



Centre for
Climate Change
Economics and Policy



Grantham Research Institute on
Climate Change and
the Environment

What do the Appendices to the Copenhagen Accord tell us about global greenhouse gas emissions and the prospects for avoiding a rise in global average temperature of more than 2°C?

Nicholas Stern and Christopher Taylor

Policy paper

March 2010

**Centre for Climate Change Economics and Policy
Grantham Research Institute on Climate Change and
the Environment**

**In collaboration with the United Nations Environment
Programme (UNEP)**



The Centre for Climate Change Economics and Policy (CCCEP) was established in 2008 to advance public and private action on climate change through rigorous, innovative research. The Centre is hosted jointly by the University of Leeds and the London School of Economics and Political Science. It is funded by the UK Economic and Social Research Council and Munich Re. More information about the Centre for Climate Change Economics and Policy can be found at: <http://www.cccep.ac.uk>

The Grantham Research Institute on Climate Change and the Environment was established in 2008 at the London School of Economics and Political Science. The Institute bring together international expertise on economics, as well as finance, geography, the environment, international development and political economy to establish a world-leading centre for policy-relevant research, teaching and training in climate change and the environment. It is funded by the Grantham Foundation for the Protection of the Environment, which also funds the Grantham Institute for Climate Change at Imperial College London. More information about the Grantham Research Institute can be found at: <http://www.lse.ac.uk/grantham/>

The United Nations Environment Programme (UNEP) was established in 1972 and is the voice for the environment within the United Nations system. It provides leadership in caring for the environment by inspiring nations and communities to improve their quality of life without compromising that of future generations. More information about UNEP can be found at <http://www.unep.org>.

What do the Appendices to the Copenhagen Accord tell us about global greenhouse gas emissions and the prospects for avoiding a rise in global average temperature of more than 2°C? ¹

Executive Summary

This paper sets out an assessment of the latest targets and intended actions for reducing emissions of greenhouse gases, which have been submitted by countries to the Appendices of the Copenhagen Accord. These targets and intended actions are quantified and assessed in terms of global emissions to provide an understanding of the extent to which planned actions are consistent with a path towards avoiding a rise in global average temperature of more than 2°C ², which is specified in the Accord.

The latest studies of the science and economics conclude that annual global emissions of greenhouse gases must peak and fall to around 40-48 billion tonnes³ of carbon-dioxide-equivalent⁴ in 2020 to be consistent with a reasonable (i.e. 50 per cent) chance of limiting the increase in global average temperature to no more than 2°C by the end of this century. This finding is in line with the earlier work that underpins the conclusions of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. A 'climate responsible' level of global emissions in 2020, reflecting both costs and risks, would be nearer to 44 billion tonnes⁵.

Our analysis suggests that, although the targets and intended actions are substantial, they would not be enough to limit annual emissions to 44 billion tonnes in 2020, but would collectively imply global annual emissions of about 48.2 to 49.2 billion tonnes. This level of emissions would represent a reduction of 6.7 to 7.7 billion tonnes compared with the associated 'business as usual' forecast for emissions in 2020 of 55.9 billion tonnes⁶.

Emissions in 2020 of about 48 billion tonnes would mean that greater and more costly emission reductions of around 4 per cent each year would be required after 2020 for a path that would just about have a reasonable chance of avoiding a temperature

¹ This is work in progress incorporating announcements as of 4 March 2010 and subject to revision as countries' plans are added, changed or be clarified. The interpretation of the targets, analysis and views expressed here are solely those of the authors and do not necessarily represent those of their organisations. Many thanks to colleagues at the Grantham Research Institute on Climate Change and the Environment and at the United Nations Environment Programme for their helpful comments and guidance, especially Alex Bowen and Kaveh Zahedi. Comments on this document are very welcome by e-mail to: r.e.ward@lse.ac.uk.

² Temperature increase in this paper refers to change in global mean surface temperature compared with pre-industrial levels (after 1850) – however, it should be noted that the Accord does not specify a baseline level against which to measure change in global average temperature.

³ 10⁹ tonnes or 1 gigatonne.

⁴ Carbon-dioxide-equivalent is a unit that combines all greenhouse gases based on the global warming potential using the warming associated with carbon dioxide as the benchmark. The method used here to calculate carbon-dioxide-equivalent is described in Stern (2006).

⁵ <http://www2.lse.ac.uk/GranthamInstitute/publications/PolicyBriefsandPapers/PBActionSternDec09.pdf>

⁶ This includes anthropogenic peatland emissions, which are estimated to be 1.8 billion tonnes annually, but this is subject to a high degree of uncertainty. The low end of the 2020 range excludes peatland emissions because of this uncertainty.

increase of more than 2°C⁷. Hence those targets and intended actions that have been submitted to the Copenhagen Accord would not make it impossible to have a reasonable chance of avoiding a temperature rise of more than 2°C, but it would make it significantly more difficult and costly.

The recent economic slowdown should make emissions targets less difficult to meet, but should mean that bigger cuts are achieved. Given that annual global emissions are currently estimated to be about 47 billion tonnes and growing, any path that has a reasonable chance of meeting the 2°C goal includes a peak within the next 10 years and further reductions afterwards.

This analysis depends on a number of key assumptions that are subject to uncertainty and risks that apply to our estimates for mitigation:

- Countries achieve their specified goals for emissions, including those that are conditional on the actions of others.
- Double-counting is avoided that could arise if financial support for offsetting emissions by one country is used to support another country in delivering its target. Widespread double-counting, or some other failure to deliver national targets (possibly linked to lack of financial support), could lead to additional emissions of 1-2 billion tonnes in 2020⁸.
- Surplus emissions allowances from previous commitment periods do not weaken future mitigation efforts. Allowances could lead to additional emissions of up to 1-2 billion tonnes in 2020, depending on how many are used to offset mitigation action.
- A system of rules is adopted for accounting for greenhouse gases released and absorbed in the Land Use, Land Use Change and Forestry (LULUCF) sector to ensure the environmental integrity of targets while providing incentives to reduce emissions and increase sinks in these sectors. Depending on interpretation and rules, this uncertainty could be equivalent to around +/-1.5 billion tonnes of emissions in 2020.
- Developing countries grow broadly in line with their aspirations. Some uncertainty remains around emissions by developing countries, as the estimates are based on actions to reduce emissions relative to 'business as usual' levels. If economic growth or the carbon intensity of growth significantly exceeds expectations, emissions will be higher. Conversely slower or cleaner growth patterns would lead to lower emissions. This uncertainty could be equivalent to around +/-2 billion tonnes in 2020.

Collectively this represents a risk of adding 2 to 4 billion tonnes to the total for 2020, and additional uncertainty of +/-3.5 billion tonnes. This highlights the importance of tackling the uncertainties and avoiding the risks that could undermine mitigation. Failure

⁷ Annual emissions of 44 billion tonnes in 2020 would require annual reductions of around 3.3 per cent up to 2050 in order to be consistent with a 2°C goal.

