THE SCIENTIFIC CASE FOR SETTING A LONG-TERM EMISSION REDUCTION TARGET

Introduction

1. This paper sets out the scientific background against which a decision on setting now a long-term emission reduction target will need to be taken. It focuses on 2050. It considers the likely course of emissions over the next 100 years and the constraints on global emissions if the world is to meet a particular target for stabilising atmospheric carbon dioxide (CO2) concentrations, noting that such a target would not be reached until well into the next century and possibly even beyond.

Background

2. The 1992 United Nations Framework Convention on Climate Change provides the framework for international action to tackle climate change. Its ultimate objective is "to achieve … stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a timeframe sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."

3. The 1997 Kyoto Protocol establishes a legal framework for delivering reductions in emissions of carbon dioxide and other greenhouse gases that cause climate change. The Protocol is expected to lead to small but real reductions in emissions from developed countries. But it is only the start of what will have to be a long-term process.

4. The Inter-governmental Panel on Climate Change (IPCC) Second Assessment Report confirmed that it will be necessary to stabilise greenhouse gas concentrations if dangerous climate change is to be avoided.

Paper context

5. Due to the current political and scientific uncertainties in this area it is not possible to determine an exact "right answer" to the question of what our emission reductions should be in the next 50 to 100 years. Therefore this paper needs to be seen as a risk assessment. The dominating factor in this assessment of risk is the fact that once a particular atmospheric concentration has been reached or will be reached, either by accident or design, there is no practical option to reduce it. On the timescale of the next few 100s of years atmospheric concentration of CO_2 can only increase. Therefore recommendations for future cuts made here are mindful of the fact that we need to be in a position in the future to be able to respond to a "worst case" scenario.

Stabilisation at what level?

6. Ideally, the first step on the path to setting a long-term emission reduction target is to consider the level at which the carbon dioxide concentration in the atmosphere should be stabilised. However, there is as yet no consensus as to what constitutes dangerous climate change or at what level greenhouse gas concentrations should be stabilised and this will be a politically contentious discussion. The IPCC Third Assessment Report (TAR), published in 2001, considers that "the basis for

determining what constitutes 'dangerous anthropogenic interference' will vary among regions – depending both on the local nature and consequences of climate change impacts, and also on the adaptive capacity available to cope with climate change." Even though a stabilisation level cannot be determined explicitly at this stage, to maintain a fixed concentration of CO_2 in the atmosphere at any level, global emissions will have to drop significantly so the issue becomes **when** a given level of cuts should take place.

7. For stabilisation to occur global emissions will have to equal natural uptake, and so reductions will have to be substantial in total and will eventually have to drop well below current levels, to approximately 1/10 of what they are now globally. Therefore, it will be impossible to stabilise concentrations unless all countries, including developing countries, eventually take on action to reduce or limit emissions as appropriate. Although all current IPCC stabilisation scenarios reach stabilisation well into next century it is important to note that the emissions in the next 50 years will significantly constrain what stabilisation levels will be possible due to the long atmospheric residence time of CO_2. Current atmospheric CO_2 concentration is 371ppm rising at 1-2ppm/year, thus at current rates we will reach ~450ppm in the next 50 years. However, global emissions are projected to rise more rapidly if no additional international restrictions are agreed, bringing forward the date for reaching 450ppm. IPCC notes that to stabilise at 450ppm requires emissions to peak and begin to fall in the next 10-30 years.

8. There is substantial uncertainty in the temperature increase for a given level of atmospheric CO_2 leading to considerable uncertainty in the resulting impacts. For example, with an atmospheric CO_2 stabilisation concentration of 550ppm, temperatures are expected to rise by between 2°C and 5°C. Table 1 below gives the predicted impacts for the range of temperature increase at which the climate will stabilise for selected atmospheric CO_2 stabilisation levels.

Table 1 Impacts for atmospheric CO_2 stabilisation levels for upper and lower bounds of possible temperature change

