2005	Population trend 1990 to 2005 in %	2020 Target compared to 2005
EU	22.5	-25.1%	0.43	-20.1%	-8%	-22.4%	4.0%	-38.1%
USA	33.8	-45.3%	0.53	-26.8%	16%	-41.5%	17.1%	-13.1%
Japan	28.7	-37.1%	0.24	-6.1%	7%	-36.1%	3.5%	-38.4%
Canada	28.3	-36.5%	0.67	-32.5%	25%	-46.8%	16.5%	-14.4%
Australia, New Zealand	26.9	-34.2%	0.77	-36.7%	27%	-47.9%	20.3%	-6.2%
Other OECD Europe	45.7	-64.5%	0.19	-2.1%	5%	-35.1%	9.1%	-30.5%
Commonwealth of Independent States	3.6	15.5%	4.66	-46.0%	-35%	6.0%	-4.6%	-42.7%
Average Developed countries		-27.3%		-27.3%		-27.3%		-27.4%

Source: JRC, IPTS, GEM-E3

Table 1 provides results of what targets would be in 2020 compared with 2005 using each of the core metrics singly. Table 2 is an "illustrative example" of targets (shown in the final column) that are derived from a hybrid of all four metrics. This illustrative example also uses some additional factors to deal with specific circumstances of some countries.

Table 2. Reduction targets, 2020 compared with 2005, using hybrid of four core metrics

	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
	(a)	(b)	(c)	(d)	(e) = (a+b+c+d)
EU27	-10.2%	-10.1%	-5.2%	1.7%	-24%
USA	-14.3%	-12.3%	-15.9%	8.2%	-34%
Japan	-12.8%	-5.6%	-12.5%	1.7%	-29%
Canada	-12.6%	-14.6%	-19.3%	7.8%	-39%
Australia & New Zealand	-12.2%	-16.3%	-19.9%	10.0%	-38%
Other OECD Europe	-17.9%	-4.4%	-11.9%	3.7%	-30%
Commonwealth of Independent States	-1.0%	-20.0%	8.0%	0.6%	-12%
Average developed countries	-10.5%	-12.8%	-8.5%	4.5%	-27%

One noteworthy point, given the earlier discussion about mitigation cost-based metrics, is that none of the core metrics proposed by the EC involves mitigation costs. However, an analysis is done (and provided in the Communication) of the estimated macroeconomic costs for these countries and country groups to meet these targets. In this way, costs are part of a comparability assessment even though they have not been used directly as metrics in the derivation of the targets.

Another key point is that the EC approach uses economy wide data. The use of sectoral level data that may present specific (and critical) national circumstances seems to not be contemplated. This can be expected to be a key concern for New Zealand (and as well the lumping in of New Zealand with Australia.)

2.4 Metrics for "other commitments and actions"

Most discussion thus far in the post-2012 literature related to metrics has been about the differentiation of countries' emission reduction targets within some overall emissions reduction task for developed countries. This raises the question about "commitments or actions" other than targets.

First this depends on the nature of such other commitments and actions. For *commitments* such as participating in technology agreements in the electricity generation or auto manufacturing sectors, relevant metrics may be some performance measure, e.g. CO_2 per MWh or CO_2 per 100km. Alternatively (or additionally) they may be 'dollars' contributed to the commercialisation of key technologies (like CCS, advanced renewables, and electric cars, for example).

A key issue will likely be how to compare targets with 'lesser' targets plus financial (or other, e.g. technology) contributions. It is feasible that these could be compared on the basis of some equivalence of costs or projected emissions outcomes. Again, these could be normalised across developed country Parties by considering factors such as population or GDP.

3 METRICS AND THE NEGOTIATING TASK – A PROCESS ISSUE

Which metrics are ultimately used by negotiators to compare the efforts of developed country Parties and set targets may be influenced by, and emerge from, the negotiation process selected. In particular, there is the issue of whether some aggregate emissions reduction task for developed countries is agreed first, thereby setting the envelope (or budget or cap) of allowed emissions over some specified period of time.

The use of metrics would then be to assist negotiators to agree countries' shares of this amount of emissions, including in the light of other "commitments or actions" the countries are making, such that their mitigation efforts are considered to be *comparable*. Note, however, that with respect to the envelope of emissions, when one country gets more, other countries would get commensurately less.

These shares of the overall effort will largely be determined by the choice of 'equalising' metrics. The metrics will therefore be in the background of the 'efforts sharing' analysis as the results will be expressed in emissions (or emissions reduction percentages), not in the values of the metrics, per se.

An alternative process approach to negotiations is that developed countries might present proposals of what emission reductions and other "commitments or actions" they can contribute to the overall effort – a sort of *offerings basket* as it were. They may also propose what they would expect of others[11]. In making these proposals, countries would identify why they consider these to be reasonable and fair, including the metrics they deem useful to make their case.

The negotiation process would then weigh up the 'baskets' in the light of the circumstances of the countries offering them, and in the light of what the proposed emission reductions (hence allowed emissions) add up to. In the situation where the sum of the emission reduction proposals falls short of what is considered as necessary to address the risks of global climate change, negotiations could focus on 'sharpening' up the proposals that are most material to getting to an acceptable outcome.

In terms of the use of metrics, the process of this approach would reveal which are the critical ones to focus on, rather than require a selection of key metrics from the outset. An 'emissions envelope' is important to both approaches, but plays a more overt role upfront in the first of these, and a more 'back calculation' role, following the tabling of initial offerings, in the second.

A third approach may be a Chair's proposal of proposed targets, followed by negotiations around this. The metrics behind this would need to be transparent.[12]

[11] The "illustrative" proposal in the recent Communication by the European Commission might be seen in this light.

[12] Arguably, this has been the model thus far, e.g. by AGBM Chair Estrada in Kyoto, by the Dutch EU Presidency for the EU "burden sharing" for the first Kyoto period using the Triptych approach and, most recently by the EU Commission in the EU energy and climate package (which used *GDP/capita* as the central metric for emissions in sectors not covered by the EU ETS).