⁸ This range is based on the assumption that developing countries which cited the need for financial support do not deliver 50 per cent of the reductions from their actions at the lower end and by the assumption that all developing countries only deliver 50 per cent of the implied emissions reductions at the high end. Failure by all countries to deliver reductions would clearly mean that global emissions would reach 'business as usual' levels.

by Annex I countries to deliver their targets, or even lower assumptions about delivery by non-Annex I countries than set out above, could lead to higher emissions in 2020. Adopting a different approach or different assumptions, including underlying 'business as usual' estimates, can lead to different findings. Although other modelling groups have reached different conclusions, most other studies have produced estimates that are in line with ours.

There is some scope for achieving further reductions, for instance by capping emissions from international aviation and shipping and by stronger national actions. The Copenhagen Accord also set the goal of mobilising financial support of US\$100 billion per annum by 2020, and US\$30 billion between 2010 and 2012, to address the needs of developing countries. A High-Level Advisory Group on Mobilising Climate Change Resources has been launched⁹ by the United Nations Secretary-General to explore how such funding could be raised. While much of this money will be used to support adaptation and wider capacity-building, a significant portion could support the transition by developing countries to low-carbon economic growth, including by protecting forested areas. Although some of this may provide support for the delivery of actions that are already planned, it could also fund greater ambition beyond existing unilateral targets and lead to a reduction in emissions, compared with 'business as usual' levels, by poorer countries that do not currently have mitigation actions included in the Appendix to the Copenhagen Accord - this could include action to reduce emissions from deforestation and land degradation.

Overall the achievement of the targets and the realisation of the intentions submitted to the Appendix of the Copenhagen Accord would represent a big step away from 'business as usual' emissions, and could be consistent with a slow start on a path to a 2°C goal. However, policy-makers could reduce the overall difficulty and cost of meeting the 2°C goal if they find ways to achieve stronger emission reductions by 2020. Further reductions of about 3 to 5 billion tonnes in annual emissions by 2020 would be required to reach a 'climate responsible' level of 44 billion tonnes. Whatever emissions level is reached in 2020, strong reductions will be required subsequently to have a reasonable chance of avoiding a rise in global average temperature of more than 2°C.

⁹ <http://www.un.org/apps/news/story.asp?NewsID=33748&Cr=climate&Cr1>

1. Introduction

On 6 December 2009, the Grantham Research Institute on Climate Change and the Environment and the United Nations Environment Programme published a joint analysis that explored the implications for global emissions and potential rises in global average temperature of the national mitigation intentions and commitments that had been announced ahead of the United Nations Climate Change Conference in Copenhagen¹⁰. A group of countries agreed to the Copenhagen Accord¹¹ at the conference, which was then noted by the parties to the United Nations Framework Convention on Climate Change (UNFCCC). Parties were invited to associate themselves with the Accord, and two Appendices allowed Annex I (developed) countries to submit their targets for emissions reductions and non-Annex I (developing) countries to submit their intended mitigation actions by 31 January 2010. In February 2010, the UNFCCC published a table of commitments by those countries that had submitted mitigation targets and intended actions¹².

This paper examines the targets and intended actions set out in the Appendices, to explore how they differ from those included in the earlier analysis of global emissions in 2020, and how they compare with the temperature goals set out in the Accord. The paper also describes the significant policy and uncertainties in the analysis.

¹⁰ <http://www.unep.org/pdf/climatechange/ActionAndAmbitionForGlobalDealInCopenhagen.pdf>

¹¹ <http://unfccc.int/resource/docs/2009/cop15/eng/l07.pdf>

¹² <http://unfccc.int/home/items/5264.php>; <http://unfccc.int/home/items/5265.php>

2. Analytical approach

It is the stock of greenhouse gases in the atmosphere, and not the flow of emissions into the atmosphere in any particular year, that affects the eventual global average temperature. Current emissions of some greenhouse gases, including carbon dioxide, could stay in the atmosphere for at least a century, and the lag in the climate system means that temperature changes slowly in response to a rise in the stock of greenhouse gases. This means that emissions over the next few decades will have an effect on the climate over an even longer period¹³. Only sustained reductions in annual emissions can limit the impacts on the climate in the future.

The decisions made by leaders and policy-makers about emissions over the next decade will have long-term consequences for the climate. In particular, maintaining the current path of 'business as usual' emissions will increase the stock of greenhouse gases in the atmosphere and will make it more costly and difficult to limit a rise in global average temperature. Strong actions over the next decade are required to realise low-cost opportunities to halt the rise in global emissions and to move from a risky 'business as usual' path onto a 'climate responsible' path. Without strong action, leaders and policy-makers are passing greater costs of mitigation and impacts onto future generations.

It is in recognition of these realities that a group of countries agreed to the Copenhagen Accord, which states:

"We agree that deep cuts in global emissions are required according to science, and as documented by the IPCC Fourth Assessment Report with a view to reduce global emissions so as to hold the increase in global temperature below 2 degrees Celsius, and take action to meet this objective consistent with science and on the basis of equity. We should cooperate in achieving the peaking of global and national emissions as soon as possible, recognizing that the time frame for peaking will be longer in developing countries and bearing in mind that social and economic development and poverty eradication are the first and overriding priorities of developing countries and that a low-emission development strategy is indispensable to sustainable development."

The Accord invited Annex I (developed) countries to submit, by 31 January 2010, their targets for emissions reductions in 2020 for inclusion in Appendix I. Non-annex I (developing countries) were invited to submit their intended mitigation actions for inclusion in Appendix II of the Accord.

¹³ Temperature changes also depend on the planet's 'climate sensitivity' to greenhouse gas levels – how much global temperatures rise eventually in response to a doubling of the concentration of greenhouse gases in the atmosphere. Exactly how numerous complicated components of the climate system respond to increased gas concentrations is subject to uncertainty. This analysis is based on what the latest science suggests is the most likely outcome, but temperature changes could turn out to be significantly lower or higher. While this uncertainty could reduce over time with scientific progress and increased observations of the Earth's response to changes in concentrations, uncertainty will remain about the temperature change to which we have committed the world. Hence designing climate change policies will always be a case of decision-making under uncertainty.

It should be noted that the Appendices to the Accord do not record emissions reduction targets or intended mitigation actions beyond 2020. Long-term emission goals, such as targets for annual emissions in 2050, give a clearer picture of the planned path, and hence of likely cumulative emissions in the future, which would allow potential impacts on global temperature to be estimated. Long-term goals provide a vision and signal the direction of policies in the short and medium term, allowing progress to be monitored. However, the most important decisions that have to be taken now are about near-term actions that are consistent with the long-term goals.

