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In case of emergency...

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Foreword

Climate Safety in presenting this examination of recent climate science brings two important messages. The first is that climate change is accelerating more rapidly and dangerously that most of us in the scientific community had expected or that the IPCC in its 2007 Report presented. The second is that, because political inaction has delayed progress for so long, the imperative for extremely urgent action on both national and global scales is now paramount.

The target that has been broadly accepted by many bodies including our own Government is that a rise in global average temperature of more than 2°C above its preindustrial value must not be allowed. To achieve this, deforestation must be halted within a decade or two at most and serious decarbonization of the energy sector must begin immediately. Can the necessary reductions be achieved? No less a body than the International Energy Agency has just reported (WEO 2008 published on 12 November 2008, also ETP published in June 2008) on how this target in the Energy sector can be achieved – but they also point out the unusual degree of political will that will be necessary.

I wish to commend the authors of the **Climate Safety** report for their carefully researched assessment of the climate future, the severity of its likely impacts as currently understood and the urgent demands that are made on both global and national action. They point out the 2°C target as currently pursued will almost certainly turn out to be inadequate and will soon need to be substantially strengthened. But they also stress that the required changes are both achievable and affordable.

In a speech at an international conference three years ago, Gordon Brown emphasised strongly the importance of considering the economy and the environment together. Recent upheavals in the economic establishment have exposed the danger of assuming that somehow the future, either for the economy or the environment, will look after itself. It will not!

The present opportunity for deliberate and effective action along the lines of **Climate Safety** must be grasped.

Sir John Houghton

Former Co-Chair of the Intergovernmental Panel on Climate Change (IPCC)
Former Director General of the UK Met Office

Summary

Science

Following the record 2007 melt in Arctic summer sea ice extent, 2008 saw a record low in sea ice volume. Arctic climate scientists are now predicting an Arctic ocean ice-free in summer by 2011-2015, eighty years ahead of predictions made by the Intergovernmental Panel on Climate Change (IPCC). Contrary to what the media coverage suggests, the significance of an earlier-than predicted Arctic melt extends beyond displaced polar bears and easier access to oil and gas.

An early Arctic melt will cause additional heating, as a shrinking ice cap reflects less sunlight into space; additional greenhouse gas emissions, as the ensuing regional warming melts frozen permafrost; and additional sea level rise, as the Greenland ice-sheet comes under increased temperature stress.

Furthermore, the Arctic melt is taking place in the context of faster change in the climate than the IPCC have predicted. It is clear that the IPCC's predictions of future sea-level rises are underestimates. Potential predicted sea level rises would put us in the region of impacts orders of magnitude greater than any we have seen to date. Carbon sinks – which provide the Earth's natural capacity to draw carbon out of the atmosphere – are degrading as temperatures rise and ecosystems are destroyed. The Earth's sinks have up to this point absorbed almost half of all man-made emissions – we may not be able to rely on them to do so in the future. Ecosystems, already under pressure from human activity, are proving more vulnerable to temperature rise than anticipated.

Change is happening ahead of schedule. This suggests that the climate is more sensitive that we thought – demonstrating that although the overall direction of climate change is very clear, there are still significant uncertainties about its speed, and details of specific regional impacts.

Targets

Statements about targets for emissions reductions inevitably simplify real-world complexity. However useful it might be politically to state that a particular level of cuts in emissions will lead to a particular atmospheric concentration of greenhouse gases, which will deliver a particular temperature rise, it is not helpful in gaining a true appreciation of the actual uncertainties involved.

The challenge is to draw sophisticated and powerful conclusions about the targets we should set based on a set of very disparate information about the impacts of climate change. One valid way to make generalisations is to examine the concept of "climate sensitivity" – the tool used for converting atmospheric concentrations of CO_2 into temperature rise.

The higher climate sensitivity is, the more the climate changes in response to greenhouse gases. The IPCC estimate a range of values for climate sensitivity - from low to high, with a mid-range "best estimate". Their scenario modelling work is based on this "best estimate" figure. They note that policymakers, to reduce the risk of impacts, may want to take the higher end of the range for setting policy. However, assuming a higher figure means that none of their suggested scenarios for emissions reductions limit temperature rise to below two degrees. Furthermore, the upper end of the range of climate sensitivity may be even higher than that suggested by the IPCC.

The observed impacts of climate change suggest that the climate is more sensitive than thought. The higher sensitivity is, the lower the targets we need to set to meet a particular temperature rise. This should suggest that we set lower targets as a very basic precautionary principle. If climate sensitivity is higher we may already be past the atmospheric concentration which will ultimately deliver 2°C of temperature rise.

As a society we are preparing for a medium-sized climate problem, despite evidence that points to the problem being greater than we had anticipated. Instead of relying of an illusion of certainty, we need to manage the risks of climate change responsibly. This means reducing atmospheric concentrations to within the range that we know the climate will maintain stability – 300 ppmv CO_2 equivalent. This would rule out a domino effect of sea-ice loss, albedo flip, a warmer Arctic, a disintegrating Greenland ice sheet, more melting permafrost, and knock-on effects of massively increased greenhouse gas emissions, rising atmospheric concentrations and accelerated global warming.

Any proposal for a target higher than 300ppmv would imply confidence that it is safe to leave the Arctic sea ice melted. If we currently have such confidence, it is misplaced. 300ppmv is below current atmospheric concentrations, but we can achieve it if we act now, because of the delay in how the climate system responds – if we can lower the atmospheric concentrations this century the system may never reach the full level of warming we are due to receive.

This reflects a key point – that the climate is not warmed by our current level of emissions, but rather by the cumulative amount of greenhouse gases in the atmosphere. We may be able to reduce our current emissions relatively quickly, but reducing the atmospheric stock means first bringing our emissions levels below the natural carbon sink capacity of the planet, and then waiting for that capacity to reduce the stock – a process which will take a lot longer. Crucially, this means that cutting emissions 80% will not solve 80% of the problem.

The scale of the challenge is daunting. Even under optimistic assumptions, meeting it will require emissions peaking globally by 2015 or sooner, and unprecedented rates of emissions cuts. Whatever our future target for emissions stabilisation – 450, 350, 300 – we ought to be doing much more than we are now. Unless we make emissions cuts in the short term the kinds of stabilisation levels we have been talking about will not be possible. We must race out of carbon – once this process is well under way we can have arguments about what level of atmospheric concentration we want. We must stop pretending that our current course of action will get us what we need. We need a programme of change altogether more ambitious.

Solutions

In the next two years the UK should cut its emissions by 10% - reversing current trends of actual UK emissions growth and peaking our emissions early. Delivering short-term actions provides the essential foundation for mid-term policies and long-term targets.

We should then cut our emissions as close to zero as possible over the next 2-3 decades, delivering a clear message of intent and urgency to the rest of the world. At the same time we should be preserving the UK's carbon sinks and funding adaptation around the world.

Cutting emissions to this degree means decarbonising the UK – a programme of action which combines wide-ranging energy efficiency measures, the rapid deployment of diverse and distributed renewable technologies, and encouraging significant behavioural change. We will have to integrate our transport system with a renewably powered national grid, and make sweeping changes in the way we insulate, heat and build our houses. Agriculture will be faced with the twin challenges of decarbonising and adapting to a warmer world.

Implementing this plan will require that we overcome significant obstacles – such an energy system can compete in terms of cost with our current fossil-fuel powered system, but will require significant investment in the short term. This is a clear opportunity for Government to invest in a sustainable future – raising Government energy bonds against the profits to be made from exporting renewable energy to the rest of Europe. Creating a planning system which can quickly and sensitively increase renewable capacity, building a national grid which can integrate and balance large amounts of renewable power, and investing to overcome skills shortages and supply constraints which are preventing rapid growth in this dynamic sector.

We may also need to explore options beyond decarbonisation. These are poorly understood at present – so-called 'geoengineering' technologies are highly problematic and most can be dismissed out of hand. However, there should be further research into less risky proposals – drawing carbon out of the atmosphere using natural processes, and 'direct air capture', as well as into cloud-seeding ships and certain forms of albedo adjustment.

International action will be required to solve the problem, but it is not a prerequisite for acting. The UK can take unilateral action, and with the currently underdeveloped and valuable asset of our huge renewable potential, is well-placed to do so. In this way, the UK could help unpick the international deadlock which has prevented faster action on climate change.

Action

Current large-scale policy responses to the problem have failed to deliver the change we require, and indeed have failed to deliver emissions reductions at all. The UK Climate Change Bill is a welcome step forward, but the situation we are in will require more ambitious action. To deliver the change we need, we will have to overcome the social and political blockages which have kept us from addressing the problem.

It will be necessary to mobilise public will to break the logjam of political progress. Different groups in government, civil society and the public have important roles to play. Rapid societal shifts are not only possible; they are a regular feature of the way our society works. Although the challenge may seem daunting, we still have the time and agency to respond. By front-loading the action we take to reverse current trends of emissions growth, cutting our emissions in the UK 10% in the next few years, and in seeking to scale up a response that meets the scale of the challenge, we can manage the risks to which we are exposed and act with agency and purpose.

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Finally, we would like to thank **Tim Holmes** for his central and excellent contribution, and for going well beyond the call of duty as PIRC's finest intern to date.

As ever, any errors or omissions are our own.

Introduction

"Arctic ice second-lowest ever; polar bears affected"

Reuters Headline, August 27th 2008

"What happens in the Arctic actually does not stay in the Arctic."

Richard Spinrad, NOAA

The annual summer warming of the Arctic in 2008 was watched closely by an army of expert observers and other interested parties around the world. Organisations such as the US National Oceanic and Atmospheric Administration (NOAA)[3] published near-daily updates on the state of the Arctic sea ice, which every year recedes from its winter maximum as the summer comes to the far north. The reason for this scrutiny was the record low level of Arctic sea ice extent observed in summer 2007, when an area of ice nearly the size of Alaska melted. The modern Arctic is a very different place to the Arctic of the past.

There is a large and growing gap between the predictions of how climate change will impact on the planet produced by the Intergovernmental Panel on Climate Change (IPCC), and the impacts that are already observable. This has profound consequences for climate policy, the setting of emissions reductions targets and the question of whether we have already passed critical tipping points in the Earth's climate system.

The question is no longer what must we do to avoid 'dangerous climate change'. Climate change is already dangerous. The signs are evident globally: in the polar north; in the Darfur famine; in Australia's record 12-year drought; in the huge and devastating Greek and Californian wildfires of 2007; in the dying coral in the Caribbean and Australia's Great Barrier Reef; in changing monsoon patterns; in widespread species losses; in the degradation of ecosystems across the globe; and in impacts on regional food-production in South East Asia and East Africa.

The UN's emergency relief coordinator, Sir John Holmes, warned in 2007 that 12 of the 13 major relief operations that year had been climate-related, and that this amounted to a climate change "mega-disaster".[4]

This report considers recent developments in the observed 'on-the-ground' physical impacts of climate change, what they indicate about our understanding of the problem, and how Britain should respond.

What the science is telling us

"It is clear that climate change is already having a greater impact than most scientists had anticipated, so it's vital that international mitigation and adaptation responses become swifter and more ambitious."[1]

Professor Jean-Pascal van Ypersele, Vice-Chair of the IPCC

"It also means that climate warming is coming larger and faster than the models are predicting and nobody's really taken into account that change yet."[2]

Jay Zwally, NASA Climate Scientist

The Arctic

Every year, the Arctic sea ice melts from its winter maximum extent to a summer minimum. In 2007 the melt was a record event, with sea ice 'extent' (roughly equivalent to area[5]) 39% below the summer average for 1979–2000, and 23% below the previous record low set in 2005[6] – a loss of area since the 2005 low equivalent to nearly five United Kingdoms.[7] Another record low in sea ice extent was avoided in 2008 due to calmer and cooler regional weather which broke up the ice less quickly.

Julienne Stroeve of the US National Snow and Ice Data Center (NSIDC) commented "I hate to think what 2008 might have looked like if the weather patterns had set up in a more extreme way."[8] Nevertheless, 2008 saw a record low in the summer volume of sea ice,[9] which was almost 70% lower than the minimum volume in 1979.[10]

Arctic ice is in its death spiral.

Mark Serreze, NSIDC

Mark Serreze, a climate scientist at NSIDC, told the Guardian in 2007 "It's amazing. It's simply fallen off a cliff and we're still losing ice."[11] By 2008 his language had become even stronger: "No matter where we stand at the end of the melt season it's just reinforcing this notion that Arctic ice is in its death spiral."[12]

Summer Arctic sea ice appears to be disappearing more than 80 years ahead of the IPCC's prediction.

As predicted, winter sea ice extent is also declining steadily as a result of global warming.[13] Moreover, winter ice is thinning at record rates, with thickness decreasing by 19% last winter compared to the previous five[14] – which suggests that the rate at which extent is declining may soon increase too. It is not just the thickness of ice that is causing concern: as a result of the record melts, existing ice is now much younger, and prone to break up more easily (Fig 1.2).

Fig. 1.1 **Arctic sea ice extent**. Satellite imagery of sea ice extent in September 1979, and at a record low in September 2007. Source: NASA

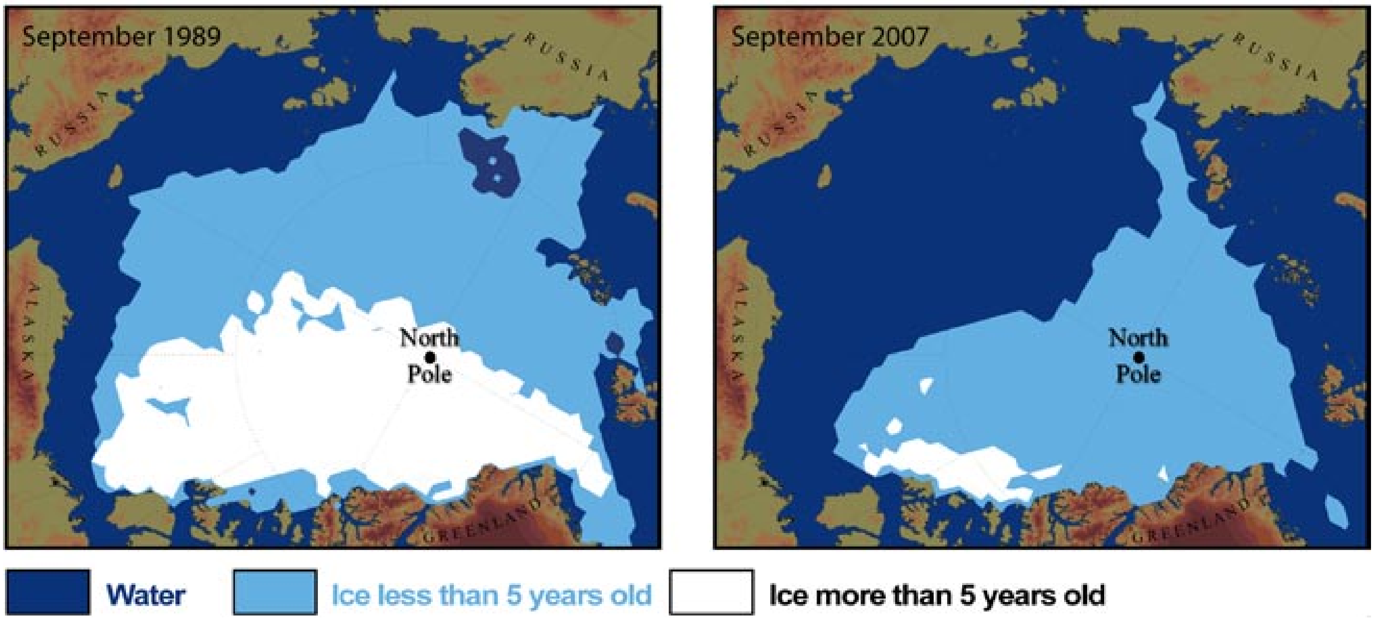
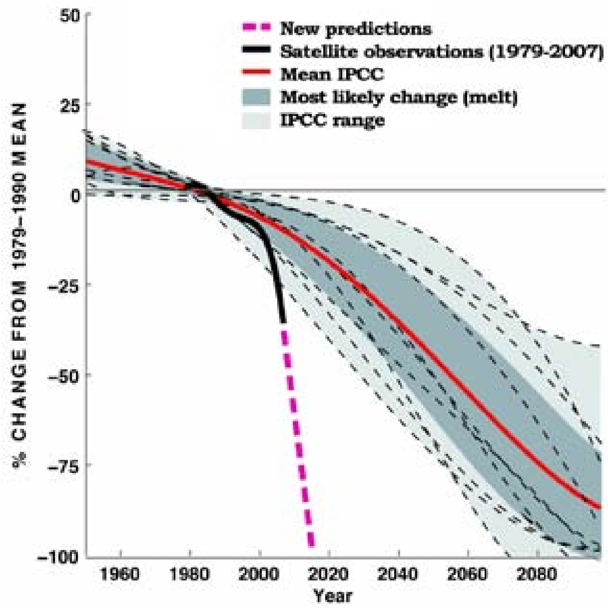


Fig 1.2 **Age of Arctic sea ice**. The image on the left shows the age of sea-ice at its minimum (summer) extent in September 1989, the right depicts the equivalent point in 2007. Source: Dr. Ignatius Rigor, Polar Science Center Applied Physics Laboratory, University of Washington

Given the unprecedented changes seen in recent years, many Arctic scientists are now predicting an ice-free summer Arctic by somewhere between 2011 and 2015.[15],[16],[17] Wieslaw Maslowski of the Naval Postgraduate College in California predicts an Arctic Ocean free of sea ice by the summer of 2013, but notes that on the basis of data from 2007 and 2005, this prediction could already be seen as too conservative.[18] Louis Fortier, scientific director of the Canadian research network ArcticNet, believes that the ocean could be ice-free in summertime as soon as 2010,[19] while NASA climate scientist Jay Zwally suggests 2012.[20] Commenting on such early predictions, Dr Walt Meier at the NSIDC said "Five years ago that would have got someone laughed out of the room; but no-one's laughing now."[21]



To put this in the context of IPCC predictions, according to the 2007 IPCC report "summer sea-ice is projected to disappear almost completely towards the end of the 21st century."[22] Summer Arctic sea ice thus appears to be disappearing more than 80 years ahead of the IPCC's prediction, even though this was made as recently as 2007.

Contrary to what the media's coverage may suggest, the significance of the Arctic melt is not simply a matter of displaced polar bears, new shipping routes, or easier access for oil and gas companies.

Fig 1.3 **Predicted Arctic melt**. Minimum summer sea-ice extent, observed and predicted, 1950-2100. Arctic ice extent loss observed to September 2007 (black line) compared to IPCC modelled changes (grey backgrounds and dashed black lines, mean as red line) using the SRES A2 scenario (high greenhouse gas emissions). The dashed pink line represents the trajectory predicted by some Arctic scientists (see above).

Original Source: Dr Asgeir Sorteberg. Bjeknes Centre for Climate Research and University Center at Svalbard, Norway.

Consequences of early Arctic sea ice loss

An earlier than predicted onset of ice-free arctic summers will cause additional heating, additional greenhouse gas emissions and additional sea level rise, over and above those foreseen by existing climate models. As NOAA deputy chief Richard Spinrad says, "What happens in the Arctic actually does not stay in the Arctic."[23]

Additional heat in the Earth system

Albedo is a measure of the reflectivity of the Earth's surface. White ice has an albedo of between 0.8 and 0.9 – meaning that it reflects between 80% and 90% of the solar radiation it receives. As a result, the Arctic sea ice cap reflects the great majority of the sun's energy that hits it. However dark surfaces, such the sea, can have an albedo of less than 0.1 – meaning that as the Arctic ice caps reduce in extent, and cloud cover is low, the larger area of exposed ocean will 'flip' from reflecting between 80% and 90% of the sun's energy to absorbing around 90% of it – a process known as the 'albedo flip'.

Most IPCC models lack a robust treatment of sea ice processes.[24] Rapid sea ice loss events, where significant ice loss occurs over a 5–10-year period, are included in some IPCC models, but are assumed to occur only in the second half of this century. A team of researchers led by David Lawrence at the US National Center for Atmospheric Research (NCAR) has found that, should rapid sea ice loss events occur, there will be "a strong acceleration of Arctic land warming" – broadly due to the albedo flip. This increased land warming would be on average 3.5 times that previously predicted by models, involving in some coastal regions an average 5°C temperature rise over the same 5–10 year period.[25] (see figure 1.4, below).

Projections of the global implications of this warming of the Arctic region are lacking, as there are currently no climate models that predict an ice-free Arctic as early as it now seems likely to occur. It is therefore difficult to predict the global temperature effects of such a regional heating. What we do know is that an Arctic free of summer sea ice will be absorbing extra heat into a global climate system already struggling with an overabundance of it.

An early arctic melt will cause additional heating, additional greenhouse gas emissions and additional sea level rise, over and above those foreseen by existing climate models.

Additional greenhouse gas emissions in the atmosphere

Permafrost is permanently frozen, often carbon-rich soil mainly found in the northern latitudes of Russia, Europe, Greenland and North America, usually defined as soil that has remained below freezing for at least two winters and the summer in between. Recent research has shown that permafrost contains twice as much carbon as previously thought[26] – in total 1,672 billion tonnes of carbon worldwide, equivalent to more than double the 750 billion tonnes in the atmosphere today. As permafrost melts it releases carbon into the atmosphere in the form of carbon dioxide or methane.