CO_2 conc (ppm)	Impacts for bottom of temperature range	Impacts for top of temperature range
450	Global mean temperature rise of 1.5 °C, some risk to unique and threatened systems (ecosystems and societal), some increase in climatic extreme events, negative impacts for some regions, positive and negative market impacts, the majority of people adversely affected, unknown but probably low risk of large scale high impact events. (e.g. major	Global mean temperature rise of 4.0 °C, significant risk to many unique and threatened systems (ecosystems and societal), a large increase in climatic extreme events, negative impacts for most regions, negative impacts in all sectors, including agriculture, the majority of people adversely affected, probable medium risk of large scale high impact

	instability of ice sheets/ocean circulation changes)	events. For example Amazon rainforest threatened and it is likely that the Greenland ice sheet will begin to melt.
550	Global mean temperature rise of 2.0 °C, greater risk to unique and threatened systems (ecosystems and societal), a some increase in climatic extreme events, negative impacts for some regions, positive and negative market impacts, the majority of people adversely affected, unknown but probably low risk of large scale high impact events. (e.g. major instability of ice sheets/ocean circulation changes).	Global mean temperature rise of 5.0 °C, severe impacts for unique and threatened systems, great increase in climatic extreme events, all sectors showing severe impacts and most people adversely affected, high risk of large scale high impact events. (e.g. major instability of ice sheets/ocean circulation changes)
750	Global mean temperature rise of 3 °C, moderate risk to a number of unique and threatened systems (ecosystems and societal), probable moderate increase in climatic extreme events, approximately even balance between regions experiencing negative impacts and those that do not, positive and negative market impacts, the majority of people adversely affected, unknown but probably moderate risk of large scale high impact events. (e.g. major instability of ice sheets/ocean circulation changes).	Global mean temperature rise of 7 °C. Extreme adverse impacts in all measures.

9. The European Union has indicated that a level lower than 550 parts per million (ppm) of carbon dioxide, which is about twice the pre-industrial concentration, should guide global limitation and reduction efforts.

10. The Royal Commission on Environmental Pollution have also recommended that, on the basis of current scientific knowledge about human impact on climate, an atmospheric concentration of 550ppm of carbon dioxide should be regarded as an upper limit that should not be exceeded.

11. For the UK Government to announce or imply that it was aiming for a stabilisation level higher than 550ppm at this stage would certainly attract widespread criticism from environmental interests and EU and developing country governments.

Global emissions

11. The IPCC has developed a number of future emission scenarios based on a variety of assumptions about population growth, economic growth, societal changes and energy futures. The projected atmospheric CO_2 concentration for six representative "marker" scenarios are shown in figure 1 below. For each scenario CO_2 concentrations are set to rise. Currently emissions from developed countries (Annex 1) exceed those from developing countries (Non-Annex 1). However, developing countries emissions are projected to become a significant proportion of the total rise, and in many cases the dominating factor as illustrated by the scenario in figure 2. Without action by developing countries to control their emissions, stabilisation will be impossible. An example pathway to achieving stabilisation at 550ppm is included. It shows how quickly global emissions levels need to peak (i.e. between 2020 and 2030) and start to fall. Eventually emission levels will need to fall to near zero.

Projected atmospheric CO_2 concentration for different IPCC SRES emission scenarios

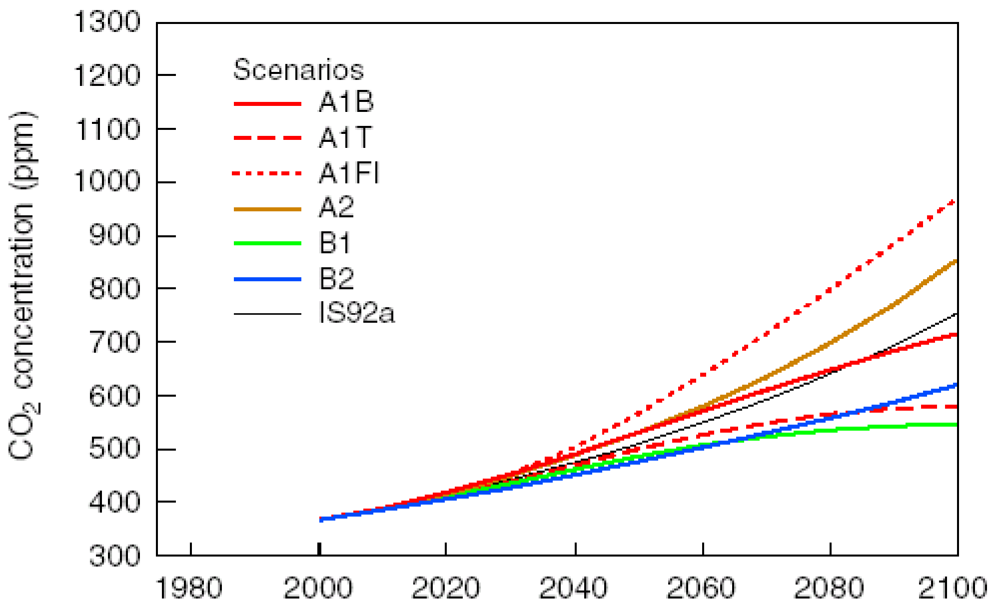


Figure 1: SRES emission scenarios assumed a variety of future populations, economic scenarios, societal changes and a range of energy futures. A1FI assumes large economic growth with energy being produces principally from fossil fuels. A1T assumes the same economic growth but with energy being provided by new (yet to be discovered) non-CO_2 emitting technology. B1 has an economy dominated by service and information industries with substantial changes towards sustainability. B2 has more moderate economic growth but with a high emphasis on sustainability and equity.