Several countries at the Copenhagen conference favoured more ambitious long-term goals, such as limiting the increase in temperature to no more than 1.5°C. The emission reductions for a 1.5°C path are likely to be much steeper and require drastic reductions much sooner if temperatures are not to overshoot the goal. Overshooting the temperature goal would be risky because it could take centuries to cool to a lower level without relying on untested and speculative geo-engineering options. There is a clear need for more research on the scientific and economic implications of such goals. The Copenhagen Accord called for an assessment by 2015 that would “include consideration of strengthening the long-term goal referencing various matters presented by the science, including in relation to temperature rises of 1.5 degrees Celsius”.

This analysis focuses on the extent to which the targets and intended actions by 2020 that have been submitted to the Accord are a credible first step towards the long-term goal of avoiding a rise in global average temperature of more than 2°C. This does not include a consideration of the implications of the limited number of national commitments to 2050 goals¹⁴.

Previous research¹⁵ by the Grantham Research Institute on Climate Change and the Environment explored a range of emissions paths that would result in a reasonable chance of keeping the rise in temperature to no more than 2°C, and considered the economic implications of these paths. The scientific conclusions of this research were consistent with the conclusions of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. It concluded that policy-makers should aim for annual global emissions to be between 40 and 48 billion tonnes in 2020 to meet this 2°C goal. Annex 1 provides a summary of the earlier research. As it is cumulative emissions over time that determine the likely increase in global temperature increase, smaller reductions in the near term mean bigger reductions in the medium to long term in order to achieve the same goal.

¹⁴ Other analyses do estimate how the Appendices targets and intended actions would affect temperature in the long term (such as <http://www.climateactiontracker.org/> and <http://climateinteractive.org/scoreboard>) but these results are driven primarily by assumptions on longer-term targets rather than just the 2020 actions submitted to the Copenhagen Accord. In particular, some of these analyses assume that most countries return to ‘business as usual’ emissions paths after 2020 if they have not announced specific targets – such an assumption inevitably leads to markedly higher estimates of the likely long-term change in temperature.

¹⁵ Ranger and Bowen (2009) available at: <http://www2.lse.ac.uk/granthamInstitute/pdf/bowenRangerPolicyBrief.pdf>

A complementary analysis concluded that annual global emissions should peak and decline to around 44 billion tonnes by 2020¹⁶, representing a sensible 'climate responsible' path, from a cost and risk management perspective, consistent with the 2°C goal¹⁷. Lower levels of emissions in 2020 would also be consistent with the 2°C goal, but would require very strong action over the next decade. Higher emissions in 2020 could also be consistent with the same goal, but would require more drastic action afterwards, which would be considerably more expensive and might not be feasible. If annual emissions in 2020 are about 48 billion tonnes, annual reductions of around 4 per cent per year would be required for the following three decades to maintain a path towards a 2°C goal. Emissions in 2010 are expected to be around 47 billion tonnes of carbon-dioxide-equivalent, and would have been close to 50 billion tonnes if the global economic slowdown had not occurred.

So how do the actions and targets set out to date in the Appendices of the Copenhagen Accord collectively compare with the 'climate responsible' target for global annual emissions of 44 billion tonnes in 2020?

¹⁶ See Annex 1 or Section 2 page 6-7:

<http://www2.lse.ac.uk/GranthamInstitute/publications/PolicyBriefsandPapers/PBActionSternDec09.pdf>

¹⁷ There is currently no political agreement that such a target for 2020 is an accepted benchmark for a 2°C path. However, we consider that this is an appropriate benchmark that is consistent with the findings of a number of independent modelling studies.

3. National submissions to the UNFCCC¹⁸

Table 1: National submissions to the Copenhagen Accord by Annex I Parties¹⁹

Annex I Parties	Quantified economy-wide emissions targets for 2020	
	Emissions reduction in 2020	Base year
Australia	-5% up to -15% or -25% Australia will reduce its greenhouse gas emissions by 25% on 2000 levels by 2020 if the world agrees to an ambitious global deal capable of stabilising levels of greenhouse gases in the atmosphere at 450ppm CO ₂ -eq or lower. Australia will unconditionally reduce our emissions by 5% below 2000 levels by 2020, and by up to 15% by 2020 if there is a global agreement which falls short of securing atmospheric stabilisation at 450ppm CO ₂ -eq and under which major developing economies commit to substantially restrain emissions and advanced economies take on commitments comparable to Australia's.	2000
Belarus	-5-10% reduction, which is premised on the presence of and access of Belarus to the Kyoto flexible mechanisms, intensification of technology transfer, capacity building and experience enhancement for Belarus taking into consideration the special conditions of the Parties included in Annex I undergoing the process of transition to a market economy, clarity in the use of new LULUCF rules and modalities.	1990
Canada	17%, to be aligned with the final economy-wide emissions target of the United States in enacted legislation.	2005
Croatia	-5% Temporary target for Croatia. Upon the accession of Croatia to the European Union, the Croatian target shall be replaced by arrangement in line with and part of the European Union mitigation effort. Base year calculated according to decision 7/CP.12.	1990
EU and its Member States	20%/30% As part of a global and comprehensive agreement for the period beyond 2012, the EU reiterates its conditional offer to move to a 30% reduction by 2020 compared to 1990 levels, provided that other developed countries commit themselves to comparable emission reductions and that developing countries contribute adequately according to their responsibilities and respective capabilities.	1990
Iceland	30% reduction, in a joint effort with the European Union, as part of a global and comprehensive agreement for the period beyond 2012, provided that other developed countries commit themselves to comparable emissions reductions and that developing countries contribute adequately according to their responsibilities and respective capabilities.	1990
Japan	25% reduction, which is premised on the establishment of a fair and effective international framework in which all major economies participate and on agreement by those economies on ambitious targets.	1990
Kazakhstan	15%	1992
Liechtenstein	Liechtenstein commits itself to reduce greenhouse gas (GHG) emissions 20% below 1990 levels by 2020. If other developed countries agree to comparable reductions and emerging economies contribute according to their respective capabilities and responsibilities within a framework of a binding agreement, Liechtenstein is prepared to raise its target up to 30%.	1990

¹⁸ Correct as of 25 March 2010.

¹⁹ More details including national submissions can be found here: <http://unfccc.int/home/items/5264.php>.

