the trajectory of climate change

Recent research suggests that current greenhouse gas emissions trends threaten future climate change at the upper end of the scenarios being developed by climate modellers, says Jeremy Carter

Above

Greenhouse gas emissions resulting from the increasing carbonisation of the global economy look ever more likely to bring about dangerous climate change, with impacts that would stretch society to the limit

Recent changes in the climate, measured globally and down to the scale of individual cities, highlight that significant transformations are occurring – and occurring at an increasingly rapid pace. Furthermore, accelerating carbonisation of the global economy, linked to trends such as the increasing use of coal in developing economies, threatens to derail opportunities to avoid dangerous climate change and increases the potential for major climate change impacts such as sea level rise of a metre or more and global average temperature increases of 4°C above pre-industrial levels by the end of the century. These impacts would stretch society to the limit.

Outlining recent research in the field, this article explores the challenging climate change agenda. With scientists pointing towards an intensification and acceleration of the causes and projected impacts of climate change, it is valuable to raise awareness of related issues and emphasise the key role that planners can play in developing responses to the changing climate.

Recent climate change

'... human-induced climate change is not an issue for the next decades or century: it is an issue facing us today.'
Bob Watson, Chief Scientific Adviser to Defra and former Chair of the IPCC, quoted in *The Guardian*, 16 February *2011*[1]

The decade 2002-2011 was the warmest on record, 0.46°C warmer than the 1961-1990 mean, with six out of 23 global sub-regions experiencing their warmest year on record in 2010.[2] Temperature highs have also been set in the UK recently, with the spring of 2011 standing out as the warmest recorded.[2] Broad changes in the UK's climate over recent decades can be evidenced – for example, in the South East of England, annual daily mean temperatures increased by 1.62°C between 1961 and 2006, and by 2°C in the winter months over this period.[3]

some communities in New Orleans and along the Louisiana coast have yet to recover fully from Hurricane Katrina, which hit in 2005.

There is mounting evidence that some of the observed changes in the frequency, duration and intensity of extreme events, typified by the European heatwave of 2003, can be attributed to increases in greenhouse gas emissions from human activities.[4,6] Research carried out at the University of Oxford has demonstrated that the UK floods of 2000 were made two to three times more likely by climate change.[7] Similarly, prominent NASA scientist Professor James Hansen and co-workers[8] have found that surface temperature extremes, such as those in Texas and Oklahoma in 2010 and Moscow in 2011, are becoming more frequent and widespread as a consequence of global warming.

Hansen *et al*. describe the systemic shift in the frequency and distribution of temperature anomalies as an outcome of the 'loading of the climate dice'.[8] But it is valuable to be able to link specific events to climate change, although, as Trenberth[9] points out,

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After Hurricane Sandy on the Rockaway Peninsula, in the New York borough of Queens – 'there is mounting evidence that some of the observed changes in the frequency, duration and intensity of extreme events can be attributed to increases in greenhouse gas emissions from human activities'

Connected to these shifts in weather and climate patterns, some extreme events are becoming increasingly common. A report from the Intergovernmental Panel on Climate Change (IPCC)[4] stresses that it is 'very likely' that there has been an increase in the number of warm days and nights across most global land masses, and suggests that there is 'medium confidence' that the frequency and duration of heatwaves and droughts has increased in many regions.

It is significant that today extreme weather events exert a huge cost on economies and societies. Since 1980 they have been responsible for the majority of Europe's economic losses caused by catastrophic events,[5] and there are question marks over how quickly societies can recover from the aftermath of extreme weather events. For example,

'All weather events are affected by climate change because the environment in which they occur is warmer and moister than it used to be.'

The climate is clearly changing, and the consensus is that the release of greenhouse gases from human activities is the principal driver of this change.[10] It is useful to ask why we should be concerned about recent trends and current extremes in climate and weather. Recent climate change is a forewarning of potential future shifts in the weather and climate. In many cases, recent trends mirror those projected to intensify over the coming decades. For example, North West England has seen increases in temperatures and the emergence of a seasonal split in precipitation patterns, with drier summers and wetter winters.[3] In this particular region, it is precisely these broad trends that are projected to run forward across this century.[11]

However, projected temperature increases for the next 100 years are taking us into uncharted territory. They risk moving society out of the stable climate system that has persisted over recent millennia during which human civilisations have emerged; from the Holocene to the Anthropocene. The drivers and potential outcomes of this shift in climate epoch are a major concern for today. The rate of change in greenhouse gas emissions levels globally will exert a strong influence on the pace and magnitude of shifts in the climate. It is to this subject that the discussion now turns.