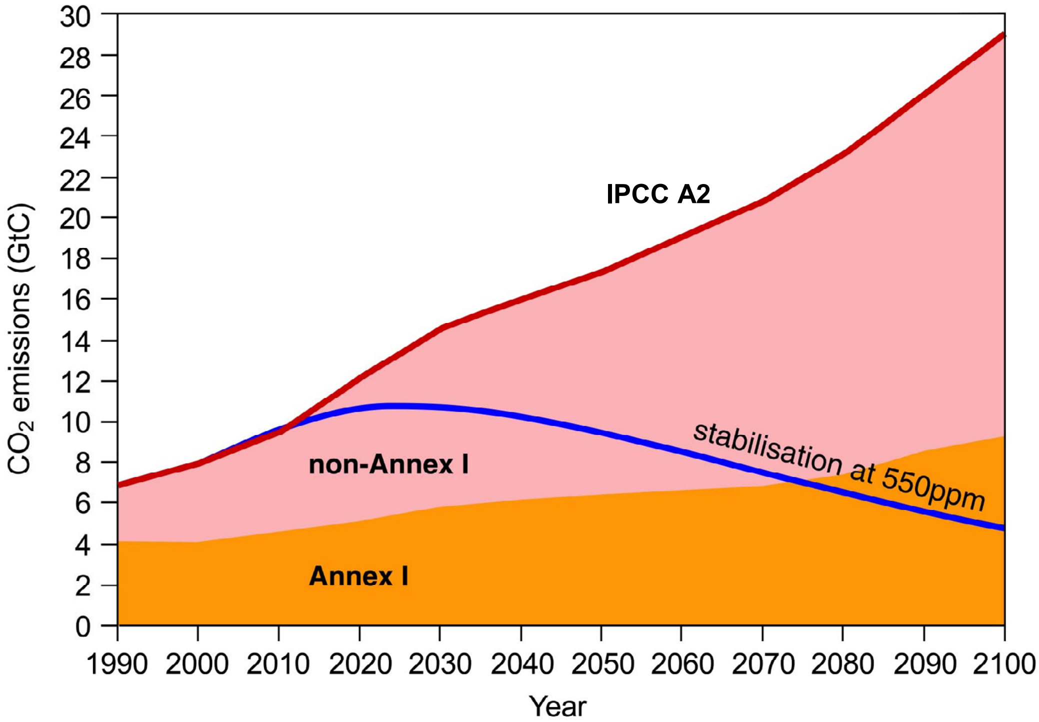


Figure 2: Projected global emissions under one business as usual scenario and a possible pathway to stabilisation at 550ppm

Burden sharing

12. If stabilisation is to be achieved, some form of burden sharing will need to be agreed about the respective contribution of Annex 1 and Non-Annex 1 countries. There is as yet no consensus about how this should be achieved. In addition, uncertainties in baseline carbon emission growth and carbon uptake by natural systems (oceans, forests, soil etc.) makes the division of commitments between Annex 1 and Non-Annex 1 parties difficult. However it is possible to assess limits or boundaries for the natural system which can then guide decision making.

13. For a given stabilisation level and assuming Annex 1 countries will continue to lead in taking emission cuts, it is possible to determine the latest date that Non-Annex 1 countries would need to take on emission reductions for the range of natural carbon uptake allowed by current scientific understanding and likely future growth in emissions. This allows, by taking into account the expected timescale in which Non-Annex 1 countries may take up emission reduction commitments, an assessment of Annex 1 reductions which are consistent with the stabilisation target. This can then guide and inform decisions on what UK reductions should be.

14. Table 2 below shows the latest date Non-Annex 1 parties can begin to make emission reductions. It assumes a stabilisation target of **550ppm** and that Annex 1 reductions have started in 2000, continue to decline steadily to either 40, 60 or 80% of 2000 levels by 2050 and then decline at a slower rate out to 2150 where they reach a level which is consistent with the carbon uptake of the natural system. Non-Annex 1

emission reductions follow a similar pattern, starting from the date on the table, reducing to 2100, and followed by a slower reduction to 2150. Two different levels of natural carbon uptake which span the current range in uncertainty are assessed as are high and low emission growth projections. Both of these have large uncertainty associated with them. For the natural carbon uptake this is due to positive feedback mechanisms which for larger temperature increases severely reduce the amount the carbon the natural biosphere can absorb potentially turning the terrestrial carbon sink into a source of CO_2. The wide range in carbon emission scenarios represents the span of possible futures that have been deemed possible by the IPCC.