Monaco	<p>30%</p> <ul style="list-style-type: none"> • To achieve this emission reduction objective, the Principality of Monaco will use flexibility mechanisms similar to those established under the Kyoto Protocol, and more specifically the Clean Development Mechanism • The Principality of Monaco will aim at becoming carbon neutral by 2050 at the latest and will consider over-achieving its 2020 target through offsetting mechanisms. 	1990
New Zealand	<p>New Zealand is prepared to take on a responsibility target for greenhouse gas emissions reductions of between 10 per cent and 20 per cent below 1990 levels by 2020, if there is a comprehensive global agreement. This means:</p> <ul style="list-style-type: none"> • the global agreement sets the world on a pathway to limit temperature rise to not more than 2° C; • developed countries make comparable efforts to those of New Zealand; • advanced and major emitting developing countries take action fully commensurate with their respective capabilities; • there is an effective set of rules for land use, land-use change and forestry (LULUCF); and • there is full recourse to a broad and efficient international carbon market. 	1990
Norway	<p>30-40%</p> <p>As part of a global and comprehensive agreement for the period beyond 2012 where major emitting Parties agree on emissions reductions in line with the 2 degrees Celsius target, Norway will move to a level of 40% reduction for 2020.</p>	1990
Russian Federation	<p>15-25%*</p> <p>*The level of reductions will depend on the following conditions:</p> <ul style="list-style-type: none"> - Adequate provision for the potential of Russian forests in the context of their contribution to the fulfilment of anthropogenic emissions reduction obligations; - The adoption by all major emitters of legally-binding anthropogenic greenhouse gas emissions reduction obligations. 	1990
Switzerland	<p>20-30%</p> <p>As part of a global and comprehensive agreement for the period beyond 2012, Switzerland reiterates its conditional offer to move to a 30% reduction by 2020 compared to the 1990 levels, provided that other developed countries commit themselves to comparable emission reductions and that developing countries contribute adequately according to their responsibilities and respective capabilities.</p>	1990
United States of America	<p>In the range of 17%, in conformity with anticipated U.S. energy and climate legislation, recognizing that the final target will be reported to the Secretariat in light of enacted legislation. The pathway set forth in pending legislation would entail a 30% reduction in 2025 and a 42% reduction in 2030, in line with the goal to reduce emissions 83% by 2050.</p>	2005

Table 2: National submissions to the Copenhagen Accord by Non-Annex I Parties²⁰
(Text from submissions in Italics)

Non-Annex I Parties	Actions	Summary for 2020 compared with 'business as usual' (BAU)
China	<i>"China will endeavor to lower its carbon dioxide emissions per unit of GDP by 40-45% by 2020 compared to the 2005 level, increase the share of non-fossil fuels in primary energy consumption to around 15% by 2020 and increase forest coverage by 40 million hectares and forest stock volume by 1.3 billion cubic meters by 2020 from the 2005 levels. Please note that the above-mentioned autonomous domestic mitigation actions are voluntary in nature and will be implemented in accordance with the principles and provisions of the UNFCCC, in particular Article 4, paragraph 7."</i>	Carbon intensity target and existing domestic policies would lead to a reduction of 9% reduction compared with BAU in 2020.
India	<i>"India will endeavor to reduce the emissions intensity of its GDP by 20-25% by 2020 in comparison to the 2005 level".</i> Plans and policies outlined in National Plan and in the 11 th 5 year plan. Many are not quantified but domestic policy initiatives with policy targets collectively amount to a deviation from BAU of at least 7%.	Carbon intensity target and existing domestic policies would lead to a reduction of at least 7% compared with BAU in 2020.
Brazil	Included in its submission is a list of voluntary domestic actions: <i>"It is anticipated that these actions will lead to an expected reduction of 36.1% to 38.9% regarding the projected emissions of Brazil by 2020".</i> Also: <i>"The use of the Clean Development Mechanism established under the Kyoto Protocol is not excluded"</i> .	36% to 39% reduction compared with BAU in 2020, with external financial support.
Indonesia	Its submission provides a list of "Nationally Appropriate Mitigation Actions" that collectively mean a reduction of "26% by 2020". Before Copenhagen, it pledged to reduce emissions below BAU by 26% unilaterally and 41% below with international support.	26% reduction compared with BAU in 2020.
South Korea	<i>"To reduce national greenhouse gas emissions by thirty (30) percent from the business-as-usual emissions by 2020".</i>	30% reduction compared with BAU in 2020.
South Africa	<i>"South Africa reiterates that it will take nationally appropriate mitigation action to enable a 34% deviation below the 'Business As Usual' emissions growth trajectory by 2020 and a 42% deviation below the 'Business As Usual' emissions growth trajectory by 2025."</i> This action <i>"depends on the provision of financial resources, the transfer of technology and capacity building support by developed countries"</i> and the <i>"finalisation of an ambitious, fair, effective and multilateral agreement under the UNFCCC"</i> .	34% reduction compared with BAU in 2020 with support from developed countries.
Mexico	<i>"Mexico aims at reducing its GHG emissions up to 30% with respect to the business as usual scenario by 2020, provided the provision of adequate financial and technological support from developed countries as part of a global agreement."</i>	30% reduction compared with BAU in 2020.

There are also submissions from: Argentina, Armenia, Benin, Bhutan, Botswana, Congo, Costa Rica, Cote d'Ivoire, Ethiopia, Eritrea, Gabon, Georgia, Ghana, Israel, Jordan, Macedonia, Madagascar, Maldives, Marshall Islands, Mauritania, Moldova, Mongolia, Morocco, Papua New Guinea, Sierra Leone, Singapore and Togo.

Note: Estimates are based on the authors' understanding of existing positions. Where countries have announced both a set of policies implying particular levels of reductions and a target for carbon intensity (or other) reductions, we have taken the larger of the two estimates of reductions (i.e. lower implied emissions in 2020). This is of particular relevance to China and India, whose announced intensity targets appear to imply larger reductions than would follow from announced policies (perhaps because there is some inherent caution about the implementation of the policies).

²⁰ More details including national submissions can be found here: <http://unfccc.int/home/items/5265.php>

Collectively these targets and intended actions by Annex I and Non-Annex I Parties reflect commitments by 75 countries which currently account for about 80 per cent of global emissions.

4. Assessment of the submissions to the Appendices of the Copenhagen Accord

Here we provide an estimate of what the targets and intended actions submitted to the Appendices of the Copenhagen Accord, if delivered, mean for global emissions. Given the uncertainty around anthropogenic peatland emissions, these have been included separately²¹.

Table 3: Estimate of global emissions based on Accord Appendix targets and actions²²

	Low intentions	Emissions in 2020 (billions of tonnes of carbon-dioxide-equivalent)	High intentions	Emissions in 2020 (billions of tonnes of carbon-dioxide-equivalent)
US	-17% compared with 2005 (1.3 billion tonnes reduction)	5.9	-17% compared with 2005 (1.3 billion tonnes reduction)	5.9
EU	-20% compared with 1990 (1.0 billion tonnes reduction)	4.5	-30% compared with 1990 (1.6 billion tonnes reduction)	3.9
Japan	-25% compared with 1990 (0.4 billion tonnes reduction)	1.0	-25% compared with 1990 (0.4 billion tonnes reduction)	1.0
Other developed countries	0.1 billion tonnes reduction	5.5	0.5 billion tonnes reduction	5.0
Developed country total		16.7		15.7
China	2010 intensity target; 2020 renewable and nuclear target (1 billion tonnes reduction)	11.4	2010 intensity target; 2020 renewable and nuclear target (1 billion tonnes reduction)	11.4
India	2020 solar mission, renewable target, 2017 forestry target (0.2 billion tonnes reduction)	3.6	2020 solar mission, renewable target, 2017 forestry target (0.2 billion tonnes reduction)	3.6
Brazil	36.1% below BAU (1 billion tonnes reduction)	1.73	38.9% below BAU (1.1 billion tonnes reduction)	1.65
Indonesia	26% below BAU (0.7 billion tonnes reduction)	2.1	26% below BAU (0.7 billion tonnes reduction)	2.1
Other developing countries	0.8 billion tonnes reduction	11.9	0.8 billion tonnes reduction	11.9
Developing country total		30.6		30.6
International aviation and shipping		1.3		1.3
Anthropogenic peatland emissions outside Indonesia		0.6		0.6
Global total excluding anthropogenic peat		47.7		46.7
Global total including anthropogenic peat		49.2		48.2