As the summer ice-melt increases, the Arctic region will warm significantly, as noted above. The increased warming will penetrate up to 1,500km inland, covering

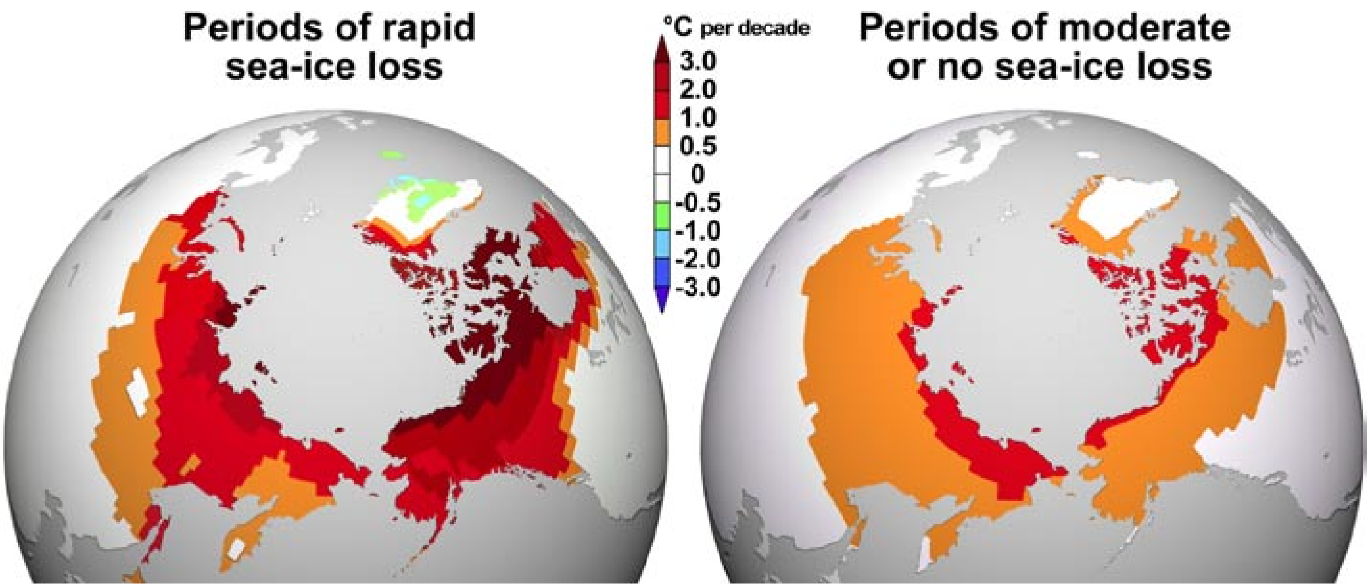


Fig 1.4 **Simulated future Arctic temperature trends**. Regional heating of the Arctic following rapid sea ice loss events. Following such events, heating extends up to 1500km inland from the sea. Source: Steve Deyo, ©University Corporation of Atmospheric Research

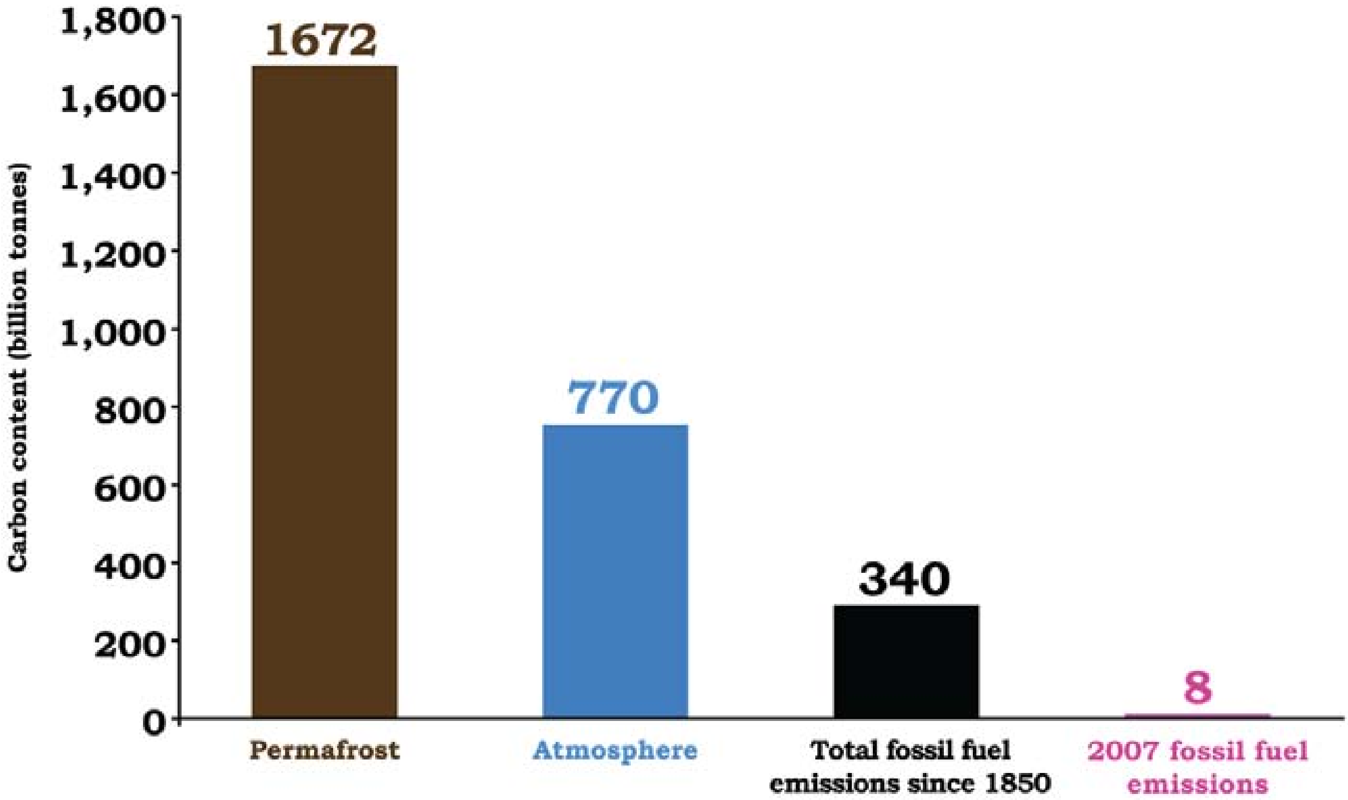


Fig 1.5 – **Carbon content**. Volumes of total carbon content estimated in billion tonnes. Sources: Schuur et al., UNEP, CDIAC.

almost the entire region where permafrost is described as 'continuous' – in other words where it is permanently frozen and its carbon locked away.[27] The NCAR researchers found that accelerated Arctic land warming "may trigger rapid degradation of currently warm permafrost and precondition colder permafrost for subsequent degradation under continued warming".[28]

If sea-ice continues to contract rapidly over the next several years, Arctic land warming and permafrost thaw are likely to accelerate.

David Lawrence, NCAR

As David Lawrence of NCAR observes, "if sea-ice continues to contract rapidly over the next several years, Arctic land warming and permafrost thaw are likely to accelerate."[29] This would inevitably lead to substantial greenhouse gas emissions from the permafrost. This alarming scenario seems all the more likely in view of a 2006 field study which found rapid degradation in key elements of the permafrost "that previously had been stable for thousands of years."[30]

The potential climate impacts of such emissions are enormous: according to Sergei Zimov, chief scientist at the Russian Academy of Sciences' North-Eastern Scientific Center "The deposits of organic matter in these soils are so gigantic that they dwarf global oil reserves … If you don't stop emissions of greenhouse gases into the atmosphere [as a result of melting permafrost] … the Kyoto Protocol will seem like childish prattle."[31]

Yet it appears that this phenomenon has already begun to take effect. The 2007 UN Environment Programme (UNEP) report Global Outlook for Ice and Snow[32] reports that

> Rising temperatures and the thawing of frozen land or 'permafrost' is triggering the expansion of existing – and the emergence of new – water bodies in places like Siberia. These are bubbling methane into the atmosphere with emissions so forceful they can keep holes open on the lakes' icy surfaces even during sub-zero winter months.[33]

Even more alarming, says Oliver Frauenfeld of the NSIDC, is that "permafrost is not incorporated at all in any global climate models right now."[34] We simply do not know how much carbon could be released from the melting permafrost, nor do we know the proportion which would be released in the form of methane, a greenhouse gas 25 times more potent than carbon dioxide (CO_2). David Lawrence has suggested we will only have some idea of potential permafrost carbon release once it is modelled, but this could take "years".[35]

There is also a possibility that regional warming could trigger the release of methane deposits below the Arctic Ocean.

There is also a possibility that regional warming could trigger the release of methane deposits below the Arctic Ocean, which would have an impact of even greater magnitude than the thawing of the permafrost. After a recent expedition to the East Siberian Sea, Dr Orjan Gustafsson of Stockholm University reported the following findings:

> we documented a field where the release was so intense that the methane did not have time to dissolve into the seawater but was rising as methane bubbles to the sea surface … The conventional thought has been that the permafrost 'lid' on the sub-sea sediments on the Siberian shelf should cap and hold the massive reservoirs of shallow methane deposits in place. The growing evidence for release of methane in this inaccessible region may suggest that the permafrost lid is starting to get perforated and thus leak methane … We have found elevated levels of methane above the water surface and even more in the water just below. It is obvious that the source is the seabed.[36]

These preliminary results are cause for concern – the East Siberian shelf is around 1,500,000 square kilometres in size, over four times the size of Germany, and contains an estimated 1,400 billion tonnes of locked up carbon.[37]

If the Arctic is ice-free in summer, within the next decade a warmer ocean could lead to the thawing of significant volumes of methane from the sea bed.

Worryingly, global methane levels already appear to be on the rise. MIT researchers have found that since early 2007, several million additional tons of methane have been released into the atmosphere, ending a period of stability in methane levels during the 1990s.[38] What has caused this increase is not yet known. It seems unlikely to be directly from human sources, since the past decade has seen concerted efforts to control manmade methane from landfill and gas leakage.[39] In the context of the observed warming of Arctic permafrost over the last several decades[40], it seems likely that the thawing of this carbon-rich soil will have played a part in increasing methane emissions levels, which makes further research into warming permafrost and peat bogs a priority.

The East Siberian shelf contains an estimated 1,400 billion tonnes of locked up carbon.

Additional sea level rise

Arctic sea ice melt will not raise sea levels – floating sea ice does not displace more water as it melts. However, as noted above, when the Arctic becomes ice-free in summer, the region will warm rapidly,[41] and this warming will extend up to 1,500km inland. In this event, the Greenland ice sheet will come under ever greater warming pressure. The ice sheet contains 2.9 million cubic kilometres of ice – the second largest body of ice on earth, holding 6% of all fresh water on the planet. Research in 2004 published in *Nature*, suggested that Greenland's 'critical melt threshold' is 3°C of regional warming.[42] If this point is passed the ice sheet is likely to melt away completely, leading to an eventual sea level rise of around 7 metres. By considering IPCC emissions scenarios, researchers concluded that the "Greenland ice-sheet is likely to be eliminated by anthropogenic climate change unless much more substantial emissions reductions are made than those envisaged by the IPCC."[43]

Fig 1.6 – **Permafrost coverage** in the northern hemisphere. Source: UNEP

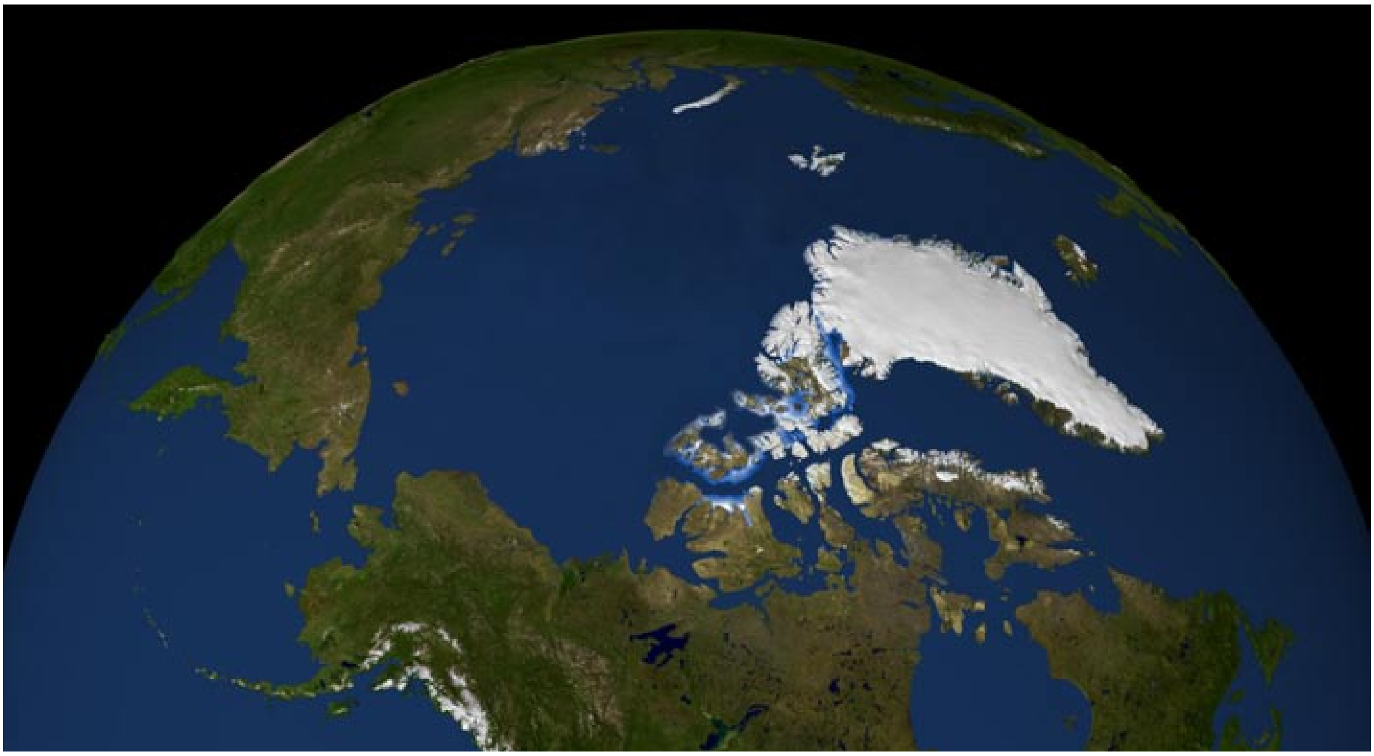


Fig 1.7 – **Would Greenland be unaffected?** How long before we see this image in reality? If predictions that the Arctic could be ice free in summer as soon as 2011-2015 are realised, rising ocean and atmospheric temperatures will put increasing pressure upon the Greenland ice sheet. Unmodified source: NASA.

The question is, how long would the melt take? It is important to understand the timescale over which this will occur – according to the Nature article the ice sheet will disappear "over the next 1,000 years or more."[44] However, new research published in 2007 is suggesting that the Greenland and Antarctic ice sheets are already melting faster than predicted by existing global climate models, (see below), and that "In both continents, there are suspected triggers for the accelerated ice discharge … and these processes could rapidly counteract the snowfall gains predicted by present coupled climate models."[45] Thomas Mote of the Climatology Research Laboratory at the University of Georgia found the summertime melt in Greenland in 2007 to be the most severe to date, 60 per cent worse than the previous highest level, in 1998.[46] The edges of the ice sheet are melting up to 10 times more rapidly than earlier research had indicated, and the ice-sheet height is falling in places by up to 10 metres a year.[47] James Hansen, head of NASA's Goddard Institute for Space Studies, has stated that it is difficult to see how a warming Arctic which had lost its summer sea ice could maintain the Greenland ice sheet.[48]

It is difficult to see how a warming Arctic which had lost its summer sea ice could maintain the Greenland ice sheet.

James Hansen

The planet is changing faster than the IPCC predicted

Sea levels will rise faster

It is already clear that the range of sea level rise (18–59cm by 2100)[49] projected in the 2007 IPCC report is an underestimate – the IPCC themselves noted that their projection does "not include uncertainties in climate-carbon cycle feedbacks nor the full effects of changes in ice sheet flow, therefore the upper values of the ranges are not to be considered upper bounds for sea level rise.'[50]

As Michael Oppenheimer of the IPCC and several colleagues have noted, rapid, dynamic ice sheet melting processes in Greenland and the West Antarctic, "have already had a significant effect on sea level over the past 15 years and could eventually raise sea level by many meters".[51] Oppenheimer adds that existing IPCC models that fail to take account of such processes "cannot fully explain observations of recent sea level rise, and accordingly, projections based on such models may seriously understate potential future increases".[52]

In 2007, Stefan Rahmstorf of the Potsdam Institute for Climate Impact Research published research which suggests that, taking account only of sea level rise trends during the 20th century (and without including an assessment of 'dynamic' ice sheet melt processes), under IPCC scenarios for future emissions we would see a sea level rise in 2100 of between 0.5 and 1.4 metres above 1990 levels.[53] These conclusions are supported by a series of other studies. For example, research published in January 2008 by Dr Eric Rignot and six of his colleagues found that ice loss in Antarctica increased by 75% in the decade to 2006 as a result of a speed-up in the flow of its glaciers.[54]

Sea level rise in between 80cm and 2 metres places us firmly in the region of impacts orders of magnitude greater than any we have seen to date.

A study by the British Antarctic Survey, using satellite imagery, tracked 300 previously unstudied glaciers in Antarctica and concluded that they were losing ice faster than the IPCC reported in 2007 and thus leading to greater sea level rise than predicted.[55] The researchers suggest in their report that "mass loss from West Antarctica is probably large enough to outweigh mass gains in East Antarctica and to make the total Antarctic sea level contribution positive."[56]

In a 2007 paper published in Science, researchers at the Institute for Arctic and Alpine Research in Colorado conclude that "glaciers and ice caps are currently contributing about 60 percent of the ice delivered to the world's oceans and the rate has been markedly accelerating in the past decade."[57] They show that ice loss from mountain glaciers has been underestimated by existing climate models, and could contribute as much as an additional 0.25 metres of sea level rise by 2100.[58]

Beyond even the aforementioned predictions by Stefan Rahmstorf, using an analysis based on palaeoclimatic data a team of researchers led by NASA scientist James Hansen has argued that non-linear increases in melting of the Greenland and West Antarctic ice sheets could lead to sea level rise of between 0.5–0.6m on 1990 levels by 2050 and "in the order of metres"[59] toward the end of the present century. A recent study in Nature[60] argues that the rise over the century is likely to reach around 80cm, but rises of up to 2 metres cannot be ruled out.

While it is concerning that there is a growing body of opinion that sea level rises are likely to be greater than IPCC predictions, we should not fixate on whether sea-level rise by 2100 is 1, 2 or 5 metres. Discussing sea level rise in between 80cm and 2 metres places us firmly in the region of impacts orders of magnitude greater than any we have seen to date; in his 2006 report to the UK Government on the economics of climate change, Sir Nicholas Stern described the consequences of a 1 metre sea level rise:

> currently, more than 200 million people live in coastal floodplains around the world, with two million square kilometres of land and one trillion dollars worth of assets less than one metre elevation above current sea level. One-quarter of Bangladesh's population (~35 million people) lives within the coastal floodplain. Many of the world's major cities (22 of the top 50) are at risk of flooding from coastal surges, including Tokyo, Shanghai, Hong Kong, Mumbai, Kolkata, Karachi, Buenos Aires, St Petersburg, New York, Miami and London. In almost every case, the city relies on costly flood defences for protection. Even if protected, these cities would lie below sea level with a residual risk of flooding like New Orleans today. The homes of tens of millions more people are likely to be affected by flooding from coastal storm surges with rising sea levels. People in South and East Asia will be most vulnerable, along with those living on the coast of Africa and on small islands."[61]

Carbon sinks are more vulnerable to temperature rise

At present, the Earth's carbon sinks effectively provide us with a 50% discount on our greenhouse gas output, by absorbing almost half of all anthropogenic emissions.[62] Their ongoing survival is vital in helping us to stabilise our climate, but their future is uncertain. The Southern Ocean sink, making up about 15% of the Earth's total carbon sink capacity, has suffered a reduction in efficiency of up to 30% over the last 20 years.[63] Scientists have attributed this to the strengthening of winds around Antarctica, which has enhanced the ventilation of carbon-rich deep waters, speeding up their release of carbon into the atmosphere.[64] Corinne Le Quéré of the University of East Anglia states "climate change itself is responsible for the saturation of the Southern Ocean sink."[65]

At present, the Earth's carbon sinks effectively provide us with a 50% discount on our greenhouse gas output, by absorbing almost half of all anthropogenic emissions.

A paper in Nature by NOAA's John Miller concluded, on the basis of two decades of data from more than 30 sites, that due to changes in autumn plant respiration (and despite an increase in forest cover attested by satellite images) the ability of forests in the frozen north to soak up CO_2 was less than predicted by current models.[66] Tropical forests, as well, may draw down carbon less efficiently as temperatures rise. An October 2008 study in Geophysical Research Letters concluded that due to an increase in tropical forest temperatures and a reduction in cloud cover, photosynthesis (and thus CO_2 sequestration) in tropical forests may be more sensitive to temperature than predicted. The authors conclude that "[the forest studied] appears to be close to a high temperature threshold, above which CO_2 uptake drops sharply."[67]

Studies suggest that this reduction in the capacity of carbon sinks is happening earlier than the IPCC has anticipated.[68,69] As Dr Pep Canadell, executive director of the Global Carbon Project, puts it, "Fifty years ago, for every tonne of CO_2 emitted, 600kg were removed by land and ocean sinks. However, in 2006, only 550kg were removed per tonne and that amount is falling."[70]

As temperatures rise, sink capacity will degrade further and stores of carbon will start to release it into the atmosphere. A 2008 study, published in Nature Geoscience, states that in northern peatlands "a warming of 4°C causes a 40% loss of soil organic carbon from … shallow peat and 86% from … deep peat"[71]. This is particularly worrying, as northern peatlands are a significant carbon store, holding between 180 and 460 billion tonnes of carbon; to put this figure in context, the entire atmosphere holds around 750 billion tonnes.