Table 2. Latest date by which Non-Annex 1 parties are required to control emissions for stabilising at 550ppm.

ANNEX 1 CUTS BY 2050 RELATIVE TO 2000	HIGH GROWTH EMISSIONS FOR NON-ANNEX1	LOW GROWTH EMISSIONS FOR NON-ANNEX1
40%		
High natural carbon uptake	2030	2100
Low natural carbon uptake	2000 – 2010	2010 – 2060
60%		
High natural carbon uptake	2030	2100
Low natural carbon uptake	2010 – 2020	2040 – 2060
80%		
High natural carbon uptake	2030	2100
Low natural carbon uptake	2020 - 2030	2040 - 2070

15. The table shows that there is a considerable range of possible outcomes. For the high natural carbon uptake scenarios, the start date for Non-Annex 1 countries appears mostly independent of Annex 1 reductions wherever they fall in the range 40 or 80 %. For the high emission growth scenarios this is due to the Non-Annex 1 emissions growing so rapidly and their total emissions out to 2150 being so much larger than Annex 1 that different Annex one emission reductions have little effect. However, it is clear that under this scenario there is an even greater need to show Non-Annex 1 countries the need for large emission cuts and leading by example. For the low emission growth scenario, it is so low that the major factor is the imposed requirement for Non-Annex 1 emissions to reach levels where global emissions equal natural uptake by 2150 in a gradual way. In fact Non-Annex 1 emissions could grow beyond 2100 and still allow stabilisation at 550ppm but would require unrealistically rapid drop in emissions to the level needed at 2150 for sustained stabilisation. This could be used to argue for smaller cuts in the short term, however, as mentioned elsewhere, should Non-Annex 1 actual emissions undergo large growth we may not be in a position to accommodate this and the lower stabilisation targets will be irrevocably missed. Current assessments of developing country economies (in particular India and China) indicate that large growth in Non-Annex 1 emission at this point seems more likely.

16. Given that Non-Annex 1 countries will not commit to emission reductions prior to 2010 and most probably not until considerably later, and the irreversible

nature of atmospheric carbon increase, a precautionary approach would suggests that a 60% cut by Annex 1 parties is not an unreasonable target.

17.	An illustration of the method used to calculate the dates in Table 2 is given in figure 3 where an emission scenario which allows stabilisation at 550ppm if Non-Annex 1 parties start emission reductions in 2030. The IPCC stabilisation emission scenario "WRE550" is included for comparison. This scenario only provides global emissions and has fairly gradual rate of emission reductions well out to 2200 and beyond. Here we have attempted to divide global emissions into Annex 1 and Non-Annex 1 emissions in addition to increasing the rate of emission reductions. This is necessary as current best guesses of emission growth in the near future are rising rapidly above the WRE550 values.

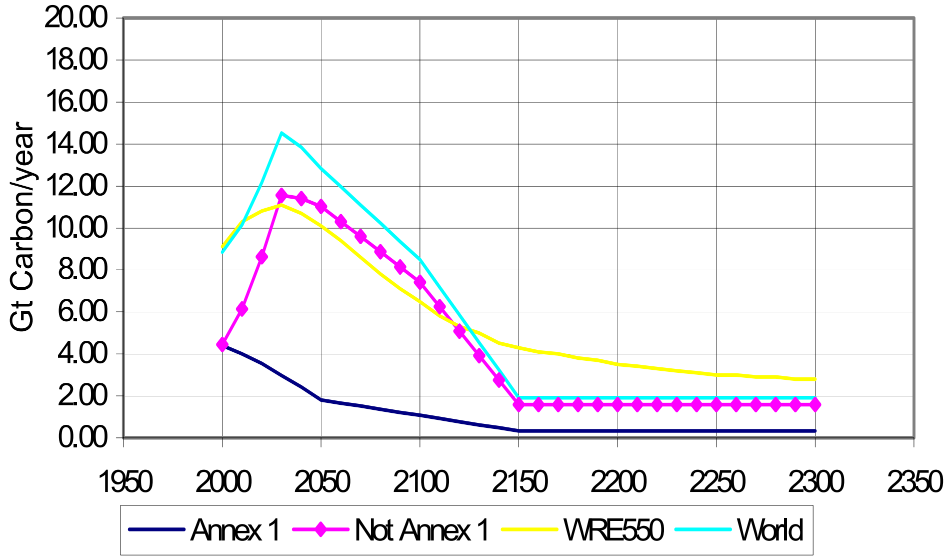


Figure 3: Emissions to achieve 550ppm stabilisation with Non-Annex 1 parties starting emission reductions from 2030. High carbon emission growth is assumed for 2000 to 2030 as is high natural carbon uptake. Total world emissions and WRE550 stabilisation profile are included for comparison