²¹ Peatland emissions are estimated to be 1.8 billion tonnes under 'business as usual', of which 1.2 billion tonnes would be in Indonesia. The Indonesian contribution is projected to fall to 0.9 billion tonnes after implementation of the target of reducing emissions by 26 per cent compared with 'business as usual', meaning global peatland emissions of 1.5 billion tonnes. Anthropogenic peatland emissions are more difficult to measure than those from other sources, such as electricity generation and even deforestation. More recently studies have suggested that current global levels are around 1.8 billion tonnes ('The Global Peatland CO2 Picture, Peatland status and emissions in all countries of the world', Draft, Hans Joosten, Greifswald University, 2009; and 'Climate regulation of fire emissions and deforestation in equatorial Asia', Van der Werf *et al.*, PNAS, 2008) but there are a limited number of projections up to 2020 and national breakdowns (other than for Indonesia) of peatland estimates.

²² In this table it is assumed that Indonesia is not supported to deliver its previous high-end 41% target in the 'high intentions' column which would deliver an additional 0.4 billion tonnes of emissions reductions. 'High intentions' refers to countries' most ambitious targets (and hence lower emissions in 2020) and 'low intentions' refers to countries' least stringent targets (and hence higher emissions in 2020).

These estimates suggest that emissions would be 6.7-7.7 billion tonnes below a 'business as usual' path in 2020 of 54.1 billion tonnes (up to 55.9 billion tonnes including peatland emissions). However, these emissions in 2020 would still be around 2.7-3.7 billion tonnes (excluding peatland emissions) above a 'climate responsible' level of 44 billion tonnes (4.2-5.2 billion tonnes higher when peatland emissions are included)²³.

Global annual emissions in 2010 are likely to be about 47 billion tonnes and are set to continue to grow in the next few years. If the targets and intended actions set out in the Appendices to the Copenhagen Accord are to constrain 2020 emissions to 48.2 billion tonnes or below, global emissions will have to peak by midway through the next decade, and strong reductions would be required up to 2020 and beyond to ensure a single maximum and a reasonable chance of 2°C.

The analysis presented here includes a number of small changes compared with the previous study published in December 2009, prior to the United Nations climate change conference in Copenhagen²⁴. At the conference, South Africa and Mexico announced ambitions to reduce emissions their emissions by 34 per cent and 30 per cent, respectively, compared with 'business as usual' in 2020,²⁵ and confirmed these in their submissions to the Accord. Since our earlier assessment, China's submission has combined its national renewable and nuclear policies, so we have slightly increased our assessment of its emissions in 2020. Canada reduced the ambition for its target for 2020 and signalled that it would be aligned with final economy-wide emissions target that is enacted by legislation in the United States of America. A number of developing countries also outlined new mitigation intentions and policies in their submissions, though their emissions are not of a magnitude that affects the overall total.

The net effect of these changes in our analysis is small as some of these shifts offset each other, although the inclusion of more peatland emissions does increase the overall total. This reflects the fact that the submissions to the Accord have represented a consolidation of ambition, rather than an opportunity through which countries could significantly increase their pledges for domestic action.

²³ The parallel climate pledge tracker identifies a global gap of 4 billion tonnes compared with high end offers. For more see: <http://www.unep.org/climatepledges/>

²⁴ <http://www.unep.org/pdf/climatechange/ActionAndAmbitionForGlobalDealInCopenhagen.pdf>. This includes revised assumptions about peatland emissions.

²⁵ This is greater than the mitigation estimate for South Africa in the previous analysis. Also our previous work included reductions of 51 million tonnes up to 2012 for Mexico.

5. Implications for a 2°C goal

If global annual emissions are at 48 billion tonnes or above in 2020, a path that has a reasonable chance of avoiding a temperature rise of more than 2°C would require annual reductions of more than 4 per cent per each year after 2020²⁶, or reductions beyond 2050 of a magnitude that many currently view as impossible²⁷. The range of possible paths that are consistent with the 2°C goal is reduced if annual emissions are at 48 billion tonnes or above. Each of the paths would require the quick emergence and deployment of technologies to drive very rapid emission reductions over the longer term, with greater risk of 'stranded assets' and bigger implications for energy prices.

Pursuing a 2°C goal from a level of 48 billion tonnes or more in 2020 would be a higher risk and higher cost strategy as lower-cost options in the near term would be missed and faster reductions would be required in the longer term. It would also be a riskier path because some modellers doubt whether such rates of change are feasible without incurring prohibitive economic costs. The recent economic slowdown has made near-term emission targets easier to meet, but this should be viewed as an opportunity for making larger reductions so that low-cost options are not missed.

Annual reductions of more than 4 per cent after 2020 would require a further step change in mitigation action and costs. More ambitious action in the near term would provide stronger price and policy signals to spur the development of new and advanced low-carbon carbon technologies. A slower start would increase the importance of investing in advanced technologies to provide more potential cost-effective options for rapid future reductions. It would also increase the importance of avoiding any of the risks and uncertainties that could undermine mitigation commitments.

Even if post-2020 reduction rates of more than 4 per cent per year could be achieved, it would be better to pursue such a path from a lower level than 48 billion tonnes in 2020 in order to increase the probability of avoiding a temperature rise of more than 2°C.

²⁶ If a 'climate responsible' level for global annual emissions of 44 billion tonnes was reached in 2020, the required annual emission reductions afterwards would be around 3.3 per cent each year.

²⁷ It may not be possible to eliminate all emissions, even on a 50- to 100-year timescale, for instance from sectors such as food production.

6. Key uncertainties in this analysis

As with all exercises involving forecasting, there are a number of uncertainties in projecting emissions in 2020 based on submissions to the Copenhagen Accord. These uncertainties, along with variations in approach, can lead independent analyses to reach different conclusions. Uncertainties also remain in projections of the amount of climate change for a given emissions path.

All analyses make the assumption that countries meet their targets. Failure to design and implement effective policies would undermine national efforts. Conversely, well-designed policies that spur innovation and investment could allow goals to be exceeded. The 'high intentions' scenario in our analysis assumes that countries deliver their higher targets, which often require the satisfaction of conditions about actions by others. This is especially the case for developing countries, for which many actions are dependent on developed countries providing adequate financial support.