Ecosystems are proving more vulnerable to climate change than anticipated

Yadvinder Malhi of the Environmental Change Institute (ECI) in Oxford leads a team which has concluded that Amazonia is warming at 0.25°C per decade, a rate 25 times faster than the temperature increase at the end of last ice age.[72] As a result, recent periods of drought in parts of the region have increased the frequency of forest fires. With a total biomass store of 120 billion tonnes of carbon across Amazonia and predictions of increasing drought in the east of the region, there is the potential for the release of large amounts of stored carbon by wildfires. A review of climate tipping points, led by Tim Lenton of the University of East Anglia, and published in early 2008, states that Amazon dieback could happen in less than 50 years.[73]

A wide-ranging study led by the Goddard Institute of Space Studies found that anthropogenic warming was already causing "significant changes in physical and biological systems … on all continents and in most oceans";[74] it concluded that 90% of changes in biological systems over the past 38 years were consistent with warming trends, and suggested that warming is likely to be a huge driver of shifts in ecosystems. The lead author of the report, Dr Cynthia Rosenzweig, comments that "The study shows the sensitivity of a broad range of systems to relatively low amounts of warming – a global average of 0.6°C since 1970. This then exacerbates concerns about future impacts of projected warming of 1.1 to 6.4°C – the IPCC Working Group 1 likely range – at the end of the 21st century."[75]

With a total biomass store of 120 billion tonnes of carbon across Amazonia and predictions of increasing drought in the east of the region, there is the potential for the release of large amounts of stored carbon by wildfires.

The tropical climatic zone is expanding

Since 1980, the area defined climatically as "tropical" has expanded by 277km in either direction away from the equator. This expansion, in just over 25 years, is greater than the worst-case IPCC scenario prediction for the entire 21st century,[76,77] and is likely to have significant effects, including "shifts in precipitation patterns affecting natural ecosystems, agriculture and water resources", over areas of the Mediterranean, the south-western United States, northern Mexico, southern Africa, southern Australia, and parts of South America.[78]

Conclusion: Change ahead of schedule

It has become clear from on-the-ground measurements that, in many cases, the observed impacts of climate change have raced ahead of the predictions made in the IPCC's 2007 report, even in the short time since it was published. Despite the best efforts of the climate science community to integrate new findings into the scientific understanding of the situation, the consequences of an early Arctic melt (additional heat inputs, emissions and sea level rise) are not included in existing climate models or predictions, and there is no obvious mechanism for speeding up the process of incorporating them into mainstream discourses such as that of the IPCC.

The challenge is that, in many cases, there is an assumption that the mechanisms of climate change are fully understood. In reality, our understanding of key components of the climate system is still rapidly developing. Given that policymakers struggle to respond adequately or quickly even to the predictions of the IPCC, the key global body for the collation and dissemination of climate change knowledge, one must ask how the rapidly developing picture of the changes caused by global warming can be made to impact on policy soon enough to provoke an adequate and timely response.

Targets

The discourse of targets is complicated, and in many cases somewhat confused.

At most climate conferences or meetings, it will be possible to find a delegate insisting that we need a particular level of reduction in emissions to avoid catastrophic, runaway or irreversible climate change. Stavros Dimas, the EU Commissioner for the Environment, recently stated that

> The European Union is trying to persuade the international partners to contribute in reaching an international agreement which will tackle effectively global warming and stop the global warming to about 2°C … by the year 2050, which will require reductions of emissions of the level of 50% globally or 60 to 80% by developed countries by 2050.[79]

This kind of formulation - "Avoiding temperature rise X will require a Y% cut by year Z" - is extremely common, yet it is also deeply problematic. The problem with such sweeping statements is summed up by Dr Paul Baer of EcoEquity in a report for the Institute of Public Policy Research: "Any analysis that connects CO_2 emissions to temperature increase must address a complex causal chain in which the key elements, while now well understood qualitatively, are subject to substantial quantitative uncertainty."[80] While we know a great deal about the processes that will bring about dangerous climate change, we cannot with such certainty infer a particular temperature rise from a particular reduction in greenhouse gas emissions.

Any analysis that connects CO2 emissions to temperature increase must address a complex causal chain in which the key elements, while now well understood qualitatively, are subject to substantial quantitative uncertainty.

Paul Baer, EcoEquity

Statements of the kind exemplified by Stavros Dimas are inevitably based on a range of assumptions, all of which are uncertain. Ignoring the complexity and uncertainty contained within those assumptions, many politicians are able to insist that their chosen emissions reduction target is an adequate one, simply by stating that "the science tells us so."

But what science does this refer to? Based on what assumptions? And what degree of risk does this imply?

The IPCC recommendations

To attempt to answer these questions, we begin with an appraisal of the recommendations of the IPCC.

The IPCC's 2007 Fourth Assessment Report states that, in order to limit global temperature rise to 2°C, global emissions must peak before 2015 and fall by 85% by 2050 – leading to concentrations of CO_2 in the atmosphere of approximately 450 parts per million by volume (ppmv) CO_2 equivalent.[81,82] They suggest a higher limit of 2.4° of temperature rise would be met by emissions peaking before 2015 and falling 50% by 2050 - leading to an atmospheric concentration of approximately 500ppmv CO_2 equivalent.

If one accepts the stipulation of the UN, the EU and the UK Government that warming "should not exceed 2°C above pre-industrial levels",[83] then by the IPCC's measure, the target for global emissions cuts should clearly be 85% in order to limit temperature rise to 2°C and the concentration to 450ppmv CO_2 equivalent.

However, if emissions cuts were to be apportioned equitably, an 85% global cut would require a greater reduction from the UK, as the environmental journalist George Monbiot comments in the Guardian with a few simple calculations:

> I looked up the global figures for carbon dioxide production in 2000 and divided it by the current population. This gives a baseline figure of 3.58 tonnes of CO_2 per person. An 85% cut means that (if the population remains constant) the global output per head should be reduced to 0.537t by 2050. The UK currently produces 9.6t per head and the US 23.6t. Reducing these figures to 0.537t means a 94.4% cut in the UK and a 97.7% cut in the US. But the world population will rise in the same period. If we assume a population of 9 billion in 2050, the cuts rise to 95.9% in the UK and 98.3% in the US.[84]

On a very simple reading of the IPCC's recommendations, then, emissions cuts of the order of 95–98% would be required in developed countries like the UK and USA.

However, the actual emissions cuts required to meet the IPCC greenhouse gas concentration target are likely to be higher still, as a result of features of the IPCC's assessment. The IPCC states that "emissions reductions … might be underestimated due to missing carbon cycle feedbacks".[85] It goes on to suggest that for a 450ppmv stabilisation level this underestimate reduces our global cumulative emissions budget – the total amount of greenhouse gases we can safely emit to achieve the atmospheric stabilisation level – by 27%.[86] We might wonder why their targets were not adjusted to reflect this, as a 27% reduction in the global emissions budget implies a global target even closer to a 100% cut by 2050.

Even greater emissions cuts will be necessary if a lower stabilisation level for atmospheric concentrations is required. While the IPCC suggests that limiting the global temperature increase to 2°C requires stabilisation at 450ppmv CO_2 equivalent, other studies conclude that to have a low risk of global temperature rise exceeding 2°C, concentrations need to be stabilised at 400ppmv CO_2 equivalent. In 2006, Malte Meinshausen of the Potsdam Institute, in a paper entitled "What does a 2°C target mean for greenhouse gas concentrations?", concluded

> Our current knowledge about the climate system suggests that only stabilization around or below 400 parts per million CO_2 equivalent will likely (85% probability) allow us to keep global mean temperature rise below 2°C in the long term.[87]

Recent studies support the need for emissions cuts at or close to 100% by 2050 if a 2°C maximum temperature increase target is to be met. Using a model cited in the IPCC reports, Andrew Weaver and colleagues at the University of Victoria in Canada modelled emissions cuts of between 20% and 100% by 2050 in 10% increments. Even with 90% global emissions cuts, temperature rise eventually broke the 2°C barrier. The study showed that cutting global emissions 100% by 2050 kept the temperature rise below 2°C, at 1.5°C.[88] Another paper published early in 2008 demonstrates that, as a result of the long lifetime of CO_2 in the atmosphere and the thermal inertia of the world's oceans, stabilising global temperatures would require the complete elimination of all CO_2 emissions by 2050.[89]

Putting the IPCC targets in the context of the latest science

The cut-off date for submissions to the 2007 IPCC Fourth Assessment Report was December 2006,[90] and as detailed in the previous section there have been a number of significant developments in the ensuing two years.

Emissions targets are rarely viewed in the context of the accelerating impacts of climate change.

Emissions targets are rarely viewed in the context of the accelerating impacts of climate change. This is largely due to the dominance of climate models in the science of target setting. Global climate models are incredibly sophisticated and take a long time to update. We also know, as Ken Caldeira, a researcher at the Carnegie Institution Department of Global Ecology at Stanford University observed recently, that "If anything, the history of climate modelling has been one of conservatism and underestimating the impacts of climate change."[91]

Existing climate models do not yet include many of the latest events discussed in Section 1, particularly the earlier than expected Arctic sea ice melt and its potential knock-on consequences. Over time, climate models will be recalibrated with this latest information; but for some of the more complex feedbacks this will take years.

Obviously it is far from ideal to have to wait so long to make an informed judgement on what the implications of these latest impacts are. The question therefore is, how can we draw general conclusions from this diverse set of changes without waiting for them to be incorporated into the climate models?

There is a tool for considering the impacts climate change causes in a more general way. It is the concept of climate sensitivity, and examining it in detail is useful in determining how we might guide a response based on the most recently observed impacts of climate change.

Climate sensitivity

Climate sensitivity sums up all the properties of the global climatic system into one relatively simple concept.

Climate sensitivity is defined as the predicted average global temperature rise following a hypothetical instant doubling of pre-industrial atmospheric CO_2 equivalent greenhouse gas concentrations. Pre-industrial atmospheric concentrations were approximately 280ppmv CO_2 equivalent. Therefore climate sensitivity is the predicted temperature rise which would ensue if atmospheric concentrations reached 560ppmv CO_2 equivalent. (Although with one important subtlety – see below.)

Climate sensitivity sums up all the properties of the global climatic system into one relatively simple concept. It provides a way of translating a CO_2 equivalent atmospheric stabilisation level into an average global temperature rise. It makes it possible to extrapolate a temperature rise from a given atmospheric concentration, and it is the tool the IPCC uses to calculate that a stabilisation level of 450ppmv CO_2 equivalent will lead to a 2°C temperature rise.

There is a feature of climate sensitivity that is potentially confusing, in that it is expressed as a temperature value. In order to translate a CO_2 equivalent concentration to a temperature rise, it is necessary to apply a coefficient which is itself a temperature.

Of course, the figures that are used to represent climate sensitivity in calculations are only estimates, as the Earth's climatic system is too complex for the true figure to be calculated with certainty. Nevertheless, we can use these estimated climate sensitivity figures to calculate temperature rises based on stabilisation levels lower than

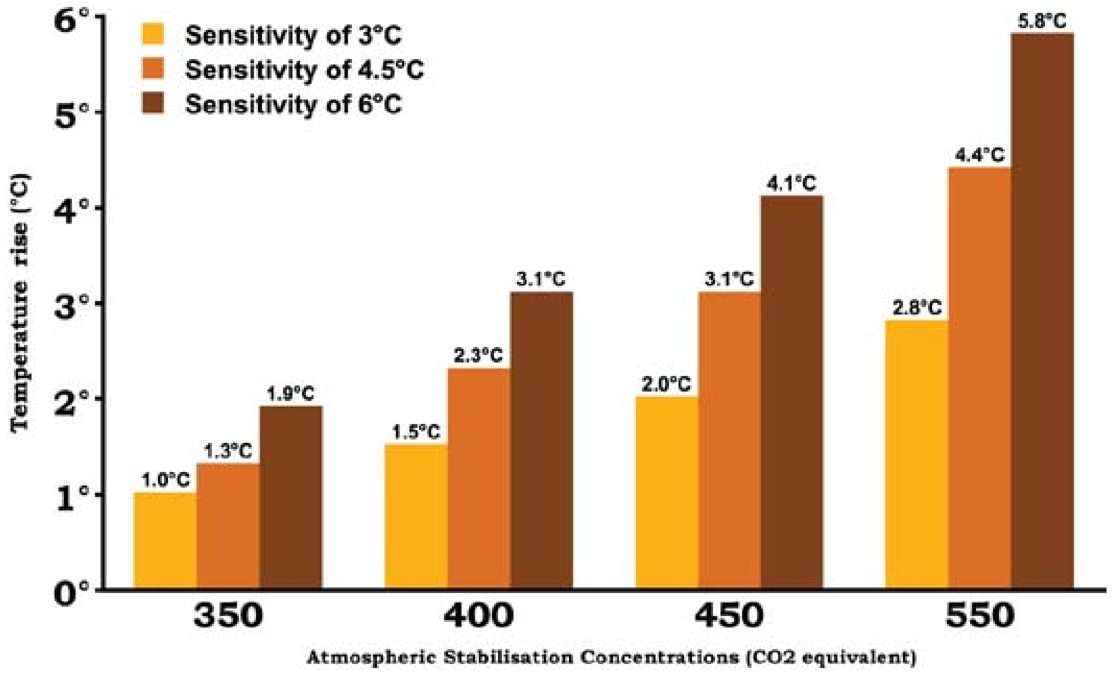


Fig 1.8 **Temperature rise from varying climate sensitivity** and atmospheric stabilisation levels in CO2 equivalent.

560ppmv CO_2 equivalent. The value that is chosen for climate sensitivity shapes our predictions about what acceptable targets are, as it dictates the temperature rise that will in theory result from a given atmospheric concentration of greenhouse gases. An example will make this clearer.

The IPCC estimates climate sensitivity to be between 2°C and 4.5°C, with a 'best estimate' of 3°C. In other words, if pre-industrial greenhouse gas concentrations were doubled, the average temperature rise would be somewhere between 2°C and 4.5°C, with 3°C being the most likely. The IPCC do caveat their estimate however, saying that "values substantially higher than 4.5°C cannot be excluded."[92]

The value that is chosen for climate sensitivity shapes our predictions about what acceptable targets are.

The cut in emissions that the IPCC says is necessary to restrict global temperature rise to 2°C – namely 85% by 2050 – is based on this 'best estimate' climate sensitivity of 3°C. But while this figure results in a 2°C rise at a stabilisation level of 450ppmv CO_2 equivalent, what rise would result if we instead assumed that the correct figure for climate sensitivity was actually at the higher end of the IPCC's estimated range, namely 4.5°C?

Such a question may seem contentious at first glance, but is in fact entirely legitimate. Indeed, the IPCC Working Group III has actually stated that "policymakers may want to use the highest values of climate sensitivity (i.e. 4.5°C) within the 'likely' range of 2–4.5°C set out by IPCC … to guide decisions."[93] This acknowledgement has serious implications for the IPCC's future modelling work, in which they generate scenarios for future emissions cuts and the temperature rise to which each scenario will lead. Despite noting the point that policymakers may wish to consider higher values of climate sensitivity to guide decisions, the Working Group III report concedes that a climate sensitivity of 4.5°C "would mean that achieving a target of 2°C … is already outside the range of [IPCC emissions reduction] scenarios considered in this chapter."[94]

In other words, the IPCC admits that, if the true figure for climate sensitivity is actually 4.5°C rather than 3°C, *none of its current emissions reduction scenarios will hold temperature rises to less than 2°C*. Global cuts of 85% will simply not be enough.

If climate sensitivity is actually any higher than 3°C, this will make a potentially vast difference to the speed and extent of the emissions cuts necessary. To return to the question, we can calculate[95] that with a 4.5°C climate sensitivity, a 450ppmv CO_2 equivalent stabilisation target would lead to a 3.1°C rise in temperature. Conversely, to hold temperature rise to 2°C would require a stabilisation level of 380ppmv CO_2 equivalent – well below the IPCC's suggested target of 450ppmv, and in fact slightly lower than the current concentration of atmospheric CO_2 alone (see below).

Unfortunately, such figures are not mere speculation: all the accelerating impacts discussed in Section 1 suggest the true value for climate sensitivity is higher than the current best estimate. In 2006 Barrie Pittock, then senior climate scientist at Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO), suggested that the "dated IPCC view might underestimate the upper end of the range of possibilities … Recent estimates of the climate sensitivity … suggest a higher range, around 2–6°C." Pittock notes this means that there is "a much higher probability" of climate sensitivity "exceeding the midlevel estimate of 3.0°C." [96]

The IPCC admits that, if the true figure for climate sensitivity is actually 4.5°C rather than 3°C, none of its current emissions reduction scenarios will hold temperature rises to less than 2°C. Global cuts of 85% will simply not be enough.

Climate sensitivity of 6 degrees?

In their paper 'Target Atmospheric CO_2: Where should humanity aim'[97], a group of paleoclimatologists headed by James Hansen argue that while the 3°C figure for climate sensitivity may be appropriate in the short term, in the long term increased warming will lead to higher temperature rises than suggested by a 3°C sensitivity value.

This is because climate sensitivity assumes that certain longer term aspects of the climate remain fixed. Ice sheet area, vegetation distribution and greenhouse gas emissions from soils or ocean sediments are assumed to remain at set values, and their potential to cause further temperature rise is ignored.[98] Together, these processes are termed 'slow feedbacks', and Hansen notes that because climate sensitivity does not include them, over longer time periods a figure of 6°C would be a more likely temperature rise associated with a doubling of atmospheric CO_2. [99] This would mean that in the long term, if the value of climate sensitivity were indeed 6°C, then a stabilisation target of 450ppmv CO_2 equivalent would lead to an eventual temperature rise of 4.1°C.

The key uncertainty here is the definition of 'long term'. Hansen suggests that slow feedbacks could "come into play on timescales as short as centuries or less..."[100] but this is a broad range and uncertainties prevent it being quantified more precisely. The sooner slow feedbacks take effect, the less time we have. In this context, the impact of an early Arctic melt on permafrost and Greenland, described in the first section, is concerning, suggesting that slow feedbacks may affect the climate sooner than previously thought.

Higher sensitivity means lower targets

James Hansen told scientists and others at an American Geophysical Union conference in December 2007 that "We either begin to roll back not only the emissions [of CO_2] but also the absolute amount in the atmosphere, or else we're going to get big impacts … We should set a target of CO_2 that's low enough to avoid the point of no return."[101]

In order to achieve the return of the Arctic sea-ice, Hansen and his co-authors have identified the target as in the range 300–325ppmv CO_2 equivalent, well below the current level.[102] Given the key role the Arctic plays in the climate system a precautionary approach would therefore suggest a long term target of 300ppmv CO_2 equivalent. This would rule out a domino effect of sea-ice loss, albedo flip, a warmer Arctic, a disintegrating Greenland ice sheet, more melting permafrost, and further knock-on effects of massively increased greenhouse gas emissions, rising atmospheric concentrations and accelerated global warming.

Any proposal for a target higher than 300ppmv would imply confidence that it is safe to leave the Arctic sea ice melted, and an assumption that this would not bring about the train of consequences just described. This is, implicitly, the view of all the major nations and organisations involved in setting climate policy. Accordingly, they must be challenged to provide a reasoned argument as to why leaving the Arctic Ocean free of ice in summer is safe. If they cannot, the only acceptable course of action is clear.

Hans Joachim Schellnhuber, Director of the Potsdam Institute for Climate Impact Research in Germany, supports this view – telling the Guardian in September 2008 that "nobody can say for sure that 330ppm is safe. Perhaps it will not matter whether we have 270ppm or 320ppm, but operating well outside the [historic] realm of carbon dioxide concentrations is risky as long as we have not fully understood the relevant feedback mechanisms."[103]

Hansen's contention that we have already passed a 'safe' level of atmospheric carbon is also supported by a paper recently published in the Proceedings of the National Academy of Sciences[104], which suggests that at current atmospheric concentrations, and assuming only a 3°C climate sensitivity, we are committed to 2.4°C of warming (or 4.3°C with a higher sensitivity of 4.5°C), as the radiation-masking effect of aerosols is reduced by anti-air pollution measures. To be clear, their analysis suggests that if we maintain current atmospheric concentrations, we are heading for a warming of greater than 2°C this century.

Any proposal for a target higher than 300ppmv would imply confidence that it is safe to leave the Arctic sea ice melted.

Aerosols

Another issue that needs to be taken into account is that of small airborne particles known as aerosols. Although the effects of aerosols are currently poorly understood, it is known that they act to mitigate climate change. However, they are destined not to do so for much longer.

As well as emitting CO_2, the burning of fossil fuel also produces aerosols – these microscopic particles suspended in the atmosphere include smoke, soot and sulphates. Aerosols have a net cooling effect on the atmosphere: both directly, by reflecting sunlight themselves, and so reducing the amount that reaches the ground; and indirectly, in that they have the effect of 'seeding' clouds, which also have a reflective effect.[105]

The effects of aerosols is popularly referred to as 'global dimming', because the overall aerosol impact is to reduce, or dim, the sun's radiation, thus cancelling out some of the warming effect of greenhouse gases. Not all aerosols in the atmosphere are manmade: for example, the 1991 eruption of Mount Pinatubo in the Philippines released 20 million tonnes of sulphur particles into the atmosphere, leading to a global cooling of around 0.3°C during the following year.[106]

However, as well as counteracting global warming, aerosols cause acid rain and other forms of pollution, while the aerosols produced by burning coal alone kill around 60,000 people through respiratory diseases and heart attacks annually in the US.[107] In response to these localised harmful effects there has been an effort to reduce aerosol emissions, in the short term this makes the air cleaner, but at the same time reduces aerosols cooling effect.

If we were to rapidly end the combustion of fossil fuels therefore, the majority of the aerosols would be rained out of the air in a few weeks, thus removing their cooling effect, but the unmasked heating of the CO_2 and other greenhouse gases already in the atmosphere would remain for much longer – for centuries in the case of CO_2.