UK Emissions

18.	The Royal Commission argue that if 550 ppm is selected as the upper limit, on the basis of a simple and equal worldwide emissions per capita basis, UK carbon dioxide emissions would have to be reduced by almost 60% from their current level by mid-century.

This is consistent with an analysis of Figure 3, with all Annex 1 parties making equal percentage emissions reductions, these would be, relative to 1990:

2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
5%	13%	23%	36%	48%	61%	64%	67%	71%	74%	77%

It should be noted that it is not necessary for the reductions to be linear with time as the crucial factor is the cumulative emissions. Therefore more modest reductions earlier in the period are acceptable if compensating greater reductions are made later.

However, as can be seen from figure 3, the flexibility available for Annex 1 emission reductions is quite limited.

Conclusion

19. To stabilise atmospheric concentrations of CO_2, global emissions will have to drop to a small fraction of what they are now and UK emissions will need to be only a few percent of 1990 values. A 60% reduction in UK emission by 2050, as suggested by the Royal Commission is a realistic target given –

- that emissions will eventually need to fall well below the 60% level if carbon dioxide concentrations in the atmosphere are to be stabilised at a level which avoids the most severe impacts of climate change,
- that there is likely to be a considerable delay before non-Annex 1 countries begin the process of reducing their emissions,
- the total amount of emitted CO_2 allowable to reach the lower stabilisation levels of atmospheric CO_2.

20. However, it is clear that should the sensitivity of the climate system to CO_2 be at the higher end of the current range of estimates, greater reductions than 60% by 2050 will be needed if the more severe impacts are to be avoided.

Background and details of this analysis can be found in Annex 1.

ANNEX 1

Constraints on global emissions to reach 550 ppm stability

Summary
The objective of this study is to explore how RCEP type cuts for Annex 1 parties (A1) influence the date when Non-Annex 1 parties (NA1) need to undertake cuts whilst still being able to stabilise at 550 ppm.

The two dominating uncertainties for achieving a chosen stabilisation level in this study are a) the level of carbon uptake (or release) by the natural system and b) the economic / carbon emission growth before Non-Annex 1 emissions are controlled. The greater the difference between uptake and emissions the sooner Non-Annex 1 controls are required. Uncertainty in the background ocean uptake rate over the next 100+ years also increases the uncertainty in these dates.

The following table gives guidance as to the **latest** date which Non-Annex 1 emission controls need to come into effect and still maintain a realistic possibility of stabilising at 550 ppm CO_2. Where two dates are given, the first corresponds to emissions reaching a level consistent with high long term oceanic carbon uptake (2 GtC/year) and the second to low (1 GtC/year). The numerous other assumptions are also discussed.

Table 1. Date by which Non-Annex 1 parties are required to control emissions

Annex 1 40% cut by 2050	High growth emissions	Low growth emissions
High natural sink uptake	2030	2100
Low natural sink uptake	2000 – 2010	2010 – 2060

Annex 1 60% cut by 2050	High growth emissions	Low growth emissions
High natural sink uptake	2030	2100
Low natural sink uptake	2010 – 2020	2040 – 2060