Paragraph 8 of the Copenhagen Accord states:

"The collective commitment by developed countries is to provide new and additional resources, including forestry and investments through international institutions, approaching USD 30 billion for the period 2010- 2012 with balanced allocation between adaptation and mitigation. Funding for adaptation will be prioritized for the most vulnerable developing countries, such as the least developed countries, small island developing States and Africa. In the context of meaningful mitigation actions and transparency on implementation, developed countries commit to a goal of mobilizing jointly USD 100 billion dollars a year by 2020 to address the needs of developing countries."

It is not yet clear how the target of US\$100 billion per year by 2020 will be raised and divided between adaptation and mitigation actions. A High Level Advisory Group on Mobilising Climate Change Resources has been launched²⁸ to explore how such funding could be raised. Resources on this scale have the potential to fund significant mitigation actions in those countries that require support. Indeed, if provided on a sufficient scale, this funding could lever further reductions beyond existing commitments, and in those countries that have not yet specified mitigation actions. For example, the funding could be sufficient for Indonesia to deliver its conditional action of reducing emissions to 41 per cent below 'business as usual' by 2020, which would result in a further cut of 0.4 billion tonnes beyond the current unilateral target of reaching 26 per cent below 'business as usual'. However, it is impossible at this stage to predict the extent to which funding of US\$100 billion would allow developing countries to deliver some, all or more of the reductions that have been considered in this analysis. Houser estimates²⁹ that international finance could lead to additional emissions reductions of up to 1.5 billion tonnes.

²⁸ <http://www.un.org/apps/news/story.asp?NewsID=33748&Cr=climate&Cr1=>

²⁹ <http://www.iie.com/publications/pb/pb10-05.pdf>.

The form of the financial support will also matter. Offsets by developed countries would shift the balance of actual emissions and would imply that funding would flow to developing countries. There must be transparency about the ‘adding up’ of emissions to avoid double-counting and to allow actual emissions after offsets to be estimated; emissions in country A, which buys the offsets, would be higher than the estimates in the analysis here and emissions in country B, which receives the flow of funding by selling the offsets, would be lower³⁰. Nevertheless offsets through the carbon market can be beneficial for both developed and developing countries³¹. This analysis assumes that offset finance is used only to fund additional mitigation action in recipient countries.

If those countries that are seeking international financial support for mitigation actions only delivered half their reductions (because of a lack of finance, weak policies or double-counting due to offsets), emissions in 2020 would be 1 billion tonnes higher. If all developing countries only delivered half their intended reductions, emissions in 2020 would be 1.8 billion tonnes higher. Similarly, a failure to implement strong policies could lead to higher emissions from developed countries.

It is important that surplus emissions allowances from previous commitment periods do not weaken future mitigation efforts, as they could represent an additional 1-2 billion tonnes³² in emissions in 2020 if used entirely to meet the targets and actions described in the Appendices to the Copenhagen Accord.

The treatment and use for future targets of emissions from LULUCF (land use, land-use change and forestry) in Annex I countries are also a source of uncertainty. Most targets are based on the traditional accounting approach of the Kyoto Protocol that excludes LULUCF from emissions targets, but allows some LULUCF actions can still be used to meet targets. However, the accounting rules are not yet set for the period up to 2020. Emissions data indicate that Annex I Parties to the UNFCCC are collectively a net sink of anthropogenic LULUCF emissions of around 1.8 billion tonnes. In general, emissions including LULUCF are used as inputs for climate models to estimate implications for global average temperature. This means that the emissions for Annex I countries that are listed in Table 3 should be adjusted to take into account whether LULUCF sinks are used to meet targets for reductions; unused LULUCF emission sinks would reduce the estimated emissions total. Some scientists fear that LULUCF emissions that have been reported are already incorporated into the natural sinks in climate models and so should not be used as a way of reducing anthropogenic emissions. In such a case, the use of credits from LULUCF should be added onto the totals in Table 3, and viewed as a weakening of targets. Intended actions by non-Annex I countries generally include LULUCF within estimates of ‘business as usual’ emissions, and are not net sinks, avoiding these complexities.

³⁰ For example, the submission by Brazil to Appendix II of the Copenhagen Accord states that the use of credits from the Clean Development Mechanism (CDM) is not excluded. A clear example of double-counting would occur if companies in the European Union bought 0.2 billion tonnes of CDM credits from Brazil, and they were then counted as contributions to meeting the targets of both the European Union and Brazil.

³¹ They can provide private finance to foster both the transformation of the energy system in developing countries and the transfer and domestic development of low-carbon technologies; and they can reduce global mitigation costs.

³² Estimated to be 2 billion tonnes in this analysis: http://www.climateactiontracker.org/briefing_paper.pdf

The system of rules for how to account for the emissions released and absorbed in the LULUCF sector should be designed to ensure the environmental integrity of emission targets, while providing incentives to reduce emissions and increase sinks in these sectors. Heavy dependence on emissions reductions through the LULUCF sector could increase overall mitigation costs if insufficient action is happening in the other sectors (e.g. due to the 'locking-in' of high-carbon infrastructure and the failure to incentivise the development of low-carbon technologies). Overall targets should be set with transparency about the extent to which such credits should be used, to encourage cost-effective mitigation in LULUCF and other sectors.

If Annex I countries continue to constitute collectively a sink of LULUCF emissions, and these are not used to meet their emissions reduction targets, global emissions could be 1.8 billion tonnes lower in 2020 (or more if these sinks were increased). However, if countries use LULUCF emission sinks that are included in natural sinks in climate models to meet their targets, they would not be reducing the amount of anthropogenic greenhouse gases reaching the atmosphere, so global emissions would be higher in 2020 by a similar amount.

Some uncertainty remains about emissions from developing countries because they are based on actions measured against 'business as usual' emissions (i.e. the path that emissions would be likely to follow without further policy action). Reductions are therefore dependent on what assumptions are made about 'business as usual'. This is easier to quantify in cases where countries measure reductions against a specified 'business as usual' path. However, in cases where 'business as usual' is not specified, uncertainties can arise from the variation in estimates of what it represents. Higher estimates of 'business as usual', for instance due to stronger economic growth, greater energy intensity or increased LULUCF sources, would affect estimates of emissions totals.

The quantification of emissions reductions due to carbon intensity targets also poses challenges. Economic growth rates are already a key determinant of emissions under 'business as usual', but also directly affect the total emissions implied by carbon intensity targets. In this analysis, we have assumed that China continues strong economic growth of over 8 per cent per year, but that existing domestic policies (emissions intensity target up to 2010 and non-fossil fuel targets for 2020) lead to significant emission reductions compared with 'business as usual'. Our analysis suggests that these domestic policies would lead to lower emissions than implied by the emissions intensity target; hence it is the domestic targets that 'count' for the purpose of our analysis. A similar situation exists for India's emissions intensity target, so existing domestic policies are included in the estimates in Table 3. Economic growth, or carbon intensity of growth, that significantly exceeds expectations would cause emissions to be higher than estimated in this analysis. Conversely, slower or cleaner growth patterns would lead to lower emissions. This uncertainty about 'business as usual' emissions and intensity targets is about +/-2 billion tonnes for emissions in 2020.