Dr Chris Jones from the UK Meteorological Office's Hadley Centre for Climate Prediction and Research likens this situation to driving with your foot on the accelerator and the brake at the same time.[108] By burning fossil fuels we are both causing heating, and simultaneously masking some of that heating through aerosol production.

By burning fossil fuels we are both causing heating, and simultaneously masking some of that heating through aerosol production.

The crucial, and often misunderstood, problem is that the accelerator does not represent the current flow of greenhouse gas emissions, but rather their atmospheric concentrations – the total stock of greenhouse gases in the atmosphere. So, as we reduce emissions, we cut aerosol production and effectively let our foot off the brake, while it remains on the accelerator – in other words, aerosols are rapidly rained out of the sky but the stock of greenhouse gases in the atmosphere remains steady. We will only start to take our foot off the accelerator as atmospheric concentrations fall, and in the meantime the atmosphere will go on heating.

As already mentioned, in order for atmospheric greenhouse gas concentrations to decrease, our emissions rate must fall below the Earth's carbon sink capacity – the rate at which carbon is currently sucked from the atmosphere by oceans, soils and plants. That would require emissions to fall more than 50% below their current level[109]: until then, our foot is still firmly placed on the accelerator.

While the IPCC's scenarios assume a declining level of sulphate aerosol in the future due to clean air legislation[110], greenhouse gas emissions cuts faster and deeper than they consider – the kind that will be necessary if we are to reduce atmospheric concentrations below sink capacity – would lead to an earlier and greater fall in aerosol levels. Rapid decarbonisation will simultaneously reduce the cooling effect of aerosols, giving a short-term boost to temperature rise, and is likely to make constraining temperature rise more challenging.

Cutting 'black carbon' soot emissions could however offset some of this effect. While most aerosols act to cool the planet, black carbon has the opposite effect. Black carbon particles (which are created by the combustion of diesel, coal and biomass and other solid fuels) act in a similar manner to greenhouse gases by absorbing heat energy, and by changing the reflective properties of ice sheets, falling on them and diminishing their albedo. A study by atmospheric scientist V. Ramanathan of the Scripps Institution of Oceanography and University of Iowa chemical engineer Greg Carmichael has found that soot and other forms of black carbon may have a total heating effect three times that estimated by the IPCC, greater than that of any greenhouse gas, and 60% stronger than that of CO_2.[111] The Arctic icecap remains particularly vulnerable to enhanced melting due to black carbon, as air circulation currents tend to trap pollutants from the northern hemisphere within the Arctic circle. Research is ongoing into how much black carbon soot is increasing polar melt, and into ways to limit the effects of this pollution.[112]

As levels of aerosols produced by burning fossils fuels are reduced, cutting black carbon emissions could balance some of the loss of cooling that would occur. The whole field of aerosols needs further research, particularly if China and India – a major contributor to 'global dimming' –start to regulate air pollution more stringently. If aerosol emissions from India and China diminish, we could see a significant spike in temperatures.

A responsible approach to risk

Nick Mabey, Chief Executive of E3G, often recounts an important thought experiment: "If you were to go into a Security Council assembly at the UN, and explain to them that you'd prepared for a medium-sized terrorist attack, you would be thrown out of the room." This is not how we as a society tend to deal with risk. As Mabey says, we generally prepare for an outcome that is "just off worst-case"[114].

We should therefore be asking why we as a society are preparing for "medium-sized climate change". Why are we taking climate sensitivity at a best estimate of 3°C without fully exploring the implications of the possibility that it might be higher?

When it comes to managing the risk of serious climate instability, the politics must fit the science and not the other way round.

Quality of Life Commission, Conservative Party[113]

Stefan Rahmstorf of Potsdam University and an IPCC lead author has said that "In view of the uncertainty, what is needed is a risk assessment rather than predictions of abrupt climate change."[115] The Institute for Public Policy Research's report High Stakes[116] is one of very few publications to take a risk management approach to target setting. It notes that "What science alone cannot tell us is what should be considered 'acceptable risk' … Such a choice demands not just scientific reasoning, but also ethical and political judgment."[117]

We cannot tell for certain what the correct figure for climate sensitivity is, or how much aerosols counteract the greenhouse effect; we do not know exactly how much the permafrost will melt; how the broader carbon cycle will respond to the heating we impose on it; or what the implications of an ice-free Arctic really are, including whether methane will start bubbling in large volumes from the Arctic Ocean.

But what we can say is that there are indicators and observations, pointing us towards the conclusion that our climate is more sensitive than we previously thought. And we can re-evaluate our response in light of these, today. While we need a more sophisticated understanding of many earth processes, and while our climate models need more computing power and require further refinement, it would be the height of folly to wait until we had resolved these shortcomings before taking steps towards reducing the risks to which the situation is exposing us.

We should be able to recognise the uncertainties implicit in climate models, and frame what they tell us in light of a precautionary response, taking a risk-averse approach to what is in effect our life support system.

When approving new pharmaceuticals, or designing aircraft, bridges, and large buildings, strict risk standards are applied: a widely used rule of thumb is to keep the risk of mortality to less than one in a million. If someone told you there was a 1% chance of the plane you were about to get on crashing, you would probably stay at home. However, governments have been quietly accepting much higher risks in setting climate change targets. For example, Sir Nicholas Stern's suggestion that we aim for a 550ppmv CO_2 equivalent target[118] means, by his own admission, accepting a 20–30% global species loss, as well as coral reef destruction, ice sheet disintegration, and economic damage "on a scale similar to [that] associated with the great wars and the economic depression of the first half of the 20th century".[119]

As University of Chicago Professor Frank H. Knight has suggested it is possible to draw a distinction between risk and uncertainty.[120] Risk refers to situations where the probability of something happening is well known, as in roulette; while uncertainty relates to situations where calculating probability is impossible – for example the price of gold in 20 years' time. Further down the order comes ignorance, where one does not even know all the things that might go wrong – in climate terms, these may be variables in the global climatic system of which we are simply unaware – the 'unknown unknowns'. One final relevant term is indeterminacy, which refers to situations where the probability of an event is incalculable because it is not a matter of prediction, but of decision. Society's response to climate change is a matter of indeterminacy – future emissions levels are indeterminate, as how far we reduce them will be consequent upon millions of actions and decisions taken all across the world.

Larry Lohmann of the environmental and social justice consultancy Corner House sums up the way to approach these different concepts: "Problems posed by risk, uncertainty, ignorance and indeterminacy each call for different kinds of precaution. Risk fits easily into economic thinking, because it can be measured easily. Uncertainty, ignorance and indeterminacy, however, call for a more precautionary and flexible, less numerical approach."[121]

It may or may not be possible to reduce the climate risk to a one in a million chance of catastrophe. What we must therefore begin to do is to be more honest about the areas where we are uncertain or ignorant, while doing everything in our power to reduce the risk we currently face. Because we know emissions levels will be determined by decisions we take, we have a key lever to pull in addressing indeterminacy, and we should embrace it – we cannot go on gambling on how far we can push the system before it breaks.

Achieving climate safety

Scientifically

In their 'Target Atmospheric CO_2' paper, Hansen and his co-authors differentiate between 'tipping levels' and what they term the 'point of no return'. They explain that while we are now past the 'tipping level' in the climate system, atmospheric concentrations being too high, that does not mean we are past the 'point of no return', where it becomes impossible to correct the problem.[122] We still have an opportunity to take advantage of the time lag between the increase in atmospheric concentrations and the increase in temperature, and thereby avoid the "[w]arming 'in the pipeline', mostly attributable to slow feedbacks, [which] is now about 2°C".[123] Malte Meinshausen illustrates how this process operates in relation to the parameters of 400ppmv and 2°C, but it would apply equally to lower figures:

> Fortunately, the fact that we are most likely to cross 400ppmv CO_2 equivalent level in the near-term does not mean that our goal to stay below 2°C is unachievable. If global concentration levels peak this century and are brought back to lower levels again, like 400 parts per million, the climate system's inertia would help us to stay below 2°C. It's a bit like cranking up the control button of a kitchen's oven to 220°C (the greenhouse gas concentrations here being the control button). Provided we can soon start turning the control down, the actual temperature in the oven will never reach 220°C.[124]

To take advantage of this 'time lag', we must lower emissions sufficiently below the global carbon sink capacity, in order to reduce concentrations, and possibly increase the rate of absorption by carbon sinks artificially, a subject discussed in Section 3.

Until we lower our emissions below the current sink capacity, we are still making the problem bigger because of the cumulative levels of greenhouse gases in the atmosphere. Cutting emissions – even globally – by 80% does not solve 80% of the problem, because it is not annual emissions levels which are the problem, but rather the already high atmospheric concentration of greenhouse gases that causes the heating. We only begin to solve the problem when atmospheric concentrations start to fall.

Crucially, what we do not know is how far we can go over the tipping level in terms of atmospheric concentrations, and for how long we can stay there, before we pass 'the point of no return'. Given this uncertainty, and given the growing climate impacts that we are seeing today after a temperature rise of only 0.8°C, it would be prudent to lower the atmospheric concentration as quickly as possible.

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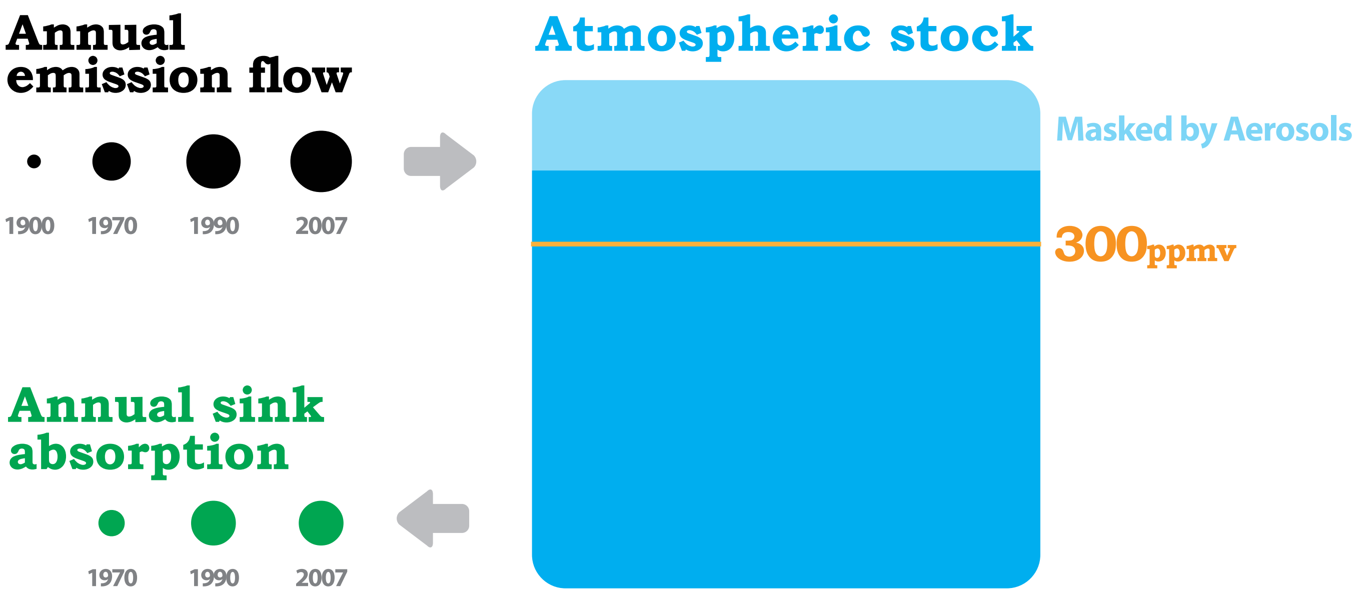

Fig 1.9 - **Understanding the challenge**. Annual emissions (black) entering the atmosphere (blue) and partially reabsorbed every year by carbon sinks (green). Emissions flow into the atmosphere (which is a stock, or a container of emissions, represented as concentrations). It is the blue square, the atmospheric concentrations that heat the planet, not the emissions. Emissions contribute to heating by increasing atmospheric concentrations (the stock). Concentrations will stabilise once emissions are equal to sink absorption (requiring approximately a 50% cut in global emissions levels). To reduce atmospheric concentrations requires emissions to drop below the level of sink absorption, in other words cuts greater than 50%. This would also see a reduction in the masking (or cooling) of aerosols (shown in light blue, offsetting some of the atmospheric concentrations), as burning fossil fuels is a large source of aerosols. This graph does not recreate the uncertainty bounds for aerosol masking. It also represents annually a process that is going on every second of every day, a constant flow of emissions in to and out of the atmosphere. Sources: Global Carbon Project, IPCC

Practically

It is difficult to overstate the scale of this challenge. In a recent paper, Kevin Anderson and Alice Bows of the Tyndall Centre for Climate Change Research demonstrate that achieving 450ppmv stabilisation level is "increasingly unlikely" and that the "current framing of climate change [by policymakers] cannot be reconciled with the rates of mitigation necessary to stabilise at 550ppmv CO_2 [equivalent] and even an optimistic interpretation suggests stabilisation much below 650 ppmv CO_2 [equivalent] is improbable."[125]

Taking the IPCC total emissions budget between 2000-2100 for a 450ppmv stabilisation (the total amount of carbon that can be released up to 2100 to stabilise concentrations at 450ppmv CO_2 equivalent) Anderson and Bows calculate the remaining portion of the budget after:

- Subtracting emissions already emitted to 2007;
- Subtracting emissions over the period emitted from carbon cycle feedbacks (as the IPCC note, carbon budgets should be reduced by 27% due to carbon cycle feedbacks, see p.14);
- Subtracting emissions over the period emitted due to deforestation (based on two optimistic deforestation reduction scenarios);
- Subtracting non-CO_2 emissions over the period, such as agriculture (based on a scenario which halves the emissions intensity of food production).

Taking this reduced budget, the authors choose three possible dates when emissions could peak (2015, 2020 and 2025), and run a set of scenarios using these variables. They conclude that to stay within the 450ppmv budget, over half of the scenarios run were in their words "politically unacceptable", requiring prolonged annual reduction rates greater than 8% per annum in 'energy and process' emissions – emissions associated with providing all our energy needs including transport, heat, electricity and industrial processes.[126]

The context which informs their assessment that such action is politically unacceptable is provided by the Stern Review, which noted that annual reductions of greater than 1% have "been associated only with economic recession or upheaval"[127]. Anderson and Bows note that:

> the collapse of the former Soviet Union's economy brought about annual emissions reductions of over 5% for a decade. By contrast, France's 40-fold increase in nuclear capacity in just 25 years and the UK's 'dash for gas' in the 1990s both correspond, respectively, with annual CO_2 and greenhouse gas emissions reductions of only 1% (not including increasing emissions from international shipping and aviation).

Using other scenarios, they note that 550 and 650ppmv CO_2 equivalent stabilisation levels would require emissions reductions "without a structurally managed precedent". A 450ppmv stabilisation is only possible, even with optimistic assumptions, if emissions peak by 2015 or before, and emissions cuts happen early. They conclude:

> If the 2°C threshold is to maintain any meaningful currency, industrialised nations have little option but to radically and urgently curtail their demand for energy.[128]

Anderson and Bows' paper makes sobering reading. Of a 650 ppmv target for stabilisation, likely to lead to between around 4 and 6 degrees of global temperature rise[129] – the authors note that "even this level of stabilization assumes rapid success in curtailing deforestation, an early reversal of current trends in non-CO_2 greenhouse gases and urgent decarbonisation of the global energy system."[130]

Conclusion

Given the impacts described in the first section, it seems likely that climate sensitivity is higher than the IPCC's best estimate of 3°C. If this is the case, then to hold temperature rise below 2°C requires atmospheric stabilisation at lower than 450ppmv, and therefore global cuts of more than 85% by 2050.

Anderson and Bows make clear that to have any chance of stabilising at or below 450ppmv this century requires emissions cuts now.

Anderson and Bows make clear that to have any chance of stabilising at or below 450ppmv this century requires significant emissions cuts now. Given their openly optimistic assumptions about future deforestation and agricultural emissions, the only lever we have to pull is reducing CO_2 emissions – those from electricity, transport, buildings and industry.

The key point is that unless we start making emissions cuts now, lower stabilisation rates will not be possible this century. The force of the science should give us clarity and agency. Whatever our target for future stabilisation, whether it is 450, 350, 300 or below, the actions we must now take are largely the same – we must race out of carbon as quickly as possible.

Once the process is well underway, and when we have a clearer idea of what we are capable of, we will have the space for sophisticated arguments about what an acceptable final stabilisation level is. Right now, we need to stop pretending that our current course of action, or even a continuation of the incremental change we have seen to date, will address the scale of the problem. We need a programme of change altogether more ambitious.

By leading the world in peaking emissions before 2015 and making significant cuts in the short-term, Britain can help smooth its future emissions pathway, and demonstrate that 450ppmv or lower is politically possible this century.

Solutions

It is no use saying, 'We are doing our best.' You have got to succeed in doing what is necessary.

Winston Churchill[131]

In fact, we must move first, because that is the key to getting others to follow; and because moving first is in our own national interest.

Al Gore[132]

The most basic test of a response to climate change should be whether it meets the scale of the challenge. Because the impacts of temperature rise above 2°C are potentially so severe, failing to work out a solution which avoids them is not an option. Aggressive stabilisation targets will not be achieved by compromised solutions that fail to address the whole problem. Whether we are aiming for a stabilisation level of 450ppmv, 350, 300 or lower, the actions we must now take are broadly similar – we must achieve a very near-term peak in emissions and a sharp decline, in order to keep the cumulative amount of carbon emitted as low as possible.

The advantage of this is that it gives us clarity in how we should approach the problem in the short term. We focus in this section on the potential the UK has, through acting as an exemplar country, to promote and encourage a global response which could deliver stabilization below 450ppmv. By demonstrating a commitment to cutting emissions backed by a clear programme to unilaterally deliver such cuts, the UK can begin a global race out of carbon, and unpick the deadlock preventing global political change in negotiating emissions reduction targets.

We focus on the potential the UK has to promote and encourage a global response which could deliver stabilization below 450ppmv.

The goal for the short-term period – the next five years – is to ensure that aggressive future stabilization levels are possible. This will require emissions peaking and falling faster than currently envisaged. While this clearly requires a global response, the key role the UK can play, in cutting energy use 10% in two years and therefore 'peaking' emissions early, is to demonstrate commitment and leadership, founded in action that matches the scale of the problem. Maintaining UK carbon sinks and stocks will prevent additional greenhouse gas emissions, while funding adaptation properly will make the clear case that with the impacts of climate change already being felt, action must be taken now.

In the medium term – over the next twenty years – we must put in place the infrastructure and drive the social changes which can decarbonise our society. This is another opportunity for strong leadership from the UK. Undertaking an infrastructure shift on the scale required by decarbonisation will provide opportunities to build resilience to the effects of climate change as they impact on us, drive job creation and economic prosperity, and establish the UK as a base of world-class expertise in zero-carbon technology and policy. Over this time period, research into carbon sequestration and geoengineering techniques can serve to inform us whether we have any other options in relation to preventing the harmful impacts of climate change.

While this cannot be a comprehensive action plan, there already exist numerous detailed studies of the different components discussed in this section, which are referenced throughout the text. With a clear idea of what kinds of measures will be necessary to meet the demands of the science, we will better understand the political, cultural, and administrative challenges to implementing change.

Short-term

10% by 2010

As an immediate, short-term objective, the UK should aim to cut its greenhouse gas emissions 10% by the end of 2010.

Delivering short-term actions provides the essential foundation for mid-term policies and long-term targets. Without short-term action, the real work has yet to begin.

The Tyndall Centre has made clear that:

> focusing on a long-term transition to low-carbon technologies is misguided, with real and substantial cuts being necessary in the short- to medium-term … Consequently, if the UK is to demonstrate effective leadership on climate change and actively pursue a 450ppmv pathway, it is incumbent on the Government to redress the balance of its policy agenda in favour of an early transition to a lower energy-consuming society.[134]

The earlier emissions peak, the easier the task of stabilising atmospheric CO_2 at a level lower than 450 CO_2 equivalent becomes. The essential short-term action is to reverse our current upward trend in emissions. While globally this will provide only a small reduction in emissions, it is the key switch of direction that can kick-start a race out of carbon. With a serious application of well-designed policies and political will, a reduction of 10% could be achieved by 2010.

The actions necessary to provide such a cut vary in the scale of the reductions they provide and in their acceptability to the general public. However, we know that very large reductions are achievable over time. We also know that the first 10% will be the easiest, cheapest and the most acceptable – made largely through reducing obvious examples of energy waste. This is the 'low-hanging fruit' of emissions cuts. Because climate science tells us that emissions cuts made now are more valuable than those made later, this low hanging fruit represents the highest-value actions we can take.

NGOs and the media have already raised some awareness on how to reduce energy and carbon emissions and we offer only a few suggestions here. The task at hand is to rapidly assess the public's preference for how we cut the first 10% by 2010, and then to put in place the immediate measures that support this.

A few suggestions:

- 'French Style' Electricity Tariffs[135] - inverted electricity charges, where energy becomes cheaper the less you use, providing clear incentives for people to find their own efficiency gains.
- Smart meters[136] - plugged into any plug socket at home, smart electricity meters give a live readout of energy use, providing householders with the feedback they need to reduce their consumption.
- Nationwide insulation and air tightness project[137] – implemented through a scale-up of existing energy efficiency programmes, delivering high thermal standards to a specified proportion of the nation's building stock.
- 55mph speed limit[138] –vehicles run most efficiently between 40 and 50 miles per hour, wasting significant amounts of energy above this level. Lower speed limits would dramatically reduce emissions from cars.
- Accelerated vehicle retirement programme[139] – The Texas Commission on Environmental Quality offers up to $3,500 to purchase and retire certain vehicles that are more than 10 years old - clearing the most polluting vehicles from the roads.
- Accelerated appliance retirement programme[140] – a similar scheme could be rolled out for the worst performing appliances: fridges, washing machines etc. – accelerating the transition to high efficiency, energy saving appliances.
- Ban the bulb[141] – bringing forward the EU ban of incandescent bulbs through rolling minimum standards set to match best-in-class appliances and installation practices – LED lights save 90% of the energy used by a traditional incandescent bulb and last 50 times as long.
- Halt domestic flights[142] – Outside of the need for air ambulances, it is difficult to justify domestic flights in the face of global climate damages. Rail and coach links can be improved and extended to take their place.