Escalating greenhouse gas emissions

'Rather than decarbonising the world is carbonising at a rapid rate, and it is doing so precisely at the time we know we have to stop it.'
Clive Hamilton, in *Requiem for a Species*[12]

Alongside the reaction of the biosphere to ongoing and forthcoming climate warming – in processes which are themselves highly uncertain owing to the presence of complex feedback loops and possible tipping points[13] – greenhouse gas emissions are central to understanding potential climate futures. The growth rate in carbon dioxide emissions is influenced by a range of factors, including:[14]

- global economic activity (via the use of fossil fuels and land use change);
- the carbon intensity of the economy; and
- the functioning of unmanaged land and ocean-based carbon sources and sinks.

Since 2000 there has been a growing global economy, an increase in carbon intensity (i.e. more carbon is being released to produce a given amount of economic activity), and a decrease in the efficiency of carbon sinks (i.e. less carbon is being absorbed by the land and oceans). Cumulatively, these factors have driven the most rapid increase in carbon emissions since the beginning of the Industrial Revolution.[14]

The International Energy Agency's (IEA's) *World Energy Outlook 2011* presents a global picture of issues related to recent trends in emissions. The *Outlook* establishes that, despite the ongoing economic malaise, world energy demand rose by 5% in 2010, with carbon dioxide emissions reaching record highs.[15] This increase has been driven by the growth of developing economies and the recovery of industrialised economies following the credit crunch of 2008.[16]

Over the last decade, which has seen emissions rise steadily, coal has provided for almost half of the increase in global energy demand, particularly in China and India. Without changes in policy, coal is set to overtake oil as the world's largest energy provider.[15] Reversing the upward trend in coal use, which is a major contributor to greenhouse gas emissions, is central to meeting aspirations to keep global surface temperature rise at no more than 2°C above pre-industrial levels; a target acknowledged at a high level by the 'Copenhagen Accord', although this is not legally binding. Energy efficiency measures and growth in low-carbon energy generation have not yet proved sufficient to compensate for growth in the fossil-fuel-intensive power and transport sectors.[16]

'Projected temperature increases for the next 100 years are taking us into uncharted territory... The drivers and potential outcomes of this shift in climate epoch are a major concern for today'

Recent research has stressed the importance of focusing on greenhouse gas emissions 'budgets' in the context of understanding climate futures.[17-19] Cumulative emissions of greenhouse gases are a key factor contributing to levels of future warming.[19] An emissions budget is essentially the quantity of greenhouse gases that can be emitted into the atmosphere over a given period (typically 2000 to 2050 or 2100) for a given temperature outcome.

Using this approach, researchers have been able to analyse the levels of emissions reduction needed to have a chance of meeting goals such as keeping within the 2°C 'guard rail' above which 'dangerous climate change' is considered more likely (see, for example, works by Huntingford *et al.*[19] and Macintosh[20]). Nevertheless, scientists believe that 2°C of warming would bring significant negative impacts within a wide range of biophysical and socio-economic systems and sectors across many parts of the world.[21]

Attention to cumulative emissions helps to emphasise the imminence and scale of the challenge facing economies and societies in the shift towards decarbonisation. Using the cumulative approach, Huntingford *et al.*[19] have established that the options for further emissions between now and 2020, and then to 2050, are extremely limited if the goal is to give us a better chance than not of keeping temperature increases to less than 2°C above pre-industrial levels. They also point out that higher emissions prior to 2020 have the knock-on effect of subsequently requiring deeper cuts in the period to 2050.

Emissions budgets call into question the validity of basing climate change policies around long-term targets, and shift the focus towards immediate annual reductions and intermediate medium-term targets to keep within budget boundaries. This approach has been advocated by the UK's Committee on Climate Change. Given the strong relationship between greenhouse gas emissions and GDP, and the lack of focus on low-carbon routes to economic growth, a huge challenge lies ahead.