7. Comparisons with other modelling groups

Table 4 lists the main results of other analyses which have assessed the pledges in the Appendices to the Copenhagen Accord. Much of the variance reflects different assumptions about the potential risks that could undermine targets and intended actions (e.g. ineffective delivery of domestic action, offset double-counting, surplus emissions allowances and weak LULUCF accounting rules). Some of the variance in the results reflects the inherent uncertainty over making such forecasts of emissions from developing countries.

Table 4: Comparison of forecasts for global emissions in 2020³³

Analysis	'Low intentions' emissions (billions of tonnes of carbon-dioxide-equivalent)	'High intentions' emissions (billions of tonnes of carbon-dioxide-equivalent)
Risø Centre on Energy, Climate and Sustainable Development/Climate Pledge Tracker ³⁴	49.9	48
PricewaterhouseCoopers ³⁵	50.3	48.3
Ecofys, Climate Analytics, Potsdam Institute for Climate Impact Research/Climate Action Tracker ³⁶	54.8	52.0
Project Catalyst ³⁷	53	49
Trevor Houser (Peterson Institute for International Economics) ³⁸	51.5	48.2

Some of these analyses (PricewaterhouseCoopers and Project Catalyst) have made comparisons between estimates of global emissions in 2020, based on submissions to the Copenhagen Accord, and their assumptions about the most appropriate path for a 2°C goal, concluding that the two are not consistent. The Climate Action Tracker and the Climate Interactive Scorecard³⁹ (not included in Table 4) assess targets and intended actions for 2020 and beyond – however, as few countries have made commitments beyond 2020, these analyses inevitably conclude that the 2°C goal would be missed and that a temperature rise of 3.5°C or more will be a likely outcome.

Our analysis broadly agrees with the conclusions of PricewaterhouseCoopers and Project Catalyst in that current targets and intended actions are not consistent with a 'climate responsible' level of emissions in 2020 of 44 billion tonnes, and are likely to require more expensive and risky reductions after 2020 in order to have a reasonable chance of avoiding a temperature rise of more than 2°C. Our analysis also broadly agrees with the conclusions of Climate Action Tracker and Climate Interactive Scorecard in that without strong mitigation action after 2020 (emissions reductions averaging 4 per cent per year) there is a greater than 50 per cent chance of global temperature increasing by more than 2°C. However, like the analysis by Trevor Houser, our analysis concludes that strong reductions after 2020 could still make it possible,

³³ Includes analyses published as of 10 March 2010. Our analysis succeeds that published in February 2010 by UNEP in its Information Note on 'How close are we to the two degree limit?'. It compared forecasts of emissions against assessments of 2°C paths by a number of modelling groups.

<http://www.unep.org/PDF/PressReleases/temperature-briefing-21-02-10-final-e.pdf>.

³⁴ <http://www.unep.org/climatepledges/>.

³⁵ These estimates do not include the identified potential for double-counting of 1 billion tonnes from offsets <http://www.ukmediacentre.pwc.com/Content/Detail.asp?ReleaseID=3571&NewsAreaID=2>.

³⁶ <http://www.climateactiontracker.org/>.

³⁷ http://www.project-catalyst.info/images/publications/project_catalyst_taking_stock_february22_2010.pdf.

³⁸ <http://www.iie.com/publications/pb/pb10-05.pdf>.

³⁹ <http://climateinteractive.org/scoreboard>

albeit more difficult and costly, to maintain a path that is consistent with the 2°C goal. It is these differences in interpretation of likely action after 2020 and use of a single or variety of paths, rather than the underlying methods, that separate the analyses to date.

8. Scope for further reductions or emission reductions

There are a number of possible ways to bridge the gap between the annual global emissions inferred from targets and intended actions for 2020 and the 'climate responsible' level of 44 billion tonnes. The simplest would be for countries to deliver and exceed their high intentions, or countries without targets or intended actions to reduce their emissions. Financial support for mitigation that is committed through the Copenhagen Accord could result in bigger reductions by focusing on cost-effective areas where reductions beyond existing targets may be possible, such as Reduced Emissions from Deforestation and Degradation (REDD). A significant additional contribution could be made by incorporating international emissions from aviation and shipping into mitigation efforts.⁴⁰

⁴⁰ For example, a reduction of 0.5 billion tonnes could be achieved through a target of cutting emissions from international aviation and shipping by 20 per cent compared with 2005 levels (if any offsets that are purchased are additional to the current targets of developed countries).

9. Conclusions

A big step could be taken towards the 2°C goal by delivering the targets and intended actions submitted to the Appendices of the Copenhagen Accord, and they should lead to global annual emissions peaking before 2020 (depending on how measures develop after 2020). All major emitters have shown their intentions to reduce global emissions. It is now vital that this is followed up with strong action and support, particularly for developing countries.

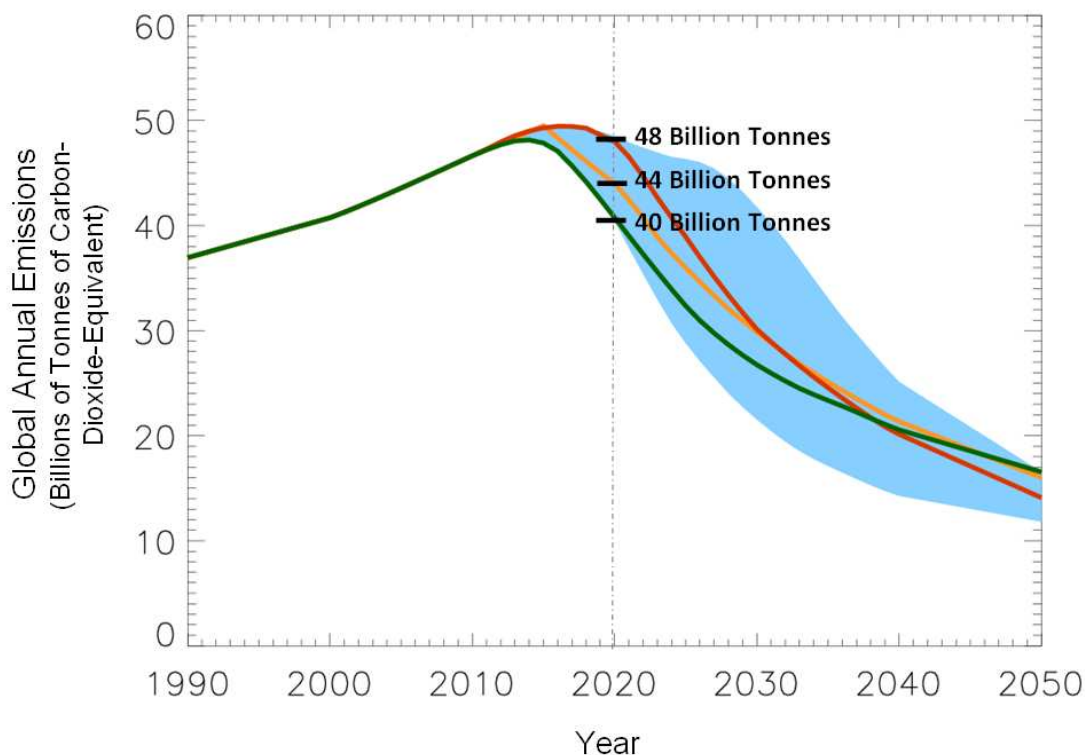
The submissions to the Copenhagen Accord to date represent a slow start but a path from such levels towards the 2°C goal could still be possible. But a slow start will require even stronger global action after 2020, which is likely to be more expensive and riskier than a strong start. To reduce these risks, policy-makers should both find ways to deliver further emission reductions, including from international aviation and shipping, and support developing countries to allow them to deliver significant reductions, including from REDD. The targets and intended actions so far are significant and valuable, but they represent only a slow start on a path towards the 2°C goal, requiring stronger action after 2020. Without strong delivery of existing commitments, a path to 2°C is unlikely to be achieved. It would be better if global annual emissions could be reduced to a 'climate responsible' level of 44 billion tonnes in 2020.