Cutting emissions successfully within a short time frame would demonstrate nationally and globally that the UK was taking immediate action consistent with its long-term policies. Most importantly it would reverse the trend of emissions growth to real emissions savings and spark the race out of carbon. Realising this objective would require a rapid quantification of the most promising steps to cut energy use, and an appraisal of the policies that would deliver them; a programme to canvas the public on preferred options; and an assessment of the carbon impact and the full costs and benefits of such a package.

Delivering short-term actions provides the essential foundation for mid-term policies and long-term targets.

Save UK carbon sinks

The natural carbon cycle, and in particular the capacity of ecosystems to act as carbon sinks, currently plays a vital role in limiting the impacts of human carbon emissions. The net sink effect of the carbon cycle has drawn down nearly half of all carbon released by human activity since 1959.[143] This means that the destruction of habitats such as forests or peatlands which contribute to the planet's carbon sink capacity is a major contributor to climate change – deforestation, for example, is responsible for approximately 20% of human emissions every year. [144]

Preserving this sink capacity is therefore of paramount importance, both within Britain and globally. There is a clear emissions-reduction argument for acting to preserve our own forests, wetlands, and to conserve and restore peatlands, a significant UK carbon sink, currently widely burnt to allow for grouse shooting. In the short-term we should direct substantial overseas investment towards sustainable forestry projects, and rapidly phase out imports of timber derived from unsustainable practices.

Fund adaptation

With the planet already warming and further temperature rise now inevitable, the IPCC provide a very cogent assessment of the current importance of adaptation – preparing societies to cope with the changing climate they exist in. However soon and seriously mitigation efforts are deployed, the IPCC note that "regardless of the scale of mitigation now undertaken, additional adaptation support for societies across the world will be required."[145]

They note that vulnerability to the effects of climate change is exacerbated by other societal stresses – current climate hazards, poverty, unequal access to resources, food insecurity, conflict and disease.[146] They are also clear that the capacity of a society to adapt to climate change is directly connected to its social and economic development.[147]

This assessment serves to underpin the clear moral argument for the global North, which bears historic responsibility for the cumulative emissions which have caused climate change, to fund and assist the parts of the world which will be disproportionately affected by its impacts to adapt.

Regardless of the scale of mitigation now undertaken, additional adaptation support for societies across the world will be required.

IPCC

Stern estimated the likely adaptation costs in less developed countries to run to tens of billions of dollars a year.[148] Yet current total pledged funds for adaptation stand at only $182 million. The UK, the biggest single contributor to funding adaptation has pledged $38 million.[149] Oxfam contrast this with plans to invest the equivalent of $347 million in "cooling systems for the London Underground, partly in preparation for climate change."[150]

In the short term, the UK should take a lead in pledging funds towards adaptation commensurate with the scale of the likely costs, and in arguing for stronger action on the international level, and building resilience in the societies which will be most immediately affected by climate change. This work will take time, and with large uncertainties over how quickly the impacts of climate change may increase, it is vital that it begins immediately.

Quite apart from the clear moral imperative to assist countries often unable to assist themselves because of limited access to finance for adaptation, we can pursue this course of action in the knowledge that it will be contributing to the socio-political stability of the planet. As the IPPR note in their 2008 assessment of the global security landscape, "Even under mid-range IPCC temperature increase scenarios, climate change is set to have a number of profound implications in the next two to three decades."[151] They identify China, South Asia, the Middle East and West Africa as regions particularly vulnerable to, variously, stress upon water supplies, declining food production, the shrinkage of glaciers which feed water sources, flows of environmental refugees. They conclude that this stress will fuel instability and that climate change "As a security issue… may quickly come to dwarf the issue of terrorism."[152]

Were significant parts of the planet to lose political stability, coordinating action to meet the scale of the climate challenge would become much more difficult. As the IPPR note, "we increasingly live in a world of shared destinies…"[153] With the necessity of coordinated global-scale change, we cannot ignore these threats.

Medium-term

In the medium-term, the core activity is to move our energy infrastructure of heat, transport and electrical power beyond carbon, first through energy savings, and then with a wholesale switch of remaining generation from carbon based fossil fuels to renewable technologies.

Decarbonisation also includes removing the carbon from other processes and arrangements – finding alternatives to carbon intensive industrial activities such as cement and steel production, as well as recognising and cutting the embodied carbon in the goods and services manufactured abroad and imported to Britain.

The term can be extended to equivalent activities with other greenhouse gas emissions but in this report we principally use it to refer to carbon explicitly.

Efficiency

The Government, in its UK Renewable Energy Strategy consultation document, states: "the starting point for our energy policy is to save energy". This is the easiest, cheapest and quickest way to reduce fossil fuel use.[154] We must change the social practices of energy use – placing energy efficiency at the heart of energy planning, both through the intelligent application of technology, and through driving behavioural shifts in energy use.

Proven efficiency programmes exist. Over the last few decades, California has held electricity consumption per capita, roughly, at a constant, while overall per capita US electricity consumption has grown by 60%.[155] We will need to reduce our energy consumption dramatically. A 2007 McKinsey report showed that using 'off-the-shelf' technology the US could cut energy use by 50 per cent[156]. While per-capita energy use is lower in the UK, similar assessments can be made. The report Zero Carbon Britain[157] showed that with a wholesale switch to electric vehicles, utilizing more efficient renewable energy technologies and an aggressive programme of retrofitting buildings, the UK could cut current energy use by 50%.

Efficiency is the easiest, cheapest and quickest way to reduce fossil fuel use.

Researcher Dr. Matt Prescott has explored in detail the challenges of shifting consumer preferences towards highly efficient appliances. Business interests alone cannot fully advise on future technology pathways that best support the public interest – maximising the use of available efficiency technologies will require Government support.

If a technology exists that meets or exceeds both Government performance standards and the public's user experience criteria, then steps should be taken to bring it more widely to market. This should be done on a case-by-case basis as part of a programme of rolling performance standards. Standards should be based on the best-in-class technologies commercially available now, anywhere in the world. They should consider full life-cycle efficiency, championing low embodied energy, low energy consumption in use, high durability as well as consumer preference criteria. Prescott recommends that this approach be applied widely; from light bulbs, to refrigerators, to cars and more.[158]

Different tools, including grants and tax breaks, will apply best to shifting consumers towards different products. The UK's contribution in legislating for higher efficiency standards can in part be national, and in part through political lobbying in Europe. EU-wide change impacts both on the larger population of Europe's 500 million, and globally, through the unofficial adoption of EU standards by China and other manufacturing giants who seek to "future-proof" their market access.[159]

Energy Efficiency vs. Energy Sales

A key factor limiting the drive to wide ranging energy efficiency measures is the existing business model of the UK's energy companies. Operating in a saturated UK market, these companies have little opportunity for growth and under anti-competitive legislation are constrained in their opportunities to buy each other out. Their profits are dependent on their ability to sell energy in volume, and maintaining shareholder value within this model demands that the volume and/or price of their energy stays high.

The energy market is fundamentally at odds with the public interest of minimising energy use.

This market is fundamentally at odds with the public interest in minimizing energy use – there is no clear incentive for the "Big 6" energy companies to assist consumers to use less of their product. The Government must urgently and openly address this core conflict of interest. A realignment of the energy market is now required that invigorates competitiveness and supports economic efficiency.

Energy

Zero-carbon energy scenarios, where energy needs are met without carbon emissions, have been designed for various areas of the world, including the UK[160], Sweden[161], France[162], the USA[163], Japan[164] and Western Europe as a whole[165]. Broadly, there are three main options for delivering low-carbon energy: Carbon capture and storage (CCS), nuclear fission power, and renewable energy.

While the Government clearly supports **nuclear energy**[166], problems still remain in terms of cost, construction delays and unresolved issues in terms of waste, decommissioning, and the proliferation of nuclear material. The delays and cost over-runs at Finland's new Olkiluoto 3 reactor[167] (the first nuclear reactor to be built in Europe since 1991) cast doubt on the ability of nuclear to play a large role in the timeframes necessary to effectively deal with climate change – the Sustainable Development Commission suggest that 10 GW of new nuclear generating capacity – replacing 10 stations scheduled to close – would provide just a 4% cut in emissions after 2024.[168] From the point of view of decarbonising energy supply completely, nuclear energy's incompatibility with high levels of renewable generating capacity is problematic.

A grid powered by decentralised renewables utilises demand management, intelligent home appliances (which vary their power consumption), increased energy storage capacity, and generally complements and encourages energy efficiency. Investing in a grid powered by centralised nuclear is failing to adapt electricity infrastructure to suit a renewably powered country.

For **carbon capture and storage** the Government has launched a competition to build the first UK demonstration plant, which should be burying CO_2 by 2014. It says the demonstration project will take "at least 15 years" to assess.[169] In a detailed study of CCS, the Massachusetts Institute of Technology concluded that it would not be commercially viable before 2030 at the earliest.[170] CCS requires the creation of a significant and expensive infrastructure to capture, compress, store, pump, transport and bury millions of tonnes of CO_2. Joseph Romm, former energy advisor to Bill Clinton, notes that for CCS to make a substantial impact on emissions "would require a flow of CO_2 into the ground equal to the current flow of oil out of the ground. That would require, by itself, re-creating the equivalent of the planet's entire oil delivery infrastructure."[171] CCS is clearly far from a mature technology, and the risk of carbon dioxide leakage alone suggests caution – given the length of time CO_2 persists in the atmosphere, the European Commission note that even a "CO_2 leakage rate at 1 per cent per year is too high for CCS to be an effective mitigation option."[172]

Given these issues, the enormous size of our renewable resource, and the potential to develop world-leading renewable industries, there is a strong argument for the UK to invest in a rapid switch to renewable energy, discouraging investment in new fossil fuel plant and avoiding carbon lock-in or reliance on CCS.

Speed

The UK is committed under its EU obligations to produce 15% of all its energy (electricity, heat and transport) from renewable sources by 2020.[173] The Carbon Trust has explored in detail the implications of this commitment, concluding that the target will require the UK to produce 31% of its electrical power from renewable sources, entailing 29 GW of offshore wind capacity and a further 11GW of other renewable technologies.[174]

They state that in order to achieve the target, very rapid growth in Britain's renewable generating capacity is required – with the British wind industry, from very limited beginnings, becoming a major global player within 12 years. They conclude:

> **Whilst this represents a challenge similar in scale to developing North Sea oil and gas, it is technically feasible. 29GW of offshore wind power is an immense deployment challenge and requires total investment of up to £75bn, equivalent to the peak decade of North Sea oil & gas development.**
>
> **The Carbon Trust** [175]

The Carbon Trust scenario for meeting EU targets envisages dramatic growth in renewable capacity flattening out after 2020, echoing the framing of the Government's own Renewable Energy Strategy Consultation. In truth, if the UK meets EU targets for clean energy generation, it will have necessarily created a young and dynamic industry, well placed to push for further opportunities for expansion. There is no inherent reason to assume that in a scenario in which we prove capable of meeting our EU targets by 2020 we would be incapable of maintaining the growth rate envisaged by the Carbon Trust for an extra decade. Within that time frame, renewable capacity could be deployed in excess of current electricity demand.[176]

Overcoming variability

Many of the more developed renewable technologies are inherently variable in their capacity to supply power. Furthermore, there is considerable fluctuation in the demand for energy placed on the power system. Grid operators are well used to managing these supply and demand issues, and when the grid is supplied by low levels of renewable power, this balancing process poses few problems. The challenge of integrating renewable energy grows as the proportion of the grid supplied by renewables grows. However, the application of four techniques to deal with the variability of renewable energy can overcome this:

1. **Deploy a diverse mix of technologies** – some renewable technologies are highly variable, such as wind and solar. However, others such as tidal range, tidal stream and combined heat and power plants burning biomass are highly predictable. By deploying a diverse mix of renewables, variability can be reduced to provide secure and predictable 'baseload' power supply.

2. **Geographically disperse power generation** – by situating renewable installations widely across the country, they can take advantage of different weather conditions and reduce variability. This approach can be extended intra-nationally with the use of interconnectors (cables connecting national grids). Gregor Czisch of the Potsdam Institute for Climate Impact Research in Germany has explored this 'Supergrid' approach for Europe. His study optimised the best possible size and location both of the renewable infrastructure and connections to areas of energy demand, finding that "A totally renewable electricity supply for Europe and its neighbourhood is possible and affordable."[177]

3. **Store energy** – by expanding pumped storage plants, developing technologies such as flow batteries, hydrogen, compressed air storage, and utilising electric vehicle batteries as distributed storage (vehicle-to-grid power or V2G), we can facilitate much higher renewable integration – balancing variability with increased storage capacity.

4. **Match demand for energy with supply**– the National Grid currently goes to enormous lengths to ensure that their supply of energy matches consumer demand. However, by prioritising and de-prioritising energy demand using real-time pricing and energy-aware appliances, it is possible to do the reverse – to shape significant portions of our energy demand to match supply. Building on this technique, Mark Barrett of University College London has created detailed energy models at UK and European levels that show how to generate 95% of our electricity and power our transport system renewably.[178]

By developing and deploying a combination of these techniques, alongside a concerted programme of energy efficiency which sees our overall energy use drop significantly, we can meet our energy needs with renewables and cut emissions quickly and securely. Overcoming the challenges of variability will put us in an unprecedented position of strength internationally, with the potential to export our expertise globally.

Obstacles to renewable development

Currently, the main obstacle to achieving higher levels of renewable capacity is not the technical challenge of deploying it, but rather legislative, supported by sectors of industry and Government questioning whether ambitious targets for clean energy can be achieved.[179,180]

Wind farms have faced significant delay through the planning process:

> since January 2006, only 54% of 167 applications to build onshore farms have received consent, a far cry from the 71% approval rating for other major developments, such as housing, retail and general industrial… The average timespan from submission to decision is now pushing two years.[181]

It is worth noting that opposition to wind energy and other renewables is not the majority view. An October 2007 review of 23 recent polls on energy policy options for the Parliamentary Office of Science and Technology found "a high level of awareness of the connection between fossil fuel sources of energy and environmental problems such as climate change"; "very low levels of public support for the use of fossil fuels"; "high levels of concern about the possibility of using up finite resources" and that "[s]ecurity of supply is a key issue and of growing concern"; while "all the reviewed polls and studies showed that renewable energy was the public's preferred energy source"; the public "were aware of the potential environmental benefits of renewable energy and recognised it as being important for climate change mitigation"; and "[t]ypically around three quarters of respondents expressed a preference for renewables over nuclear energy". [182] However, it is clear that in moving towards higher levels of deployment for renewables, the impact of infrastructure on local communities must be considered. The Government is currently consulting on how to improve the planning situation.[183] A key step forward would be to make community benefits from power generation compulsory - through a community infrastructure levy, a local tax rebate or a similar mechanism. A 2005 report to the Department for Trade and Industry concluded that "The routine provision of meaningful benefits to communities hosting wind power projects is likely to be a significant factor in sustaining public support and delivering significant rates of wind power development." [184] The report also suggests that Denmark, Spain and Germany have seen far higher levels and faster rates of wind power development than the UK due to the inclusion of meaningful community benefits.[185]

However, potential obstacles to progress are not only contained within the planning system.

1. **Grid access** – there is currently 9GW[186] of wind power at various stages of development awaiting connection to the National Grid. To put that in context, we currently have 2GW installed.[187]

   If we are to fully exploit our renewable energy resource, it is clear that we need a national grid optimised for drawing on and supplying renewable electricity. It will need to manage demand efficiently and intelligently, and distribute power from renewable sources all over the country – from huge offshore wind farms, all the way down to small domestic installations. It will need to be integrated with our transport and heating systems – with much of our current energy use in transport and heating, meeting our needs in these sectors with zero-carbon electricity will enable greater emissions cuts. This renewable grid would be quite different to the current system, which prioritises large, centralised power generation near population centres, rather than being well-equipped for moving power from where the greatest resources of renewable energy exist - North Scotland, Wales and offshore.

   There is now general agreement that significant investment in new grid infrastructure is necessary – the Innovation, Universities, Science and Skills Select Committee notes that "much of the current [grid] infrastructure is reaching the end of its 50 year lifetime and will need to be replaced or upgraded."[188] If we do not build a grid capable of dealing with high levels of renewables now, we will lock ourselves into reliance on fossil fuel power generation for another 50 years. According to the IPPR "this is an area where incremental reform will not be enough – the national grid needs to be rebuilt for the age of renewables."[189]

   Coordination and planning are essential. To create a renewably powered grid will require a national programme of construction similar to the programme which built it in the first place. Due to planning issues and construction, grid strengthening is likely to take longer than installing many of the renewable technologies which will actually deliver power. We therefore need to start planning large-scale grid investment immediately. Denmark have recently undertaken this task with its EcoGrid project,[190] designed to deliver a grid "so that wind power can supply up to half of the power generated and many other renewable energy sources can be incorporated into the system".[191]

2. **Supply constraints** – there are only three manufacturers of offshore wind turbines in the world, all of them based in Germany, with current lead times for orders of three years.[192] There are also shortages of many other components for wind turbines and photovoltaic solar panels, as well as UK biomass feedstocks. While supply constraints will be a major issue over the next few years, over the medium-term there is a clear opportunity for the British manufacturing and engineering sectors. The Government should ensure that the UK does not lose out in a multi-billion pound market. The news that BP and Shell have effectively departed the UK renewables market in favour of the US,[193] where Barack Obama has promised a large government-backed programme on efficiency and renewables, suggests that we must quickly and effectively incentivise low-carbon manufacturing in the UK.

3. **Installation delay** – there is currently only one purpose-built offshore turbine installation vessel in Europe. It has been estimated that 7-15 are needed in Britain to meet the 15% target.[194] Again, this is another opportunity for the UK to invest – as the nation which once had the largest shipping industry in the world, and with significant offshore wind potential there is a clear case to be made for creating the wider infrastructure necessary to roll out renewables rapidly, and reinvigorate stagnant sectors of the manufacturing industry.

4. **Skill shortages** – A recent ENDS report notes that "The lack of engineers capable of working in the renewables industry "threatens" the delivery of the [15%] renewables target".[195] As a recent report to BERR concludes this is "symptomatic of a historic lack of national investment in all levels of skills development in engineering."[196]

These problems require direct intervention and investment, with Government leading the way.

These problems require direct intervention and investment, with Government leading the way. Given recent, large-scale government interventions in the financial sector, proposing such action is clearly no longer a radical view. With a new and expanding industry directly assisted by Government, an effective renewable power supply system can be brought on-stream quickly. This leaves the question of how much it will cost.

The cost of renewable energy

Any energy system must be costed in relation to alternatives. For a gas price of 55p/therm, the Carbon Trust finds that 40GW of wind power would add 3%-20% to electricity prices for consumers. This compares favourably with the average 30% rise in electricity prices in 2008 alone, a result of fossil fuel price increases.[197] The Carbon Trust found that if the gas prices at the time the report went to press (around 90p/therm) were to persist, the extra wind capacity would not increase electricity prices at all. For a price higher than 90p, deploying wind energy on this scale would actually reduce the cost of electricity.[198]

The Carbon Trust found that with a gas price higher than 90p/therm, deploying 40GW of wind energy would reduce the cost of electricity.

The state of supply and demand for fossil fuels globally suggests that further rises or price volatility – itself a cost – are likely to continue in the future. A recent International Energy Agency report predicts that oil prices will rebound to more than $100 a barrel, rising to over $200 by 2030.[199] "While market imbalances could temporarily cause prices to fall back," the report suggests, "it is becoming increasingly apparent that the era of cheap oil is over." [200] In order to counter the steep rates of decline of existing oil fields and find enough extra oil to satisfy the growing demand of countries such as China, the oil industry will have to invest $350bn each year until 2030[201] – roughly $7 trillion dollars in total. If a portion of this sum were spent on renewable energy, particularly research and development into marine technologies, we could expect significant cost reductions as best practices are learned and developed, and as economies of scale come into play. The Carbon Trust estimates that an investment of £0.6-1.2 billion would reduce the costs of installing 29GW of offshore wind by up to £14 billion.[202] UK funding of renewable research, development, demonstration and deployment currently amounts to only £44 million a year.[203]

In light of fossil fuel prices' inherent volatility, therefore, combined with renewables' lack of ongoing fuel costs, the cost of renewable technologies is not high. Two recent studies suggest that in the long-term the costs of large-scale renewable energy systems may not exceed future costs implied by spiralling fossil fuel prices.

The International Energy Agency (IEA), costing a variety of scenarios for global energy provision, estimates the total cost of energy provision through fossil fuels until 2050 – its "Baseline Scenario" – at $250 trillion. Under an alternative "Blue Map Scenario", involving a complete transition to renewable energy supplies over the same period, while total costs rise by $45 trillion, these are more than offset by $50 trillion in avoided fossil fuel costs.[204]

Gregor Czisch costs the wholesale price of electricity under a Europe-wide renewable energy scenario (wholesale price is lower than consumer price) at 4.5€c/kWh.[205] Significantly, this is lower than current wholesale electricity prices in the UK, which have traded between 5.5€c/kWh and 13€c/kWh over the 12 months up to November 2008.[206]

Once in place, it appears from this evidence that renewables would supply power more cheaply than our current energy system, and be free from the price volatility of a fossil fuel-powered network. It is harder to estimate the costs of integrating large amounts of renewable energy and balancing their inherent variability. The challenge now is securing the investment necessary to fund the initial infrastructure shift, and the wider programme of measures proposed in this section. We return to this topic below.