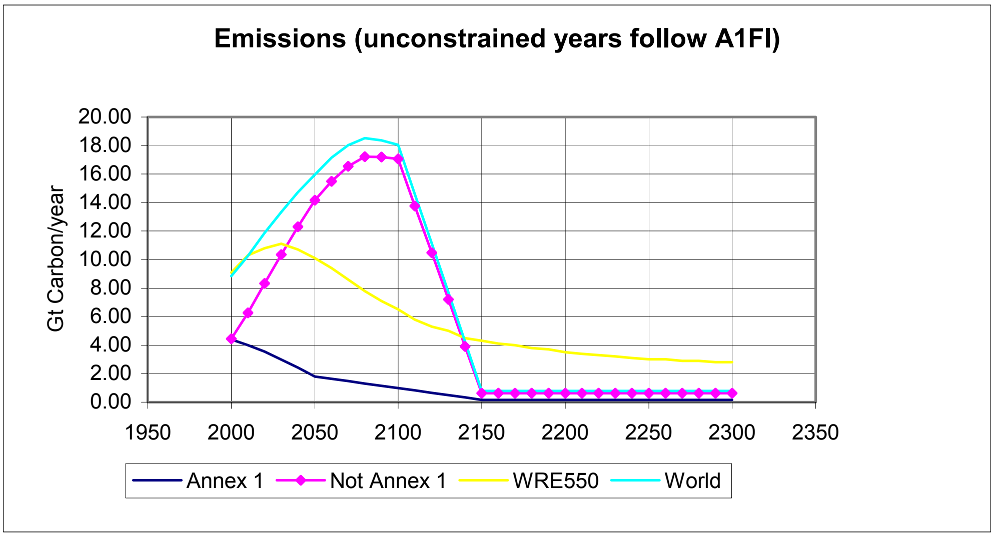
Annex 1 80% cut by 2050	High growth emissions	Low growth emissions
High natural sink uptake	2030	2100
Low natural sink uptake	2020 - 2030	2040 - 2070

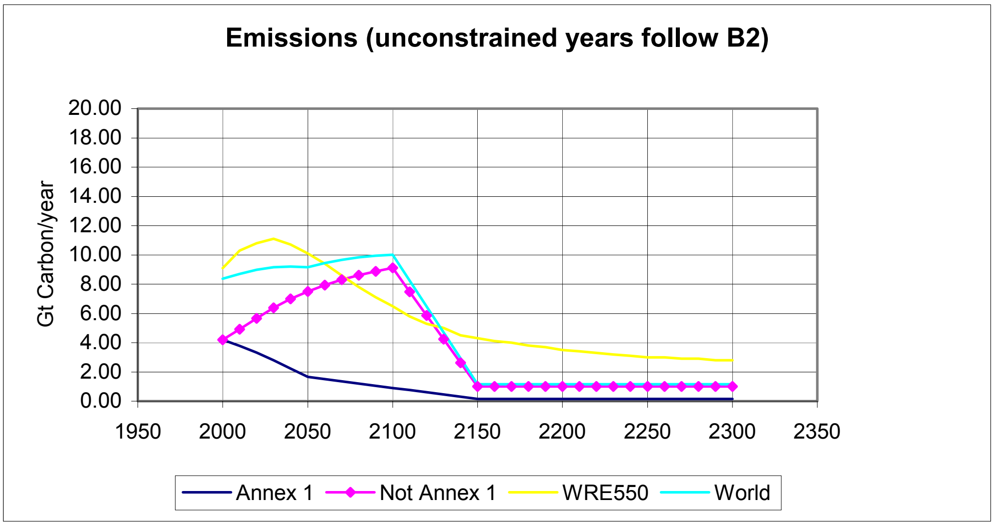
Annex 1 cuts follow a RCEP pattern, linear to specified 2050 value in the table and then linear down to 2150 target which varies from 92 to 96% cut from 2000 values.

Main issues/results

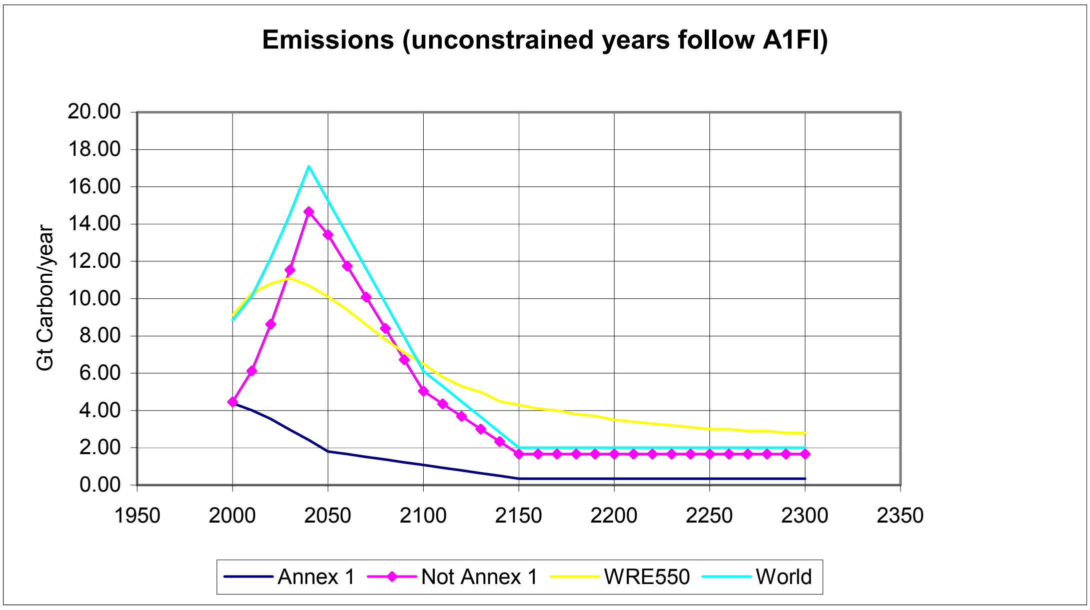
1. The range in estimates of emission growth for NA1 is very large; between 7 and 17 GtC/year at 2050. This is the dominant source of uncertainty. It should be noted that while A1FI allows market forces to run free, B2 incorporates considerable sustainable development constraints and should therefore not be considered as following a free market and achieving such restraint will have its own difficulties.