Annex 1: Estimating emissions in 2020 that are consistent with a 2°C goal⁴¹

A1. Paths that have a reasonable chance of avoiding a temperature rise of more than 2°C

There are numerous emissions paths that result in similar temperature changes (Figure 1). Since it is cumulative emissions over time that matter most, smaller reductions in the near term must be matched by bigger reductions to lower emission levels in the medium and long term. Our previous analysis identified some paths towards the 2°C goal that require global annual emissions to reach levels below 40 billion tonnes in 2020. However, these were discarded as they require annual reductions of more than 2 per cent per year, on average, between 2010 and 2020, which is not considered realistic given current emissions. Paths located nearer to the top of the range for 2020 in Figure 1 drop towards the bottom of range in 2050, and vice versa.

Figure 1: Range of paths for global annual emissions that mean a reasonable chance of meeting a 2°C goal



The findings of a simulation of plausible emissions paths that lead to a probability of 50 per cent of limiting global warming to no more than 2°C above pre-industrial levels (Bowen and Ranger, 2009)⁴². The blue shaded region shows the envelope containing simulated emissions paths consistent with this goal, based on a low

⁴¹ More details are available at: <http://www2.lse.ac.uk/granthamInstitute/pdf/bowenRangerPolicyBrief.pdf>

⁴² 'Mitigating climate change through reductions in greenhouse gas emissions: the science and economics of future paths for global annual emissions'. These results are based on the Hadley Centre climate model MAGICC. There are some key uncertainties. The majority of this uncertainty is in the response of the Earth's system to human emissions of greenhouse gases and is due to carbon-cycle feedback, with a smaller contribution from climate sensitivity. This uncertainty, of at least +5 to -10 billion tonnes (skewed towards the negative end), provides the rationale for adopting early targets for big emissions reductions to maintain the option of moving to a more ambitious path if new evidence indicates the need for stronger action. For 2050, an uncertainty of about ±4 billion tonnes of carbon-dioxide-equivalent is estimated for each emissions path due to, in particular, the uncertainties relating to aerosol emissions and abatement options for different gases.

aerosol emissions scenario. Paths towards the upper end of this envelope in 2020 continue towards the lower end of this envelope in 2050 (and vice versa). The green, orange and red lines represent three plausible emissions paths passing through 40, 44 and 48 billion tonnes of carbon-dioxide-equivalent in 2020, respectively. Each path leads to a median estimate of warming of 2.0°C above pre-industrial levels under a low aerosol emissions scenario (and 1.9°C under a high aerosol scenario).

A2. 'Climate responsible' paths

A 'climate responsible' path is one that has a reasonable chance of avoiding a temperature increase of more than 2°C above pre-industrial level, without entailing excessive costs or risks. A credible start along these paths means laying the foundations for greater reductions in the future, while not missing low-cost opportunities and not passing on much greater costs to future generations. The features of a 'climate responsible' path are:

- Emissions peak – the sooner and lower the peak in emissions, the smaller the annual reductions that are required in the future. But it takes time to build the domestic political consensus on how to act and implement the required policies and investments to achieve rapid reductions.
- Annual rate of decline – the faster the rate of reductions, the greater the overall costs, as it requires a more rapid deployment of new low-carbon technologies, early retirement of existing assets and a larger impact on energy prices.
- How low emissions go beyond 2050 – very low levels of emissions beyond 2050 require technologies to decarbonise to very low levels in all sectors, which may not be feasible and may be much more expensive.

A3. Implications for emissions in 2020

Feasible paths that offer a reasonable chance of avoiding a temperature increase of more than 2°C require global annual emissions to be between 40 and 48 billion tonnes in 2020. This finding is broadly consistent with the conclusions of the IPCC Fourth Assessment Report. A later and higher peak in global annual emissions would leave fewer subsequent options and would require the quick emergence of technologies to drive very rapid emissions reductions over the longer term, with more 'stranded assets'. This would represent a higher risk and higher cost strategy as lower-cost near-term options would be missed and greater reductions would be required in the longer term. A 'climate responsible' path, with global annual emissions of 44 billion tonnes in 2020 would require annual reductions of around 3.3 per cent each year after 2020 and annual emissions of about 16 billion tonnes in 2050, which is plausible but still ambitious. This 'climate responsible' path would balance the risks and opportunities appropriately⁴³, realising the economic benefits of early action, while leaving time between now and 2020 for policies to take effect.

There is some flexibility in the date by which emissions must peak, but a later peak would have to be compensated for by more rapid reductions thereafter. Annual emissions above 48 billion tonnes in 2020 would require reductions at an average rate of more than 4 per cent per year in the following decades, to below 14 billion tonnes in

⁴³ See Section 2:

<http://www2.lse.ac.uk/GranthamInstitute/publications/PolicyBriefsandPapers/PBActionSternDec09.pdf>

2050 - this would be considerably more expensive than a path that involved earlier action.

Evidence shows that a delay in participation in a global policy regime for climate change is likely to increase significantly the costs of meeting the 2°C goal, without benefiting the late adopters, and may make the target unattainable. Limiting the rise in global temperature to no more than 2°C above pre-industrial levels is a demanding goal. But, with well-designed policies applied consistently across countries, industries and greenhouse gases, modelling exercises suggest it can be reached and need not cost more than a few percentage points of GDP, against a backdrop of continued strong economic growth. We should not see the route to the low-carbon economy merely, or mostly, in terms of cost and burden-sharing. These are innovations, investments and opportunities: green technologies could create the most dynamic and innovative period in economic history with many co-benefits (e.g. greater energy security, safety, biodiversity) beyond the fundamental one of managing the risks of climate change.