With North Sea oil and gas reserves dwindling, the UK is becoming increasingly reliant on energy imports. Only home-grown efficiency and renewables can insulate us against fossil fuel price increases, while creating thousands of jobs and strengthening our economy.

With North Sea oil and gas reserves dwindling[207] and the UK becoming increasingly reliant on energy imports[208], only domestic renewables and energy efficiency measures can provide insulation against future increases in the price of fossil fuels and avoid a precarious over-reliance on insecure foreign energy supplies, while creating thousands of jobs and strengthening our economy. Short-terms costs associated with overcoming variability would be investment in a long-term asset for the UK, and in developing a valuable skills and knowledge base. By investing early, the UK can gain the advantage of being a first mover in the enormously important growth industry of high-penetration renewables, with expertise that can be exported all over the world.

Transport

The key to achieving zero-carbon transport is electricity. Electric vehicles are not only more efficient than those powered by the internal combustion engine; they would also provide valuable distributed storage capacity through the connection of their batteries to the national grid.

The key to achieving zero-carbon transport is electricity.

A major challenge for electric vehicles is their range. As the Energy Savings Trust point out, however, 99% of all journeys take place over distances of less than 100 miles.[209] Accelerating the installation of charging points and developing the technology for battery-swapping (exchanging fully-charged batteries at filling stations mid-journey) would help deal with this issue, as would greater innovation in battery technologies, increasing their life cycle and reducing costs.

The cheapest and most efficient option for cutting transport emissions is to scale down the amount we currently travel, making greater use of video-conferencing and other telecommunications alternatives. Investment in an urban environment designed to encourage cycling and walking, alongside incentives to make shorter journeys on foot or by bike will have a clear impact in reducing emissions, as will increasing the average occupancy of our existing cars, which currently stands at only 1.6 passengers.[210]

We will require electric buses, light goods vehicles and trains. Only one third of the UK rail network is currently electrified – the European average being 50% – and additional electrification will be essential if the rail network is to handle further passengers and reduce the amount of car travel.

Aviation is perhaps the most problematic transport option in a zero-carbon future, and no simple solutions are immediately available. The extent of land-use change necessitated by a biofuels programme makes this an unsustainable option for powering planes. Generation of hydrogen fuels would require an extensive renewable energy infrastructure, while emissions of water vapour at altitude would continue to contribute to climate change.

Viable alternatives include expanding electrified rail links in the UK and across the EU as an effective substitute for short-haul flights, while streamlining ticket purchases and reducing prices for longer train journeys. When it comes to aviation, we must dramatically reduce demand by promoting alternatives. It is clear that in a future with very ambitious emissions cuts, aviation in its current technological state will necessarily be dramatically curtailed.

Buildings

The challenge of zero-carbon housing does not concern new homes, but existing homes: 80% of the homes we will inhabit in 2050 have already been built[211]. The same is largely true of commercial and public buildings.

Refurbishment of existing homes is estimated to produce around a third of the emissions of building a new one.[212] According to Government estimates, however, “the average existing home requires four times as much energy to heat as the average new home.”[213] With new homes having to meet increasingly stringent in-use carbon emissions targets, therefore, it is imperative that refurbishment of the existing stock also tackles the task of reducing emissions from occupancy of the house.

Dr Brenda Boardman of Oxford’s Environmental Change Institute has undertaken an extensive study on how to achieve an 80% reduction in emissions from UK housing by 2050. Her key recommendations include:

- Minimum energy standards for homes at the time of sale or letting based on Energy Performance Certificates
- Solid wall insulation and other measures applied across entire streets at a time, bringing costs down
- Savings through behavioural change, driven by installation of smart meters and other ways of communicating energy information to building users
- Immediate 3.7% annual reductions from the housing sector, the “first few years” being “critical to changing mindsets and the present flat trajectory”[214]

These measures have the potential to reinvigorate the UK’s construction industry and to develop skills in sustainable building practices.

Spending on construction in the UK is split roughly in half between new build and refurbishment (repair, maintenance and improvement).[215] Refurbishment work is predominantly carried out by smaller firms. Changing the practices of these firms will be of critical importance in improving the environmental performance of buildings.

Some sectors of the industry are well-placed to support efforts to refurbish the existing stock. The Federation of Master Builders recently asked the Government to set out a policy framework for mandatory refurbishment standards consistent with an 80% CO_2 reduction target by 2050. This “Code for Sustainable Refurbishment” would provide much greater benefits than the Government’s existing 2016 zero-carbon target for all new homes.

Timescales are important. The urgency of ensuring climate safety requires that current voluntary standards such as the Code for Sustainable Homes and Building Research Establishment Environmental Assessment Method for non-domestic buildings be made compulsory as a Code for Sustainable Buildings, with standards set high and soon.

Agriculture

Agriculture currently accounts for 7% of UK total emissions.[216] The two largest sources of greenhouse gas emissions from agriculture are methane from livestock and nitrous oxide from artificial fertilisers. As temperatures rise, agriculture will be one of the first sectors to feel the impacts of climate change, creating a twin challenge of adapting to these changes, and reducing greenhouse gas emissions.

The agricultural sector will face the twin challenge of adapting to climate change and reducing greenhouse gas emissions.

As the Tyndall Centre note, reducing agricultural emissions to zero is likely to be impossible, due to the sector's importance in food production:

> Given that the majority of the non-CO_2 greenhouse gas emissions are associated with food production, it is not possible, with our current understanding of the issues, to envisage how emissions could tend to zero while there remains a significant human population.[217]

The aim of the agriculture sector must be to reduce emissions as far as possible. Mitigation strategies should include the use of anaerobic digesters, changing livestock diets, along with reductions in overall livestock numbers and artificial fertiliser use. This should encourage a shift towards more organic farming, leading to greater carbon retention in soils.

Invest in skills

In addition to resource constraints, current shortfalls in the level of skills and training in the UK and the urgency of swift action make the problem of delivering on the Government's current targets on renewables and energy efficiency considerably more difficult. Several reports have been carried out in the last two years into the skills shortages holding up progress in sustainable housing and renewable energy.

A report by Gavin Killip of Oxford's Environmental Change Institute, commissioned by The Federation of Master Builders, examining the role of the construction industry in reducing emissions, found that current levels of understanding constitute a major obstacle. According to Killip "the skill-sets of traditionally-defined tradespeople (for example, plasterers, electricians, etc) will need to be expanded so that they understand enough of the low-carbon refurbishment agenda to play their part effectively. This is likely to include a better understanding of how the interaction of different trades on-site can lead to loss of overall building performance." [218] Training is most effective where trainees comprehend the reasoning behind a new mode of operation. Instructing plasterers to plaster walls to floor level rather than skirting height, for instance, will be more successful if they understand that this minimises draughts.

The UK Industry Taskforce on Peak Oil and Energy Security recently concluded that

> A national skills programme is needed to address the dangerous shortfalls in skills and manpower evident in all areas of the energy industry… To gain maximum economic benefit and to ensure a secure supply of renewable generation technologies we should manufacture a substantial proportion of the technology within the UK. This will necessitate a significant re-skilling – training many tens of thousands of professionals in new energy skills and approaches. It will result in jobs for construction workers, engineers, economists, agriculturalists and many others. [219]

The Government needs rapidly and urgently to undertake such a course of action, through such policies as: creating zero carbon academies, particularly for buildings, engineering and agriculture; establishing bursaries and grants for trades-people and trainees to move into low-carbon sectors; assisting declining industries (such as North sea oil and gas) to transfer their skills; and promoting closer ties between zero-carbon industries and universities to promote research and foster clear career paths.

Adaptation at home

The developed world has, for the most part, not yet felt the impacts of climate change. But the IPCC note that "Even societies with high adaptive capacity remain vulnerable to climate change, variability and extremes. For example, a heat wave in 2003 caused high levels of mortality in European cities (especially among the elderly), and Hurricane Katrina in 2005 caused large human and financial costs in the United States."[220]

As the UK decarbonises, it must also ensure that changes in housing, agriculture and infrastructure are designed with a future in mind where the effects of climate change are impacting on the country.

There are good examples of applying precautionary principles to future-proofing countries against climate change. The Delta Committee, set up to advise the Dutch government on adapting to climate change, concluded that, including the effects of land subsidence, plausible upper limits for sea level rise were "0.65 to 1.3 meters … for 2100, and from 2 to 4 meters in 2200."[221] Pavel Kabat of the Wageningen University and a member of the committee said, of the 1.3 metre figure, that it was "A plausible upper limit. Plausible in the sense of 'it is possible' and 'it cannot be ruled out'. Compare it to building a bridge. When designing it, what do you do? You take the heaviest traffic as starting point and add a safety margin. That's what it is, a safety margin. On the basis of the state of the art in science, that is 1.30 meters."[222]

As the UK decarbonises, it must also ensure that changes in housing, agriculture and infrastructure are designed with a future in mind where the effects of climate change are impacting on the country.

Cap emissions

While the technical potential for renewable energy is clear and a strong financial case can be made for both energy efficiency and renewable energy, these alone do not guarantee the elimination of carbon emissions. What they are able to achieve is an opening of the political and social space for strong regulation to scale down fossil fuel use. The simplest approach to such legislation is a cap on absolute carbon budgets, contracting year on year.

The Climate Change Bill incorporates a carbon budgeting scheme but has been undermined to date through loopholes allowing international carbon trade with regions not as rigorously capped. A carbon cap will be essential to ensure that energy savings from efficiency are not counteracted by increased energy use in other sectors – the so-called 'rebound effect', and genuine long-term emissions cuts are made. A cap on carbon creates incentives to cut carbon emissions and provides a legislative structure that can completely remove it from our economy.

Energy efficiency and renewable energy do not alone guarantee emission reductions.

The act of defining a carbon cap effectively allocates property rights to the atmosphere. In allocating these (valuable) rights, care must be taken to ensure a distribution in favour of the public interest. Defining, allocating and potentially trading a national or global carbon budget should be seen as a means to the end of decarbonisation, rather than a new currency.

Save global sinks

As the IPCC note "Considering that forests store more carbon dioxide than the entire atmosphere ... the role of forests is critical." At present deforestation is a major cause of destruction of current carbon sinks and stocks – Hansen et al. note that "Deforestation [has] contributed a net emission of 60±30 ppm over the past few hundred years."[223] According to the IPCC, deforestation and associated processes account for around 17.4% of man-made greenhouse gas emissions, with tropical deforestation in particular "the single largest contribution of land-use change to global carbon emissions". Stopping deforestation is thus a high priority for mitigation efforts. Most deforestation occurs as a result of such land-use change, but with "expansion of settlements, infrastructure and unsustainable logging practices" also playing a role.[224]

Deforestation [has] contributed a net emission of 60±30 ppm over the past few hundred years.

IPCC

Fortunately, means of averting further deforestation at a relatively low cost are available. As the IPCC point out, there has recently been "increased attention to reducing emissions from deforestation as a low cost mitigation option, and with significant positive side-effects", as outlined by the Stern Report. At a comparatively low price per ton of CO_2 ($27) tropical "deforestation could potentially be virtually eliminated".[225] This can most effectively be achieved through commitment to sustainable forestry practices. In effect, current policies of destroying forests for agricultural land and logging are consuming the Earth's "stock" of natural capital. A more productive approach would be to "live off the interest" – the services and materials provided by the forest year on year – while preserving (and indeed extending) this stock.

As the IPCC observe, "In the long term, a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fibre or energy from the forest, will generate the largest sustained mitigation benefit."[226] In particular, recycling of wood waste needs to be stepped up, along with active measures to prevent fire and diseases from pests. The IPCC also note an increasing trend towards intensive management, with forest plantations that account for only 5% of total forest cover providing 35% of the total wood harvest. Through serious curbs on consumption, greater use of waste materials from sustainable forestry programmes, product substitution where feasible and limited use of such intensive management, it seems highly likely societal needs for forest-derived material could be met while deforestation is effectively eliminated.[227]

The regulatory infrastructure underpinning such an arrangement would surely require an outright ban on further deforestation. This solution is attractive in its simplicity, but problematic in terms of implications for national sovereignty. In effect, the ecological benefits of forests are "internationalised": they are recognised as impinging on the global community and their management is therefore subject to international jurisdiction. However, the economic costs of a ban – in terms of jobs and revenues lost in the forest's host country – remain confined to a particular state. In order to rectify this, economic costs must be covered by the international community: compensatory funding should be provided to the country in question, equal to the value of the economic benefits forfeited as a result of the ban.

Such monies could be earmarked to fund the expanded forestry sector required to preserve and maintain forests. Similar schemes must also be created to protect and in some cases restore other, smaller carbon sinks and stocks. These include peatlands and wetlands – often subject to burning and draining – as well as soils and grasslands. Tickell estimates that covering preservation, restoration and management is likely to cost around $300 billion a year – less than OECD countries currently spend on agricultural subsidies.[228] By comparison, the monetary cost of deforestation has been estimated at around $2-5 trillion per year.[229] The UK can play its part by championing such a scheme at the international level.

Research sequestration

Accelerating carbon sequestration takes advantage of processes in the climate that we understand relatively well – taking us back into the zone of lower atmospheric concentrations which we have already experienced. The "Target Atmospheric CO_2" paper suggests that reforestation of degraded land, and improved agricultural practices that retain soil carbon, could lower atmospheric CO_2 by as much as 50 ppmv.[230] However, the implications of using the biosphere to carry out this process, when it is already under stress from the changing climate and other degradation, are currently unclear.

Bio-sequestration

Most approaches to 'artificially' drawing carbon out of the atmosphere involve enhancing the capacity of ecosystems to sequester carbon.

Techniques include:

- Biochar – creating industrial charcoal;
- Re-afforestation – restoring forest cover, and creating new forests;
- Biomass energy with capture and storage (BECS).

Each of these sequestration techniques comes with concerns over the effect deployment on the kind of scale necessary to have an impact on atmospheric concentrations will have on ecosystems:

Biochar – The partial burning of biomass, such as crop residue or wood, through a process known as pyrolysis – optimally an anaerobic (oxygen-free) thermal process in which biomass is baked in a kiln to produce charcoal – is able to transform it into agricultural charcoal, or biochar. This carbon-rich material can then be buried in the soil, where it may effectively sequester atmospheric carbon for hundreds, or even thousands of years. Increased use of biochar has various potential advantages. It can enrich soil, increasing fertility, water retention and productivity – analogies are often made between biochar and terra preta or "dark earth", the carbon-rich, fertile soil of the Amazon basin. It has also been found to directly reduce soil emissions of methane CH4 (up to 100%) and nitrous oxide N2O (by around 50%), and may also obviate the need for nitrogen fertilisers, currently a significant source of nitrous oxide, a potent greenhouse gas. Johannes Lehmann of Cornell University estimates that biochar schemes, working with biofuel production, could store up to 9.5 billion tonnes of carbon a year – more than is emitted by all of today's fossil-fuel use.

There are also concerns around the effects of introducing biochar into existing ecosystems, many of which have successfully acted as carbon sinks without human intervention.

Nevertheless, risks and uncertainties surround this process, including around biochar's long-term stability in soils. As Michael Bird of the University of St Andrews comments, "[t]he unknowns that remain are exactly how long [the charcoal] stays in the soil. In some circumstances it can be millions of years, or decades, depending on how it is made, and soil conditions." There are also concerns around the effects of introducing biochar into existing ecosystems, many of which have successfully acted as carbon sinks without human intervention.

A recent study by researchers at the Swedish University of Agricultural Sciences found that in boreal forest soils in the Northern hemisphere, the long-term sink potential is partially offset by a loss of native soil organic matter and soil carbon (though these concerns may be overstated).[231] Some concerns also surround the use to which such technology may be put, and the regime of governance within which it would be utilised. Biochar schemes could have similar damaging effects to biofuels, with impacts on food availability and destruction of existing ecosystems' natural sinks through land-use change for monoculture crop-growing – though for the foreseeable future biochar will utilise waste biomass that would otherwise be burnt.

Overall, however, researchers are in general optimistic that with concerted research efforts into developing viable biochar the potential benefits of this technology are real and significant.

Attempting to increase sink capacity by planting vast monocultures would risk doing more harm than good.

Re-Afforestation – having first focused our attention on ending deforestation, and sustainably managing existing forests, we may examine further options. The Intergovernmental Panel on Climate Change concluded that "a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber fibre or energy from the forest, will generate the largest sustained mitigation benefit."[232]

Afforestation (planting new forests) and reforestation could provide further benefits in terms of drawing down carbon, but must be done sensitively and sustainably. Attempting to increase sink capacity by planting vast monocultures would risk doing more harm than good – monocultures can lower overall biodiversity and thus risk actually reducing overall sink capacity. A clear positive step would be to make a wholesale switch in our building materials industry, away from concrete, metals and plastics, to timber. This would mean growing sustainable forests which maintain biodiversity and then harvesting timber before it reaches full maturity, locking that carbon away in the form of building materials.

Biomass energy with capture and storage (BECS) – using this technology with sustainably produced biomass would result in net-negative carbon emissions, as the carbon sequestered during the growth of the biomass would be captured and stored, thus removing carbon from the atmosphere.[233] Smaller scale carbon capture and storage plants that have already been built and are operating, they would be available long before large-scale CCS would be commercially viable. The cost implications of storing carbon from numerous small locations are unclear, however. The key factor is the sustainability of the biomass feedstock. In the UK, BECS would provide an invaluable flexible energy technology that can easily be turned on and off, helping to balance the variability of other renewable technologies.

Air Capture

Direct capture of carbon dioxide from the air – the "Holy Grail" of climate techno-fixes – is an effort to replicate the mechanisms of sequestration that occur in the ocean and during photosynthesis on an industrial scale, using industrial technology.

There are three key issues a successful air capture system must overcome:

- **Energy**: University of Calgary climate scientist David Keith claims to have created a means of "captur[ing] CO_2 directly from the air with less than 100 kilowatt-hours of electricity per tonne of carbon dioxide".[234] If scaled up, such technology could theoretically capture the equivalent of all current CO_2 emissions from fossil fuel at an energy cost under one tenth of current global energy demand.
- **Cost**: estimates range from $80-500[235,236] per tonne of carbon captured. Such estimates involve assumptions about future energy costs, however, and with the IEA concluding that "the era of cheap oil is over"[237] it is hard to see the lower-end of this range materialising. James Hansen and his co-authors point out that the artificial removal of 50 ppmv of CO_2 from the air at $100 per tonne would cost $20 trillion.[238]
- **Scalability**: it is likely that a vast surface area would be needed to absorb significant quantities of carbon dioxide from the atmosphere. Given the experimental stage of many devices[239,240,241] it is currently unclear whether this will be a limiting factor.

The advantage of air capture over bio-sequestration is that it does not involve harnessing poorly-understood natural carbon sink mechanisms to draw carbon out of the air, with potential side effects and risks of environmental "blowback" associated with overloading the biosphere. While air capture takes carbon out of the biosphere, bio-sequestration may put more pressure on ecosystems to lock-up the additional carbon, while unintentionally degrading existing sinks. Air capture is also more likely to receive international support and financing.

The advantage of air capture over bio-sequestration is that it does not involve harnessing poorly-understood natural carbon sink mechanisms which risk overloading the biosphere.

Air capture deserves further research, but clearly framed in the knowledge that it cannot provide a substitute for decarbonisation. As section 2 made clear, we must decarbonise as quickly as possible, which will require an enormous social and financial investment. Air capture might conceivably be a long-term aid to returning to atmospheric levels below 450 ppmv CO_2 equivalent, but this will depend on costs – both financial and in terms of energy.

Research geoengineering?

The associations of the label "engineering" with precision and certainty make "geoengineering" a highly misleading label for the current state of research into mechanisms for directly altering the climate. As Alex Steffen suggests, a more accurate term might be "geo-experimentation or geo-gambling."[242] The Economist notes, "History is littered with plans that went awry because too little was known about complex natural systems. As with irrigating Soviet cotton fields from the Aral Sea in Central Asia or introducing rabbits to Australia, modifying the climate will have both physical and biological consequences."[243]

According to Stanford climate scientist Ken Caldeira, "The history of interventions in natural systems is one of systems responding in unanticipated ways. You can be sure that whatever we have in our models, if you actually did this, something would happen that's not represented in the models. So I'd council in favour of a cautious approach."[244] The IPCC suggests geoengineering proposals "remain largely speculative and unproven, and with the risk of unknown side-effects".[245] That the scientific community, in the face of political inertia, is now desperate enough to float such proposals is an alarming reflection of how desperate they perceive the situation has now become.[246]

The Earth's climate system is complex and dynamic, and, as noted above, can respond unpredictably to change. Overall, even with the extraordinary advances in climate science to date, our understanding of it has not developed to such a point as to allow confidence that deploying direct cooling techniques would not cause more harm than good. Furthermore, as Professor in Geophysical Sciences at the University of Chicago Raymond T. Pierrehumbert notes, "One also has to wonder whether the international treaties and organizations needed to agree on and execute a geoengineering scheme are significantly easier to realise than the agreements needed to decarbonise the energy future."[247]

History is littered with plans that went awry because too little was known about complex natural systems.

The Economist

However, we are already undertaking two uncontrolled experiments globally in relation to climate change, thickening the blanket of greenhouse gases and injecting aerosols into the troposphere (largely from coal-fired power stations). As we established above, these aerosols mask heating and cause changes to the climate. There is already serious uncertainty as to the effect reducing such aerosols would have over coming decades, as air quality standards start to bite (particularly in Asia) and as we begin reducing emissions which contain aerosol particles. Adding to these uncontrolled experiments may pose still further risks.