It appears that the decarbonisation pathways needed to meet emissions reduction targets developed via the cumulative emissions approach will require rapid and radical socio-economic transformations. Vaughan *et al.*[22] established that to meet a 2°C target, emissions reduction strategies would need to have started by 2010 at the latest; alternatively reductions in excess of 5% per year are going to be needed. Anderson and Bows[17] point out that a roughly equivalent level of emissions reduction was seen following the collapse of the Soviet Union in the early 1990s. Here carbon dioxide emissions fell by 37% between 1990 and 1995, principally as a result of falling energy demand and production levels post-collapse.[23]

As the socio-economic factors driving greenhouse gas emissions over the coming decades cannot be predicted with any certainty, scientists use a variety of emissions scenarios as inputs to climate models. From these models emerge different projections for future changes in variables such as temperature and precipitation. It is the use of different emissions scenarios and climate models that creates the wide range of climate projections, such as the 1.8-4°C 'best estimate' rise in global average surface warming by the end of the century offered by the IPCC.[10]

'Given growth rates of greenhouse gas emissions of 5% in 2010, even the IPCC's highest emissions scenarios are now being overshot. As a result, the 21st century's emissions budget is being consumed at a rapid rate'

As carbon dioxide emissions have increased further and faster than expected, emissions levels now sit at the upper edge of the scenarios used by the IPCC to develop climate change projections.[24] Indeed, given growth rates of greenhouse gas emissions of 5% in 2010, even the IPCC's highest emissions scenarios are now being overshot. As a result, the 21st century's emissions budget is being consumed at a rapid rate.[18] There is a need to recast the climate change debate in recognition of this pressing challenge, accelerating both emissions reduction and the development of adaptation responses to prospective climate change impacts.

This article now turns to the potential consequences of escalating emissions, focusing on sea level rise and temperature change.

Sea level rise

'Given the massive heat capacity of the ocean, the Earth is already committed to many more centuries of sea-level rise due to thermal expansion alone.'
Katherine Richardson, Will Steffen and Diana Liverman, in *Climate Change: Global Risks, Challenges and Decisions*[25]

NASA Goddard Space Flight Center

Above

'The melting of the polar ice sheets has, to date, been a relatively small contributory factor to observed sea level rise. However, this is expected to change'

Observations indicate that the pace of sea level rise is increasing. Globally, sea levels increased at an average rate of 1.8 millimetres per year between 1961 and 2003, and by 3.1 millimetres per year between 1993 and 2003.[10] Much of this has been driven by the thermal expansion of the oceans, which is the most significant cause of recent sea level rise. In effect, the oceans have been absorbing a large proportion (over 80%) of the additional heat generated by climate change, with measurements showing that the temperature of the global oceans has increased as a result to a depth of at least 3,000 metres.[10]

There is much debate over the likely magnitude of sea level rise over the course of this century and beyond. Details of recorded changes in sea level in the past can provide insights into possible future conditions.[25] During the last interglacial period, which it has been suggested provides a good analogue for sea level rise over the coming centuries, levels were 6-9 metres higher than the present day.[25]

In contrast to the IPCC's estimates of sea level rise at a level between 18 and 59 centimetres (depending on the scenario selected) by the end of this century,[10] NASA's Professor James Hansen believes that changes in sea level could be of a much higher order of speed and magnitude. He points in particular to rapid observed increases in melting of ice caps in areas such as Greenland and Antarctica,[26] which has been seen to accelerate further over recent years. The melting of the polar ice sheets has, to date, been a relatively small contributory factor to observed sea level rise. However, this is expected to change, with polar ice sheet melt becoming the key cause of sea level rise towards the end of this century and beyond.[25]

Hansen notes that as a result of non-linear positive feedback loops connected to ice sheet melt (which the IPCC estimates[10] did not account for), sea level could rise by several metres by 2100, yet he also acknowledges that the 'nonlinearity of the ice sheet problem' makes it impossible to predict with confidence what degree of sea level rise to expect by a specified date.[26]

As a result of issues such as this, and the use of different modelling approaches, recent projections for possible sea level rise over the course of this century range from 18 to 215 centimetres.[25] Summarising current understanding of the issue, Richardson *et al.*[25] highlight that 1 metre of sea level rise by the end of this century is 'a distinct possibility and that somewhat higher values cannot be excluded'. It is important to recognise that sea level rise forced by climate change is a process that will unfold over centuries.[27] In a scenario where there is a 50% chance of warming of 2°C occurring by the end of the 21st century, Schaeffer *et al.*[27] project 2.7 metres of sea level rise by 2300, with sea levels still rising at double the present day rate at this point in the future.