2. There is 50% uncertainty in the cumulative emissions permissible, between 1150 and 1760 GtC out to 2300. This is due to the potential of climate change to reduce the level of carbon uptake by natural sinks. Carbon release by the natural sinks is also a possibility.
3. At stabilisation, emissions must equal natural carbon uptake and ranges between 1-2 GtC/year. This uncertainty only has an impact on NA1 start date when low sink uptake is considered, as the smaller the total, the greater the impact of smaller contributions.
4. The two figures below show unconstrained high and low NA1 emission scenarios up to 2100 illustrating the large divergence in the next 50 years. The second figure is consistent with stabilisation at 550 ppm if high sink uptake is assumed but not otherwise. WRE 550 ppm stabilisation is included for comparison together with global emissions.

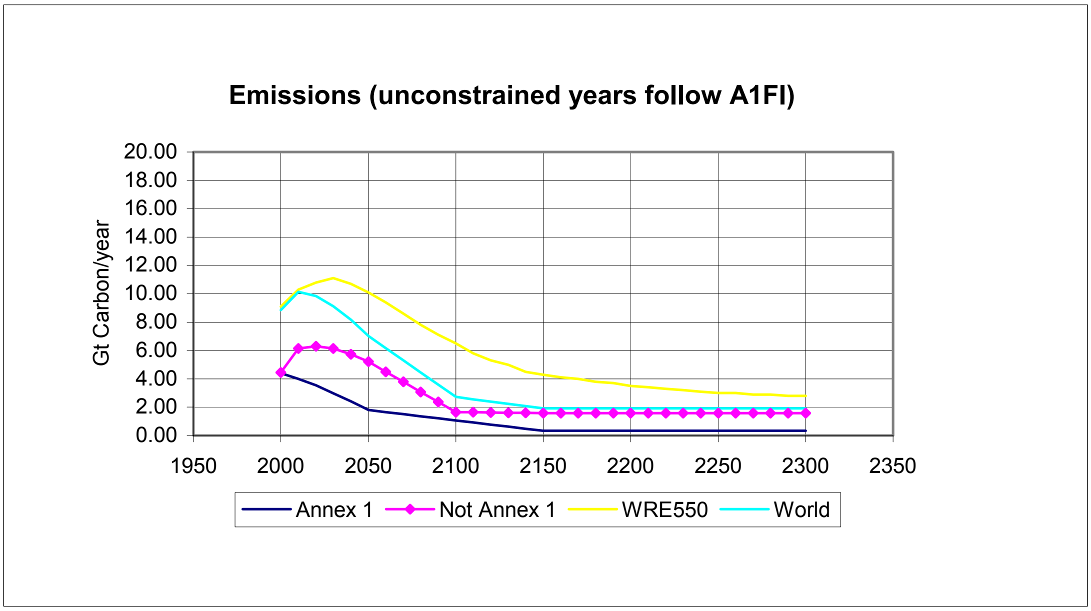




5. The following figure illustrates a particular combination of parameters. As per RCEP, A1 emissions reductions start at 2000, a 60% cut to 1.8 GtC/year by 2050 (1.2 tC/person/year), and a 2150 target of 0.3 GtC/year (0.2 tC/person/year). High economic growth and high sink uptake are assumed. NA1 emission reductions delayed until 2040 results in the rapid growth of NA1 emissions up to this date, peaking at 14.7 GtC/year requiring an equally rapid decline afterwards to 5 GtC/year by 2100 (0.7 tC/person/year) and a continued decline to 1.7 GtC/year by 2150 (0.2 tC/person/year). Such extreme growth/reduction paths were rejected as impossible practically.



6. The following figure illustrates the worst case scenario for 60% cuts for A1 by 2050 (as per RCEP) with low sink uptake and high economic growth. WRE 550 assumes high sink uptake and shows higher emissions than the world emissions (light blue). This necessitates NA1 emission control to start by 2010.