Ideas on how to go about directly modifying our climate are not hard to find, and include:

- building mirrors in space to reflect a portion of the Sun's energy;[248]
- seeding the stratosphere with reflective sulphate aerosols, encouraging the propagation of clouds, which in turn reflect light back to space;[249]
- mining moon dust to create a shielding cloud;[250]
- seeding the Oceans with iron to stimulate plankton growth, storing carbon as they die and sink;[251]
- placing large vertical pipes in the oceans to bring nutrient rich water to the surface, triggering algal blooms, which also store carbon when they die;[252]
- using fleets of unmanned 'cloud seeding' boats to spray mist created from seawater into the air to thicken clouds and thus reflect more radiation from the earth;[253]
- reflective plastic sheets covering 67,000 square miles of desert, to reflect the Sun's energy.[254]

Most proposals can be dismissed as phenomenally expensive, misguided, dangerous, or all of these things.

Deploying mirrors into space on the scale necessary would involve colossal quantities of energy and resources, and risk making a warming world reliant on infrastructure of unprecedented delicacy.[255] Pouring sulphates into the stratosphere risks damaging the ozone layer,[256] causing mega-droughts[257,258] and has various other potential unwelcome side effects.[259] It also makes us dependent on further, continual injections into the atmosphere, which we might not be able to guarantee and whose absence would lead to a pulse of warming that would severely damage many ecosystems.[260] Moon dust clouds would be highly unpredictable, and again would require enormous resources in a location that we have to date only placed the 210kg lunar rover and a few astronauts. While seeding the oceans with iron could be undertaken with existing technology, it might not lock up carbon as intended[261] and could have significant impacts on the marine food chain.[262] No geoengineering measures would prevent further acidification of the ocean because of the raised concentrations of CO_2 in the atmosphere, meaning the degradation of ocean ecosystems that currently sequester carbon would continue.[263]

Two of these proposals, however, deserve further research. Cloud-seeding ships would be relatively cheap and reversible – they could simply be turned off. They also appear to have fewer obvious negative side-effects: they do not require enormous amounts of energy or artificial chemicals, nor do they rely on intensifying natural processes. Clouds remain one of the most poorly understood elements of the climate system, however, and the seeders could potentially cause warming as well as cooling. The particles thrown up could have unknown and potentially severe consequences for the higher atmosphere.[264] All of these issues need further research.

Most proposals can be dismissed as phenomenally expensive, misguided, dangerous, or all three.

Reflective plastic sheets covering such an enormous area are not problem-free. Replacing and maintaining them would require an enormous effort, over a very long period. There are also geopolitical considerations, with an implicit assumption – as in the case of the DESERTEC proposal to deploy large amounts of solar capacity in the Sahara – that other countries will co-operate for a certain price. Albedo-altering techniques appear to be relatively benign, however, and deserve further investigation. Recent research suggests that whitening the pavements and roofs of the world's largest 100 cities would offset the equivalent of 44 billion tonnes of CO_2 per year, and save money through reduced air conditioner use.[265] Even a fraction of this would potentially have positive effects.

Research into these two proposals is therefore required. This should ideally be internationally funded, by the UN or an equivalent body, with programmes not associated with any one country and including measures to prevent profiteering by vested interests. Research must also be carefully observed and regulated, with a moratorium on private experiments.

Martin Rees, President of the Royal Society told the Guardian in September

> It's not clear which of these geo-engineering technologies might work, still less what environmental and social impacts they might have, or whether it could ever be prudent or politically acceptable to adopt any of them. But it is worth devoting effort to clarifying both the feasibility and any potential downsides of the various options. None of these technologies will provide a 'get out of jail free card' and they must not divert attention away from efforts to reduce emissions of greenhouse gases.[266]

Crucially, we must clearly recognise the context in which geoengineering is likely to be discussed – it is likely to be promoted overwhelmingly as an alternative to decarbonisation.

Crucially, we must clearly recognise the context in which geoengineering is likely to be discussed – with powerful vested interests heavily invested in perpetuating fossil fuel use, it is likely to be promoted overwhelmingly as an alternative to decarbonisation. Given the highly speculative state of the discussion, and the imperative for immediate action to constrain emissions, it cannot replace serious action on reducing emissions now. Geoengineering must not be allowed to distract us from the scale of change that will be required to achieve decarbonisation and ambitious emissions cuts.

The most dangerous geoengineering options must be ruled out, with cautious research devoted to the relatively benign, cloud seeding and albedo modifications, without losing focus on the challenging task of decarbonisation. As Alex Steffen notes, "Hacking the only planet we've got rather than simply changing the way we live shows a lack of judgment, to put it mildly." [267]

Hacking the only planet we've got rather than simply changing the way we live shows a lack of judgment, to put it mildly.

Alex Steffen, World Changing

Long-term

In the longer term, and informed by extensive research into the mechanisms and implications of cloud-seeding and albedo modification, we can consider whether these techniques should be deployed. Although these are the only two geoengineering options which have no immediately obvious side effects which rule them out, it may well be that they are found lacking following further research and should be discounted. It is currently difficult to envisage under what sort of international agreement or framework they might be deployed, but in the longer term there may have been further progress in coordinating international efforts.

Even in the context of successful ambitious medium-term action, the scale of change that is ultimately necessary will require pursuing the emissions reduction agenda in a variety of different global contexts. It will require universalising and incentivising opportunities for decarbonisation, to the extent that low-carbon technologies and modes of behaviour become a new and unassailable social norm.

Allowing every nation and community the space to break out of short-term thinking and address the long-term goal of living within sustainable limits will also require pursuing a wider agenda.

Allowing every nation and community the space to break out of short-term thinking and address the long-term goal of living within sustainable limits will also require pursuing a wider agenda – ensuring universal access to basic human and social rights, reducing inequality, promoting peace and security and creating powerful models and mechanisms to drive low-carbon development. These are good things to do in themselves, and we should pursue them in the short and medium term for a range of reasons, but in the long term, securing a firm societal foundation from which to manage our relationship with the environment wisely will require that the freedom to choose climate safe options is enabled and supported throughout the world. Without a wider social justice agenda which can remove the necessity to pursue only short-term interests, global sustainability, in the most basic sense of the word, will continue to allude us.

Financing the transition

Clearly, such a course of action requires financing. Decarbonisation will require the rebuilding of our energy infrastructure; adaptation requires further funding commitments; preserving carbon sink capacity is likely to involve, at least in part, compensating those who are currently degrading it. There are clear economic arguments which justify the expense – much of our energy infrastructure will have to be replaced in any case, and protecting forests represents a very cheap mitigation option, but still the question remains of where the capital to pay for the programme will come from.

Large portions of the finance will have to come from Government spending its own money. Such an important programme of action requiring large scale coordination cannot safely be entrusted solely to the market to deliver. The programme of green spending recently outlined by Barack Obama[268] provides an indication of the direction our own Government should take. Government spending can in itself be a boost to economic activity, a point that has underpinned much discussion of a 'green new deal' to boost economies with targeted green spending.

Further finance will also be required, and in parallel, the Government should seek to attract and leverage private sector investment. The simplest mechanism is through the creation of Energy Bonds, issued by the Government, and financed either through Government or private purchase. Energy bonds could provide the central finance tool for large scale projects to develop the nation's energy assets: Strong grid infrastructure covering the windswept coastline of the UK; international grid connections; wind turbine factories; new ships to lay cable and install the largest of the new offshore wind turbines: R&D into large scale marine energy deployments.

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By investing early, the UK can gain the advantage of being a first mover in an enormously important growth industry, with expertise that can be exported all over the world. The wind and marine resource of the UK are uniquely powerful, representing some 40% of the entire European resource[269].

As a nation we have been slow to realise the full value of the resource we hold. Development of this resource need not be bound by the constraint of the UK's own variability of supply and consumer demand, which is already well balanced. With expanded international grid links, the UK (population 60M) has access to a much larger European market (population 500M). The Government should be able to issue bonds and begin development now, with confidence that the energy generated can either be sold overseas or the UK can manage its own demands to match this new supply, allowing the nation to enjoy avoided costs from imported fuel.

As a nation we have been slow to realise the full value of the resource we hold. The UK could be an energy exporter and a power-house for Europe. Energy bonds could provide the central finance tool for large scale projects to develop the nation's energy assets.

This will require setting up the financial arrangements that can facilitate development of wind and marine generating assets. A national business plan is urgently required, commissioned by the Government, written by the Treasury and drawing on expertise from DECC, BERR and the Carbon Trust. Britain has the potential to serve as a powerhouse to the rest of Europe – exporting clean renewable energy to the continent and recouping large profits.

Conclusion

The climate situation is now so pressing that it is forcing change upon us. However, we can plot a plan of action which would ensure we are doing everything in our power to meet the challenge and deliver change.

International agreement is not a prerequisite for action - indeed, the slow pace of change on the international climate policy stage presents an opportunity for unilateral action to speak loudly. As a nation we can: make immediate reductions in our own emissions; fund and support international adaptation; preserve our carbon sinks and support the global preservation of carbon sinks; pursue rapid decarbonisation; adapt our own country to climate change; increase research funding into potential sequestration practices, and press for impartial international funding and cooperation for further research into cloud-seeding and albedo modification. Such a programme should begin with a clear, substantive statement of intent – a set of policy initiatives and steps to cut UK emissions 10% by the end of 2010.

In pursuing these steps, we would not only advance our own response to climate change dramatically, we would also significantly change the international context. We would send a clear message to the world that although the challenges posed by climate change are serious, we have an opportunity to meet them, deliver a quality of life worth striving for, improve the capacity of the world to collectively respond to the challenge, and attain our climate safety.

These are ambitious goals – but we start from a position of strength. With the size of our potential renewable energy resource, and as a high-profile state, Britain is particularly well-placed to make the necessary transition, demonstrate that maintaining wellbeing in a zero-carbon society is possible, and lead the world out of fossil fuels. The reality of the situation is that we have come to the point where only ambitious goals will do.

International agreement is not a prerequisite for action, indeed, the slow pace of change on the international climate policy stage presents an opportunity for unilateral action to speak loudly.

The obvious challenge is the constraint put upon our ambition by current 'political and economic realities'. How can we maximise our ambition, and deliver on it? What kind of action in the political arena will be required to drive this change forward?

These are ambitious goals – but we start from a position of strength. With the size of our potential renewable energy resource, and as a high-profile state, Britain is particularly well-placed to make the necessary transition, demonstrate that maintaining wellbeing in a zero-carbon society is possible, and lead the world out of fossil fuels.

Action

There are risks and costs to a program of action. But they are far less than the long-range risks and costs of comfortable inaction.

John F. Kennedy

The greatest obstacle to transforming the world is that we lack the clarity and imagination to conceive that it could be different.

Roberto Mangabeira Unger

Moving forward

Thus far, we have endeavoured to demonstrate the scale of the challenge we face, outline an adequate response to the problem, and sketch a programme of action to transform the UK into an exemplar in its response to climate change.

Clearly, achieving a response of this kind even on the scale of one country is a massive endeavour. Both the scale and the character of our response must shift significantly and rapidly. In this section, we outline how "business as usual" and "politics as usual" have failed to address the problem, and ways we might move forward.

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Current large-scale policy instruments

The most visible examples of large scale, collective responses to climate change thus far have been policy programmes designed to curtail greenhouse gas emissions, but which contain significant flaws. On the international level, there is still no example of a policy programme applied universally to all nations or actors: the Kyoto protocol binds only 'Annex 1' developed countries, while the European Emissions Trading Scheme is limited to the EU states plus Norway, Iceland and Liechtenstein. The most prominent policy on the UK level is the forthcoming Climate Change Bill.

The Climate Change Bill

The Committee on Climate Change, set up by the Government to provide advice on how the UK can meet its climate change goals, has made progress in more clearly and closely linking policy-making and climate science. Their initial recommendations in October 2008[270] (to increase the emissions target to 80% by 2050, including a consideration of emissions from international aviation and shipping, and suggesting the need to decarbonise the power sector before 2050) initially appear stringent and well-founded. A more detailed analysis, however, reveals that their recommendation is based on a global deal with emissions cuts of 50-60% by 2050. Atmospheric concentrations are projected to stabilise as high as 460ppmv in 2200, having previously peaked even higher.

The Committee on Climate Change's recommendations are based on a global deal with emissions cuts of 50-60% by 2050. Atmospheric concentrations are projected to stabilise as high as 460ppmv in 2200, having previously peaked even higher.

Such a target fails to reflect the risk-based approach outlined above. As we have already established, a long-term stabilisation of 450ppmv would lead to a temperature rise of 3.1°C, assuming a sensitivity of 4.5°C. While the Committee detail a number of the accelerating climate impacts observed since the 2007 IPCC report, they fail to integrate these into their findings, relying on a single model from the Hadley Centre. Although this is one of the world's leading climate models, it does not include a number of crucial feedbacks and other processes, in particular the effects of an early Arctic melt. As a result, the Climate Bill will leave us with targets that, even if successfully implemented, would not succeed in securing a safe climate.

Nevertheless, the Climate Change Bill displays potential, in that it demonstrates a clear commitment to policy based on an appraisal of climate science, and communicates this understanding through the policies it advocates. The provisions contained within the bill include setting carbon budgets and five-year short-term targets for emissions cuts. This is a significant step forward over longer term target setting. In this respect, the Climate Change Bill is both a sign of how far the climate issue has come in the UK over the past five years, and of how far there is still to go.

The EU ETS

The EU Emissions Trading Scheme is the largest and most sophisticated carbon trading scheme in the world. It has a key place as the "cornerstone of the [UK] Government's policy framework to tackle climate change."[271] The Environmental Audit Committee state that the EU ETS "has been undermined by weak caps and inaccurate and unsatisfactory methods of allocating allowances to individual sectors and installations… through a methodology… prone to being influenced by industrial lobbying."[272] In some cases participants (such as the Netherlands) have been allocated more credits than they are estimated to need even to continue emissions at a stable level, making it unlikely that the EU ETS will have any constraining influence on their emissions.[273] Over-allocation of permits to industry has in many cases provided a subsidy to some of the biggest polluters.[274] In the 3 years it has been operational, weakened by over-allocation of credits, complicated 'flexibility mechanisms' for offsetting emissions reductions and the efforts of industry lobbyists, it has failed to reduce net carbon emissions by a single kilogram,[275] a situation which may continue until 2012.[276]

Carbon trading is a weak instrument for driving deep infrastructure change. By promoting cost as the key incentive in driving change, it has to date failed to effect the significant infrastructure shifts to clean technologies that will be required to meet demanding emissions cuts. The EUETS draws on similar flexibility mechanisms to Kyoto, notably the 'Clean Development Mechanism' - as a result of which, a September 2006 report from the Dag Hammarskjöld Foundation concluded,'[w]ith a bit of judicious accounting, a company investing in foreign 'carbon-saving' projects can increase fossil emissions both at home and abroad while claiming to make reductions in both locations.'[277]

The EU ETS is more difficult to redeem as an example of effective policy – in part because it has such a clear record of failure, and in part because the Climate Change Bill has at least the potential to set a limiting cap over a particular area, (the UK). In the case of the EU ETS, the scheme's flexibility mechanisms mean that there is no effective 'hard cap' on carbon emissions – that is, there is no guarantee that the EU ETS will reduce emissions within the EU. The most encouraging aspect of the EU ETS is that Phase I, which finished at the end of last year, has been characterised as the "learning by doing" phase of the scheme. It is clear there are lessons to be learned as we now continue with Phase II. Targets set by the EU ETS have been undermined by industry lobbying and obscured by flexibility mechanisms. The scheme has not penalised high emitters and may even have subsidised them. It has not incentivised deep infrastructure change, and critically, such a complicated and opaque mechanism, undermined by such widespread lobbying, has not provided clear signals about what kind of action is necessary, and why.

Kyoto Protocol

The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) is, to date, the most substantial global policy instrument for engaging with climate change. However, in 1997 when the agreement was negotiated, it reflected political compromise above and beyond any connection with the demands of the scientific evidence. The protocol is thus beset with limitations – it has no clear basis for the commitments to which it seeks to hold parties and doesn't cover all greenhouse gases or all sectors of emissions. "Flexibility mechanisms" built into the structure of the protocol allow parties to offset emissions reductions by trading permits, or by financing large-scale low-carbon development projects in the less-developed world – weakening the force of the protocol to drive emissions cuts in real terms.[280] Perhaps most critically, Kyoto fails to include any enforcement or compliance mechanisms which carry weight.[281] Weakened by these inherent shortcomings, Kyoto has failed in its objectives to avoid dangerous climate change. Although by 2005, overall Kyoto parties had reduced their emissions by 2.7% (0.5GTC) from 1990 levels,[282] with emissions now rising in 17 signatory countries[283], it is clear the overall 5% target will not be met.

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Critically, Kyoto has not motivated changes in behaviour. Emissions cuts have occurred largely due to events disconnected from climate policy – attributable to shrinking economies caused by the collapse of the Soviet Union, and, in countries like the UK, shifts from coal to gas in generating electricity, driven by cost considerations rather than climate policies. Now, as the economies of former Soviet countries have been strengthened, and with rising gas prices encouraging a shift back to more polluting fuels such as coal, emissions are again rising, at growth rates three times faster than the IPCC's "worst-case" scenario.[284] Kyoto has not restricted high-polluting behaviour, has not incentivised change in emissions levels, and, reflecting political compromise rather than scientific rigor, has provided no clear signals as to what effective and appropriate action is required to cut emissions. As Tony Blair has stated "it is clear Kyoto is not radical enough."[285]

Kyoto's replacement is scheduled to be agreed in Copenhagen in December 2012. The challenge for policymakers and civil society is to ensure that whatever mechanism replaces Kyoto embodies a risk-based response to the science, and includes strong enforcement mechanisms. It must also quickly drive substantive short-term action to curb global emissions. Early signs have been concerning, with the debate currently being framed by the aim of achieving 50% cuts in global emissions by 2050.[286] If this is the basis on which an international agreement is to be negotiated, it will inevitably be inadequate.

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The social and political context for responding

Specific blockages

Various features of the climate crisis make it inherently difficult for the public to fully come to terms with. Climate change fails to register easily on our natural "risk thermostat"[287] – the dangers are difficult to perceive and often indirect, with effects that are often uncertain, as well as geographically and temporally distant. The ingrained short-termism of mainstream politics, constrained by the electoral cycle, has made it more difficult for climate change to gain a central position on the public agenda. As a result, there is a risk that our response may come only as the severest impacts of climate change kick in, impacts which may well be greater than we can successfully adapt to.

The media's ownership, structure, advertising-led funding model and reliance on PR material have served to align it with economic interests strongly supportive of business-as-usual. As a result, climate change has been pushed down the public agenda, with government intervention and regulation, as the IPPR note, often quite successfully framed as issues of government intrusion, "green spin" and stealth taxation.[288] Climate change deniers, largely funded by fossil fuel interests, have been able to gain access to the media through misleading PR efforts – on which an under-resourced media, with a lack of specialist scientific expertise and shortfalls in both time and personnel, have often been reliant.[289] The alignment of many media institutions with the economic status-quo has been at least as significant in acting as an echo chamber for the arguments of climate change deniers,[290] while tending to promote piecemeal, "reformist" solutions to climate change.[291] The resulting contrast between such small day-to-day actions and frequent reports on the catastrophic scale of the problem, as the Tyndall Centre's Tim Lowe points out, can "make the public's response seem insignificant, futile and in some cases too late to make a difference".[292]

The profound influence of business on Government represents another significant barrier to change. Funding for political parties, potential economic damage from divestment and capital flight, lobbying efforts, and the "revolving door" of influence between policymakers and major business representatives are all important levers open to businesses wishing to influence policy. The main business lobby group in the UK, the Confederation of British Industry, has lobbied hard and often successfully to water down the Climate Change Bill, and has supported the expansion of aviation and coal-fired power, in collaboration with particular businesses from these sectors.[293]

The ingrained short-termism of mainstream politics, constrained by the electoral cycle, has made it more difficult for climate change to gain a central position on the public agenda.

A culture of "reasonableness"

While political pragmatism therefore orients policy in one direction, scientific necessity urgently demands a radically different one. In many cases, those formulating and advocating policy on climate change have been willing to fudge the conflict between the two, forcing scientific evidence into the constraints of political "realism". Individuals whose advice has been central to the advancement of climate policy – such as David King, until recently the Government's chief scientific adviser, and Nicholas Stern, lead author of the UK Government report on the economics of climate change – have embraced an emissions threshold widely accepted as constituting dangerous climate change, Stern advocating stabilisation of concentrations at 500 ppmv CO_2 equivalent[294], while King advocates a "reasonable" and politically realistic target of 550 ppmv CO_2 equivalent.[295]

This compromise is accepted on the basis that their advice would not otherwise be taken seriously, or would not be "politically possible". With high-profile policy advocates tailoring their advice in this fashion, campaign groups and other commentators have often felt unable to question these targets, despite growing evidence that they are not sufficient to keep us in the climatic safe zone.

Discussion of climate change appears to have been constrained by a culture of "reasonableness", with groups and individuals active on policy advocacy not willing to step too far outside the bounds of perceived 'political reality'. Stating fully and frankly the implications of the most recent scientific evidence is to risk being marginalised and dismissed as "alarmist" or "crazy", losing access to the media and to policymakers, and potentially also to support from funders. This has been combined with a deep-seated culture of reticence in scientific circles, exacerbated by constant, vocal attacks from climate change deniers and delayers. As a result, a self-reinforcing cycle of buck-passing has been established, with:

- **scientists** deferring to policymakers on targets and definitions of "dangerous climate change";
- **climate action groups** deferring to the IPCC and conservative scientific predictions;
- **large NGOs** constrained in what they can advocate by the need to secure continued access to policymakers;
- **politicians** reluctant to appear extreme by "outbidding" environmental groups;
- **civil servants and public administrators** deferring to conservative scientific predictions;
- **businesses** constrained by their own commercial interests and the perceptions of the wider business community.