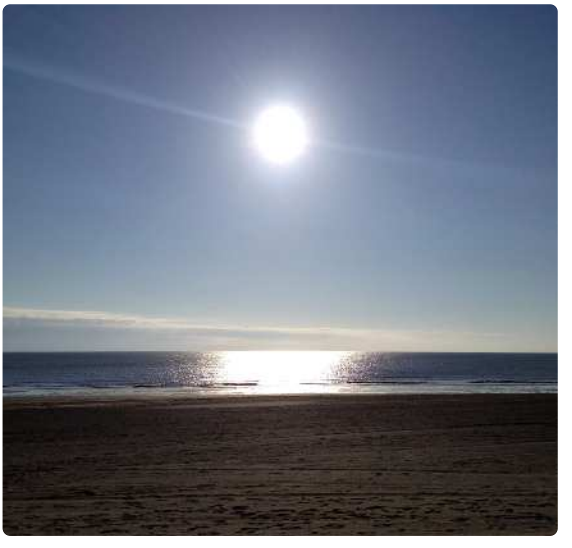
In order to reflect uncertainties surrounding setting limits on future sea level rise, the UK Climate Projections (UKCP09) include an 'H++' scenario. This places a plausible upper limit of a 1.9 metre sea level rise by the end of the 21st century (within a range between 0.93 and 1.9 metres).[28] However, this does not include potential storm surges, which in the Thames Estuary, for example, could be between 0.2 and 0.95 metres within the 21st century.[28] The Environment Agency's Thames Estuary 2100 project 'extreme' scenario, which accounts for sea level rise and storm surge, is a 2.7 metre increase in maximum water levels this century, although the Agency does suggest that without effective mitigation this level could be higher.[29]

H++ is a high-impact, low-probability scenario, which, although deemed by the UK Climate Impacts Programme to be unlikely, is of potential benefit for decision-makers looking to explore the upper end of climate change risks and associated adaptation responses. Future sea level rise will depend in no small part on the level of temperature increase that is seen over the course of this century, and it is to this issue that the discussion now turns.

Temperature rise

'... despite high-level statements to the contrary, there is now little or no chance of maintaining the global mean temperature [increase] at or below 2 °C.'

Kevin Anderson and Alicia Bows, in 'Beyond dangerous climate change: emission scenarios for a new world'[18]



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It now looks unlikely that the global average temperature rise by the end of this century will be kept below 2°C – but the global implications are not well understood

The message emerging from the climate science community is that the chance of keeping temperatures to no more than 2°C above pre-industrial levels is slim at best. This is due to a combination of factors, not least that greenhouse gas emissions are already close to reaching levels that would trigger this degree of warming. Also, there is a palpable lack of engagement of politicians and business leaders in grappling with the challenges associated with decarbonising society. This was most recently evidenced by the Rio +20 conference, which delivered little and demonstrated that there is currently no appetite for multi-lateral action on planetary agendas such as climate change.

Rio +20 compounds the failure to deliver a successor to the Kyoto Protocol, and means that post-2012 there will no longer be any global policy architecture to commit nation states to reducing their greenhouse gas emissions. As a consequence, researchers stress the importance of developing approaches to deliver urgent emissions reductions: 'keeping below 2°C with any reasonable probability will be possible only with urgent and stringent mitigation measures. In practice, this will necessitate almost immediate emissions reductions by rich nations, followed soon after by reductions from developing nations.'[30]

With 2°C now looking like an unlikely marker for global average temperature rise by the end of this century, recent research has raised the realistic prospect of 4°C and beyond above pre-industrial levels.[31] Others have gone further. Without new policies, the IEA believes that there is a potential for temperature rises of 6°C or more in global average temperatures by 2100.[15]

New *et al*.[30] indicate that, with 4°C of global warming, locations across the world, including parts of Australia, Brazil and India, would have average temperatures that are higher than in any part of the globe today. Taking this into account, they state that: 'Warming of 4 °C or more would have consequences that might be beyond the ability of humankind to cope, particularly if those consequences are allied with other stresses.'

'The prospect of rapid climate change and associated risks demands a fundamental re-assessment of social and economic priorities across sectors and spatial scales'

Given the projections for a level of temperature rise of 4°C and beyond above pre-industrial levels by 2100, the magnitude of risks associated with climate change are clear. Social, environmental and economic systems across the world would be severely disrupted by such rapid climate change. Despite the magnitude of the threat, the global implications of this level of climate change are not well understood, yet are thought to include coastal flooding, increases in water stress, risks to agricultural systems, spread of vector-borne diseases, and disruption of ecosystems.[10,30]

Planning for the climate challenge

'... mainstreaming climate change adaptation considerations into current urban development has to be a central strategy for dealing with climate change.'
Katherine Richardson, Will Steffen and Diana Liverman, in *Climate Change: Global Risks, Challenges and Decisions*[25]

The core aim of this article has been to raise awareness of the trajectory of climate change as indicated by recent climate research, particularly concerning the factors underlying and potential future outcomes linked to the pace of recent climate change and the magnitude of future projections. Related issues linked to reducing greenhouse gas emissions and adapting to impacts related to the changing climate have not been covered. There are, however, clear implications for both agendas. The prospect of rapid climate change and associated risks demands a fundamental re-assessment of social and economic priorities across sectors and spatial scales.