7. The table below shows the corresponding emission reductions for the UK in MtC (and corresponding NA1 percentage reductions) for the RCEP type recommendations – reductions starting 2000, 60% reduction by 2050, emissions at 2150 consistent with background ocean uptake over the next few centuries of 2 GtC.

2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
152	138	122	103	84	62	57	52	47	42	37
5%	13%	23%	36%	48%	61%	64%	67%	71%	74%	77%
	2110	2120	2130	2140	2150	2160	2170	2180	2190	2200
	32	27	22	17	11	11	11	11	11	11
	80%	83%	86%	90%	93%	93%	93%	93%	93%	93%

Limitations

1. This approach assumes that there is no environmental impact by the rate of emissions. There is some evidence that rapid increases in atmospheric concentration of CO_2 is more environmentally detrimental than a gradual increase to the same stabilisation level.
2. The "burn now, pay later" is a high risk approach as it relies on future administrations implementing cuts. It also removes the option in the future to attempt a lower stabilisation level. This approach is also difficult to implement as it requires the decommissioning of carbon infrastructure soon after it has been installed. So encouraging NA1 to develop high carbon dependant economies on the assumption they will be willing to transfer across to non-carbon technologies could be naive.
3. The large range of dates in the table 1 could be used to argue for a "wait and see" approach. This can be countered with the argument that, should it transpire that we need a higher level of cuts, say due to lower sink uptake, we will not have the option to do so. We cannot un-emit what we have emitted.
4. Annex 1 countries which currently have no intentions to reduce emissions complicates the issue but does not undermine the conclusions. Conceptually such countries can be included into the non-Annex 1 states bumping up their emissions. The result of this is that the dates for emission cuts are rather optimistic and should therefore be sooner if such countries continue not to curb their emissions.
5. Across the board reductions of 60% for Annex 1 should be considered as an average for the group. If this is seen as too ambitious then a smaller average cut would result in lower and or earlier targets for NA1.
6. These curves do not take into account feasibility, practicality or economics. For example it is possible to delay NA1 action with high economic growth but this results in very steep increases in emission to be followed immediately by steep cuts which economically is nonsense. Such cases are deemed impossible and excluded.
7. The study only looks at 550 ppm but can easily be extended to cover any other level. Lower levels, say 450 ppm, may be useful in showing that under certain

condition like high emission growth and low sink uptake we have missed the boat already.

Methodology

The framework of this study builds on the RCEP work which uses a convergence and contraction methodology. Whilst prescribed per capita emissions are retained, the flexibility is such that these are only a tool to constrain total emissions and this should not be considered a typical contraction and convergence (C&C)[1] approach (although any mechanism which brings all emissions to a level lower than today's will have an element of C&C). The RCEP restricted itself to UK emissions whereas this study addresses global emissions but only subdivides into Annex 1 parties (A1) and non-Annex 1 parties (NA1) and so cuts are assumed to be equal across each group. This study also differs from RCEP in that it takes into account emissions out to 2300. There are considerable cumulative emissions post 2100 in the WRE stabilisation profiles and this study allows the redistribution of these far future emissions into this century. As with RCEP, population is held constant after 2050 although the results are not found to be sensitive to population numbers. The methodology is best illustrated by presenting the steps taken:

1. Assume the level of cumulative carbon emissions allowed to reach chosen stabilisation level. To the first order, stabilisation is determined by the cumulative emissions. Depending on the level of carbon uptake by the natural system this is between 1150 and 1750 GtC for stabilising at 550 ppm. No other stabilisation level has been considered in this study.
2. Assume an economic and population projection. Here, SRES B2 is used as the lower bound and SRES A1FI as the upper bound.
3. Set A1 emissions reductions to start at 2000, at 2050 to be 60% of that at 1990 and by 2150 at a level consistent with world emissions of 2 GtC if high carbon uptake is assumed and 1 GtC if low uptake. One of the primary objectives of this study is to explore the consequences of the RCEP recommendations.
4. Set dates for NA1 start of emission controls, first emission target and second target. A range of start dates is explored with the first target constant at 2100 and the second constant at 2150.
5. Once a start date for NA1 emission control is chosen the emission level for the 1st target is adjusted until the cumulative emissions equal the chosen level in step 1. The second target is chosen to be, like for A1, consistent with world emissions of 2 GtC if high carbon uptake is assumed and 1 GtC for low uptake.

[1] Contraction and convergence is an international policy framework for dealing with global climate change developed by the London-based Global Commons Institute.