Government inaction has lowered expectations, which has continued to hinder serious action. When opportunity knocks, or new evidence demands new responses, imaginative and bold leadership seldom emerges.

Unfortunately, action adequate to meet the scale of the challenge seems to be beyond the capacity of the political process in its current mode.

Inspiration

In seeking to understand the speed and scale with which change can come about, we can draw inspiration from historical examples of vast or rapid societal change in response to an overwhelming threat, or a change in circumstances.

The nature of the threat posed by an enemy during wartime is very different to that posed by climate change. Nevertheless, the Second World War provides a clear and striking example of how entire economic systems can be quickly re-ordered in times of dire need. During the Second World War, over five years the US expanded military spending by 42 times and shifted the entire focus of their society to serve the war effort, in the process reinvigorating the economy, slashing unemployment and boosting GNP.[296]

Widespread instability in global financial markets has recently seen massive and rapid government intervention. Nicholas Stern has warned that the risk consequences of ignoring climate change will be greater than the consequences of ignoring risks in the financial system. Faced with instability in the global financial system, the US Government instigated a $700 billion bailout package for US banks – the UK Government following suit with a £400 billion aid package with up to £50 billion investment of public money in the banking sector.[297] When a threat to something seen as vital is perceived as sufficiently urgent and serious, a rapid response can be mobilised. As Gordon Brown put it, "extraordinary times call for bold and far-reaching solutions."[298]

When a threat to something seen as vital is perceived as sufficiently urgent and serious, a rapid response can be mobilised.

Massive infrastructure change is not only possible, but a well-understood feature of our recent past. The Carbon Trust note that the challenge of deploying 29GW of offshore wind by 2020, a change which would make the UK self-sufficient in energy over the first half of the 21st century, is similar to the scale of the challenge in developing North sea Oil and Gas.[299]

The Danish island of Samso has over the last ten years achieved a 140% reduction in its carbon footprint – selling 40% of its energy back to the Danish mainland to balance emissions from transport and other sectors. Impressively this has been achieved in a community that before 1997 had little interest in where their energy came from, and now contains a large number of renewable energy enthusiasts. Although a small example, Samso demonstrates the potential for turning substantial action to meet the climate challenge into a social norm, in a planned, involving and ultimately highly successful way.[300]

In different ways, these examples show that when it is required, whether in response to a change in circumstance or the desire to develop something new, rapid change is possible. Clearly each of these examples has its limitations and caveats, but equally, these different examples demonstrate a breadth of considerable creativity and resilience in their responses to challenging problems.

Massive infrastructure change is not only possible, but a well-understood feature of our recent past.

Mobilising public will

While ambitious responses that meet the demands of the scientific evidence have been lacking to date, it is not so much the practical feasibility of transformative programmes that have constrained action, as a lack of political will to implement them. As political analyst James Humphreys has pointed out, "a couple of competent civil servants could within a week or two have drawn up a robust plan to deliver the necessary reductions, at any point over the last 15 years – had the political will been there."[301] David Miliband, Labour's Foreign Secretary, has stated that "[t]he challenge we face is not about the science or the economics. It is about politics – breaking the logjam that holds back progress."[302]

How can this logjam be broken? For a number of reasons, mobilising public will is crucial in creating the impetus for change.

How can this logjam be broken? For a number of reasons, mobilising public will is crucial in creating the impetus for change. While governments can and often do pursue policies in the face of public opposition, this tends to require the backing of other powerful interests and sectors, particularly of business and the media. In the case of climate change, however, such sectors tend to present obstacles to government action. Nonetheless, as we have seen in the case of such issues as GM food, sufficient public opposition can succeed in overcoming such influence. Governments can also successfully win round public opinion to new policies by taking risks. The depth and scale of the change required, however, are likely to have a marked and readily-discernible impact on the day-to-day lives of citizens, making clear public backing a necessity.

There is some compelling evidence that, in the absence of such backing, governments feel sharply constrained. Al Gore, for instance, while acting as a strident voice for change in the public arena, has, in a step that many find deeply counter-intuitive, turned down the offer of a place in the US Government. Instead, he is using his political platform to help build a broad popular mobilisation, countering the vested interests that he himself acknowledges prevented any effective action during his previous term in office.[303] In the UK, Greenpeace Director John Sauven remarks that "[Gordon] Brown will say to you, he's said to me before: 'What are you doing to mobilise the public? Why aren't you getting the public on board? Why aren't you opening up the political space?'"[304] Both of these examples attest to the same fact: mobilising public support will be crucial in creating the conditions for strong and swift government action.

Specific observations

Different groups can play different roles in mobilising the public. Below, we outline our suggestions for how the resources at our disposal can best be directed towards this task – identifying the most effective role a range of key actors can play in mobilising the political will required. Such an outline cannot deliver any "magic bullet" or chemical formula that will bring about the necessary change overnight. Rather, we can identify broad areas and key proposals that, if pursued effectively and persistently, can help move us to an effective response.

NGOs – Campaign groups, think tanks, political parties

There is pressure from multiple sides on organisations which seek to effect change – from the climate science community comes a sense that despite the progress that has been achieved, the pace of change is not sufficient to meet our growing understanding of a worsening situation. From the political world there are examples of leadership on climate change which goes beyond what NGOs, constrained by the difficult game of balance they must play, are able to offer. Political parties are constrained by the necessity of appealing to their constituencies, who often rate environmental concerns as relatively unimportant.

The time has come to assess wider strategic goals.

With the introduction of the Climate Bill in the UK in no small part due to the efforts of environmental organisations, a moment of opportunity has opened up for NGOs engaging with these issues. The time has come to assess wider strategic goals. NGOs can play a valuable role in framing the debate and in mobilising their constituencies of support.

Share and promote expertise. The climate science community and renewable energy specialists are keen to see their work communicated and influencing policy to a greater degree. Closer engagement with these communities would allow their often excellent and highly relevant work to be brought to a wider public. It would also provide a solid foundation for ambitious policy advocacy on climate change which meets the scale of the challenge.

Present a united front. The environmental movement has done a good job of unifying behind several key issues – recently in calling for the 80% target and in opposing new coal. The challenge is to replicate and widen the successful cooperation of recent years in the service of even-stronger calls for change, providing broad and consistent support for a powerful message which does not reflect only 'lowest-common-denominator' agreement. Sectors of the NGO community with a clear stake in the issue – including refugee and human rights groups – have in the past tended largely to ignore climate change.[305] There is an urgent need to engage and involve the expertise, experience and communities such sectors represent.

Promote core values. A good deal of NGO activity has thus far been aimed at promoting small-scale behavioural change, often pursued by utilising mainstream marketing techniques. Yet evidence is accruing that certain "core values" are crucial to the commitment and persistence with which environmental goals are pursued by the public, while such standard marketing techniques, by aiming to exploit the existing, "materialistic" and "extrinsic" motivations of a largely consumerist society for pro-environmental ends, may in fact be helping to foster and reinforce precisely the kind of values that currently represent a serious barrier to change. A debate needs to take place among environmental organisations on whether, given the urgency of the situation, a different approach is needed. Such groups may instead need to draw on and promote the values and principles which guide their work.

In their report Weathercocks and Signposts, WWF suggest that in order for NGOs to contribute to substantial change, they must seek to foster and potentially to frame campaigns in terms of

> intrinsic values – a sense of connectedness with the natural world, or empathy for people in a drought-stricken country or for future generations … While campaigns remain focused on appeals to extrinsic goals [such as social status or financial success], it will be correspondingly more difficult to motivate individuals to adopt significant behavioural changes; such behavioural change will be seen as 'out-of-reach', and emphasis will remain on simple and painless steps.[306]

Such an approach requires that insights into human motivations from the fields of marketing and communications be directed towards significantly different ends – nurturing "latent" values and challenging those that may be actively harmful.[307] While this change of direction cannot happen overnight, NGOs need urgently to consider whether current strategies are sufficient to address the scale and urgency of the problem.

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Government & Policymakers

Government holds a pivotal position in enabling an effective response to the climate crisis. Government can set the framing conditions within a society that give rise to, prompt, and enable change. They have the legislative potential to instigate wide-ranging and systematic reform on a large scale. Few bodies are as well resourced to draw on assessments of the scientific position, or to undertake work examining how to change the way that society operates. While Governments are clearly subject to significant constraints, there are nevertheless a number of ways they may effectively use the political space open to them to open up further space for change.

Make actions consistent with messages. The public are understandably unlikely to buy into serious action on climate change if the Government is visibly pursuing environmentally damaging and often high-profile policies.[308] Government must therefore be prepared to 'walk the walk'. In order to demonstrate their commitment to meaningful action to the wider society, Government departments can lead the way in making and publicising emissions cuts in a range of areas across the public sector. Decisions across different departments must also be co-ordinated and consistent. Clear progress has recently been made in creating a unified Department of Energy and Climate Change, yet questions remain over how effective or committed it is likely to be. The Government should use the creation of this body as a clear opportunity to demonstrate that climate change will indeed be a central concern in guiding policy.

Engage the public. With Government leading the way, public information campaigns, much like those on public health issues, can allow Government to convey clearly that climate change is happening now, and that there is an urgent imperative for action. Yet such schemes may not achieve the level of public engagement that is so urgently required. Opening political space further with the public may best be facilitated through a wide-ranging public process of deliberation and discussion, to stimulate engagement with the issue, raise awareness of the urgency of the problem, and further demonstrate the status of climate change as a Governmental priority. The overarching aim must be to draw the whole society into dialogue as stakeholders.[309]

In this way, Government could effectively facilitate an open discussion, taking place across the country, on how to respond to climate change. Expert involvement will be crucial in ensuring that such a process has access to key information. Such a process should also aim to involve and energise existing social networks – religious communities, or local branches of the Women's Institute, for instance. Since public distrust may well prove to be an obstacle, a figurehead with clear perceived and actual independence should be appointed to guide and oversee the project. It should be co-ordinated, informed and tied together nationally through a mass media component, guided by trusted and authoritative voices. Individuals such as

David Attenborough, already involved in communicating the issue and who topped a poll of the most trusted individuals in Britain,[310] may provide the perfect example of candidates for such a role.

Show leadership, take risks, and exploit windows of opportunity. Policymakers are often best placed to bring about far-reaching reforms during periods of expanded political possibility. When Governments or administrations change, space can open for new policy direction. Significant political changes in other parts of the world – the inauguration of a new US President, for instance – may help shift the political ground. Governments should be ready to use such opportunities to advance solutions to the climate challenge.

Perhaps even more compellingly, the pressing need for a solution to the economic crisis, for instance, may have placed new opportunities on the public agenda. With the Government preparing major programmes of public spending as a stimulus to the economy, a range of voices – Sir Nicholas Stern, Barack Obama and the United Nations among them[311] – are calling for such a programme to be oriented along the lines of a "green new deal", to rapidly develop the infrastructure for a future sustainable economy. With significant economic and social benefits providing a powerful incentive, the Government must capitalise on this opportunity for urgent and concerted action.

Communicators – Climate scientists, public figures

Make the science visible, real and accessible. The Tyndall Centre describes public perceptions of climate science as occupying the status of a "quasi-reality" – a "reality that thus far is defined by expert knowledge and is surrounded by uncertainty".[312] Yet with vested interests able to summon their own "experts" and exploit the perception of uncertainty, public perceptions have been left confused and distorted. It is valuable that the underlying facts of climate change are presented as "presumed knowledge" – preventing the efforts of climate skeptics from sapping energy needed to communicate the problem well. However, we cannot rely that the presentation of the issue in this way will be sufficient – communicators must also be able to explain why the underlying facts deserve this status, communicating with clarity significant scientific developments and the risks they pose without reopening debates that have already been hard-won. In communicating the science effectively, they must emphasise that climate change is not some distant disaster waiting to destroy society, but rather that it is a current reality – a rapidly accelerating process, the effects of which are being felt now.

Convey hopeful futures. While the rhetoric of climate change as a looming catastrophe has been well developed, depictions of viable and hopeful futures have yet to be envisaged and represented to the same extent. Nevertheless, there is evidence that the public wish to hear about such solutions.[313] These solutions need to be made as real as the problems, with narratives of optimism becoming integral to the stories we tell about climate change. A strong case can be made, indeed, that positive visions should now assume a central position. Such visions must be coherent, powerful, and compelling.[314]

Promote a change in values. Prominent writers and cultural producers can be an important source of ideas that change public consciousness and lay the basis for wider social change. In particular, their output can help catalyse a shift in public values and perceptions. Recent work exploring the bases of human happiness and challenging current societal and governmental priorities have opened crucially important areas for reconsideration and public debate. Nonetheless, the depth of this vital, "profound philosophical discussion [on] who we are and what progress means"[315] needs to be given a much higher profile, and to penetrate much further.

Challenge political "realism". Public policy advocates have often limited their public pronouncements to avoid stepping beyond the constraints of what is "reasonable" or politically feasible. In watering down proposed targets and policy goals, however, they have served to limit the pressure on Governments for the kind of serious action required. Ironically, this has helped to turn such perceptions of "political reality" into self-fulfilling prophecies. Communicators should acknowledge the potential, and historical precedents, for rapid and far-reaching societal change. Public communicators from the fields of politics and climate science have recently pursued such approaches with a good deal of success by challenging prevailing notions of what is "politically possible" and recalling periods in history when major, rapid change has been mobilised.[316] This approach has made progress already, and should be adopted much more widely.

Citizens

Build change from below. The Danish island of Samso, which reduced its carbon emissions by 140% in 10 years, provides an inspirational example of how social dynamics can be used to effect some remarkable changes. As Robin McKie writes in the Observer, "What has happened here is a social not a technological revolution. Indeed, it was a specific requirement of the scheme, when established, that only existing, off-the-shelf renewable technology be used. The real changes have been those in attitude."[317] Such transformations from below can thus provide inspirational examples of what can be achieved through concerted grassroots action. Community activists and members of the public can help catalyse a shift towards collective engagement by forming and promoting bottom-up organisations and networks. Already-existing community groups and social networks – such as the Women's Institute, Transition Towns, religious communities and local organisations – may provide fertile ground for raising awareness, mobilising support and exerting pressure on Government.

Pursue active citizenship. The widespread emphasis on "green consumerism", and on "small actions" by individuals, have too often allowed public appetite for change to be misdirected into insubstantial actions.[318] In its place, action should be framed by a discourse of active citizenship, directed at shaping the overarching framework of Government policy. One promising example of this approach has been Friends of the Earth's "Big Ask" campaign, which successfully mobilised a campaign of public pressure for Government legislation on climate change.[319] In the United States, the 'We Can Solve It' campaign is taking a similar approach, using a mass mobilisation to press for a transformative policy shift. Recent instances of civil disobedience in the UK have won support from climate scientists and members of all main political parties, while raising the profile of damaging policies. Perhaps most promisingly, such actions also appear to have energised areas of opposition to these policies within Government.[320]

Conclusion

Serious, entrenched obstacles to change remain, as the scientific evidence continues to worsen. Yet in area after area, the prospects for ambitious action on climate change in the UK are more promising than they have been at any point to date. Notably, in the last few years alone, public discourse on the issue has shifted in ways that would have been almost unimaginable only a few years ago. An Inconvenient Truth, the high-profile Stern and IPCC reports, and many other efforts have helped bring the issue to a wider public – climate change is now part and parcel of public discourse, with politicians and political parties often seeking to out-bid one another in establishing their green credentials. The Big Ask campaign has galvanised mass popular pressure, with half a million people writing to MPs and achieving a landmark success in bringing the Climate Change Bill into being. In concert with further public mobilisation, major NGOs have successfully worked together in strengthening the Bill in the face of sustained opposition from the business lobby. Recent Climate Camps have become major focal points of media attention, raising public consciousness and bringing serious, concerted pressure to bear on Government. In the US, the "We" Campaign has brought together nearly two million people to campaign for decarbonisation of electricity in the next 10 years.

While these major strides forward have helped condition the political landscape, a sudden convergence of recent events may have left it primed for significant change. With the environmental sector declaring victory over the Climate Change Bill, space for stronger calls to action has opened up. A rapidly worsening economic crisis has provided three stark lessons: that when governments let go of the steering wheel, disastrous results can ensue; that prioritisation of short-term benefits can lead to catastrophe in the long-term; and that, given the political will, concerted emergency action can quickly be mobilised. In the US, the Palaeolithic climate policies of the Bush administration have been consigned to the political wilderness. And the prospect of government action through a "Green New Deal" – with Barack Obama, Nicholas Stern, Germany's Vice Chancellor and the UN among its proponents – looks ever more convincingly like an idea whose time has come. A window of opportunity to seize the political initiative has opened.

A rapidly worsening economic crisis has provided three stark lessons: that when governments let go of the steering wheel, disastrous results can ensue; that prioritisation of short-term benefits can lead to catastrophe in the long-term; and that, given the political will, concerted emergency action can quickly be mobilised.

Yet even as the window of political opportunity expands, the crescendo of climate change continues to build. Arctic sea ice is melting, across the planet ecosystems are degrading, rising atmospheric concentrations of greenhouse gases are trapping heat in the Earth system at ever more dangerous levels, even as heat caught in the thermal inertia of the oceans continues to drive temperature rise. Coal power plants continue to be built, forests continue to be destroyed, politicians continue to play for time, uncomfortable truths continue to be obscured, and vulnerable people continue to be displaced, dispossessed and killed by the impacts of climate change. Scientific reality is bringing the horizon of the future relentlessly closer.

Although the challenge may seem daunting, we still have the time and agency to respond. We may even find that setting out along the course of an appropriate response will settle some of the fears and questions which accompany engaging with the issue. By front-loading the action we take to reverse current trends of emissions growth, cutting our emissions in the UK 10% in the next few years, and seeking to scale up a response that meets the challenge, we can manage the risks to which we are exposed and act with agency and purpose. We must respond with creativity, and with a commitment to long-term sustainability which has to date largely eluded us. The goal is not merely to survive, but to overcome the enormity of the challenge and create a future that we would wish to realise in any other circumstance. We must clearly articulate visions of what a resilient, climate safe society will be – a society which will be written in the language of policy, but will have to be made real in the imagination and creative spirit of those who build it. That is, of us all.

As ever, the past grows longer, and the future grows shorter. And the time to start is now.

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About PIRC

The **Public Interest Research Centre** - www.pirc.info - is an independent charity integrating key research on climate change, energy & economics - widening its audience and increasing its impact. Our **recent work** includes collaborating with the Centre for Alternative Technology on their Zero Carbon Britain report and producing **coalintheuk.org** – an interactive map of UK coal expansion.

The Climate Safety report outlines the results of a process of deliberation and discussion within our own organisation. We will continue this discussion through our work, and through the **climatesafety.org** website, where you will find:

- A **free PDF copy** of this report.
- A **blog** exploring and detailing some of the issues contained within this document.
- Supplementary information – including **briefing papers, graphs and graphics**.
- 'Science' & 'Action' **annexes**, with further discussion and detail supporting the sections in the report
- Related **multimedia resources**, including video explanations of key issues contained in the report.
- Opportunities to **discuss and debate** the material contained within the report.

Our **future work** will include developing the themes and discussions of 'Climate Safety'; projects detailing the potential for high-integration renewable energy in the UK, and work examining the financing of energy infrastructure change.

For more information about us visit **www.pirc.info**

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"You cannot overstate the importance of this report: it has opened my eyes to levels of climate risk far beyond those of which I was aware. It shows that we have to rethink completely our responses to it. Crisp, clear-headed and profoundly shocking, this report should be read immediately by everyone who cares."

George Monbiot, author and journalist

"A report to keep every policy maker awake at night, this is a devastating and unflinching exposé of the profound gap between the predictions of how climate change will impact on the planet produced by the Intergovernmental Panel on Climate Change, and the already observable impact of global warming on the ground. We need nothing less than the declaration of a global state of emergency if we are to avoid the worst. Generating the political will to act, which has so far been conspicuous by its absence across the world, is the most urgent task all of us face, so that we can have a chance of creating the social, cultural, and economic circumstances required to deal with the climate crisis."

Caroline Lucas, leader of the Green Party

"It is becomingly increasingly clear that seeking to limit the effects of climate change to 2 degrees of temperature rise is dangerously optimistic. Climate Safety plainly shows us that we need to inject a sense of urgency into the debate about how we respond to climate change. It's not about gradually reducing emissions any more, it's about recognising the risks we face and cutting our emissions to zero as quickly as possible."

Mark Lynas, author of 'Six Degrees'

"Now is not the time to focus on the long-term. Every day our emissions rise, the risk of destructive climate impacts increases. Reframing the current debate away from 2050 targets to address cumulative emissions through short-term intervention will not only give us a better chance of achieving a more desirable future, but may ground the message in a timeframe within which we see our own futures."

Alice Bows, Tyndall Centre for Climate Change Research

"Climate Safety is a cogent summary of the indisputable case for rapid decarbonisation that recognises that the only obstacle is our capacity to believe in ourselves."

George Marshall, founder of the Climate Outreach Information Network (COIN)

"Every time we peep out from behind the sofa, the horror movie of climate change looks more scary. And this report shows that it is not a movie; it is real life as it will be experienced for generations to come. Unless we act now, tipping points in the climate system are likely to take us into a new world of climatic extreme. Forget polar bears; it is a modern global civilisaion that is at stake."

Fred Pearce, author and journalist, New Scientist

"Finally, the generation who moved from producer to consumer, broke its connection with the land and found by doing so that life was lonelier, less fulfilling and less nourishing, has a mission. That mission is nothing less than an unprecedented effort to creatively prevent runaway climate change. Climate Safety sets out clearly where we find ourselves and what we need to do. Our mission, should we accept it, could be the making of us, revealing a resourcefulness and ingenuity we never would have believed possible."

Rob Hopkins, Transition Network, author of 'The Transition Handbook'

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