There are strong connections between spatial planning and climate change. Features of planning systems that support responses to this agenda include their long-term strategic focus, the forums provided for wide stakeholder involvement, and planning's capacity to connect sectors and spatial scales. Further, spatial planning has a crucial role to play through its influence over the development and use of land and issues linked to building design. Planners sit in a central position to respond to the climate change challenge. The 'ratcheting up' of climate change projections places additional responsibility on planners. Two related themes are introduced below – the spatial implications of climate change impacts; and guidance to planners:

- ***Spatial implications:*** The spatial implications of climate change impacts in the UK, such as sea level rise and water resource shortage, are potentially far-reaching. For example, additional development pressure in the South East of England, coupled with water supply constraints due to reducing rainfall, may impinge on growth aspirations in the region. Threats such as this open up issues concerning the relative weight afforded to pressures on natural resource availability and maintaining current patterns of economic geography in future strategic development decisions. It is also clear that sea level rise threatens some of England's most productive agricultural land, for example around the Wash. With climate change in other parts of the world raising issues of food security, developing approaches to protect nationally significant resources such as this presents a major challenge to planners and policy-makers.
- ***Guidance to planners:*** Climate change projections, prepared for Europe within projects such as ENSEMBLES and nationally via the UKCP09 climate change projections, generally cover several emissions scenarios. Hence they generate a broad range of projections for different climate variables such as temperature and precipitation. In the UK, the UKCP09 projections are used to inform strategic national climate change initiatives such as the Climate Change Risk Assessment (CCRA),[32] which will in turn inform the forthcoming National Adaptation Programme (to be published in 2013). The CCRA drew on a range of emissions scenarios, each of which was deemed equally plausible, noting that

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Flooding in Hebden Bridge, West Yorkshire – we need to develop climate-proactive policy responses to reduce the risk of impacts such as heat stress and surface water flooding

it is too early to establish whether actual emissions are following a particular scenario.[33]

This article outlines research emphasising that current actual emissions and short-term emissions trends are at or beyond the upper end of the suite of scenarios presently being considered by climate modellers. If this is acknowledged, it has significant implications for the development of strategic climate change adaptation policy and the design of adaptation responses in practice. The acceleration of emissions over recent years, coupled with limited options for staying within emissions budgets thought necessary to avoid dangerous climate change, raises the prospect of rapid and severe climate change impacts over the coming decades.

Specifically, this raises questions over how planners, who exert a lasting influence over the form and function of land and development, should be guided on this issue, and whether or not they have the appropriate climate change benchmarks on which to base their decisions. For example, following the precautionary principle, should the projections for the 2080s now be taken as a more reliable indication of the degree of climate change in the 2050s than the existing projections for this period?

'The spatial implications of climate change impacts in the UK, such as sea level rise and water resource shortage, are potentially far-reaching'

Further, in terms of adaptation responses, should strategic developments in coastal areas now be pressed to plan for the H++ sea level rise scenario, and should new developments and redevelopments in urban centres now be required to incorporate certain adaptation measures to reduce future climate risk? With the trajectory of climate change moving in the direction outlined above, such adaptation responses, and many others like them, now appear to be essential.

The task now is to communicate these issues to a broad range of audiences, although there are significant challenges in doing so. Within the planning profession there is a need to redouble efforts to reinforce understanding of basic terminology and of data linked to climate change impacts and adaptation, and to build awareness of the role of planners in setting and responding to adaptation and mitigation agendas. It is also now time to take emerging opportunities to develop climate-proactive policy responses and implement adaptation actions, such as urban green space provision, to reduce the risk of impacts such as heat stress and surface water flooding.

It is clear that a heightened awareness of the climate crisis and the need to develop strategies and actions in response is emerging at a time of economic crisis. This should not be taken as a reason for delay, nor should responding to the challenges posed by the trajectory of climate change be seen as an endeavour that conflicts with progressive visions of the future.

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