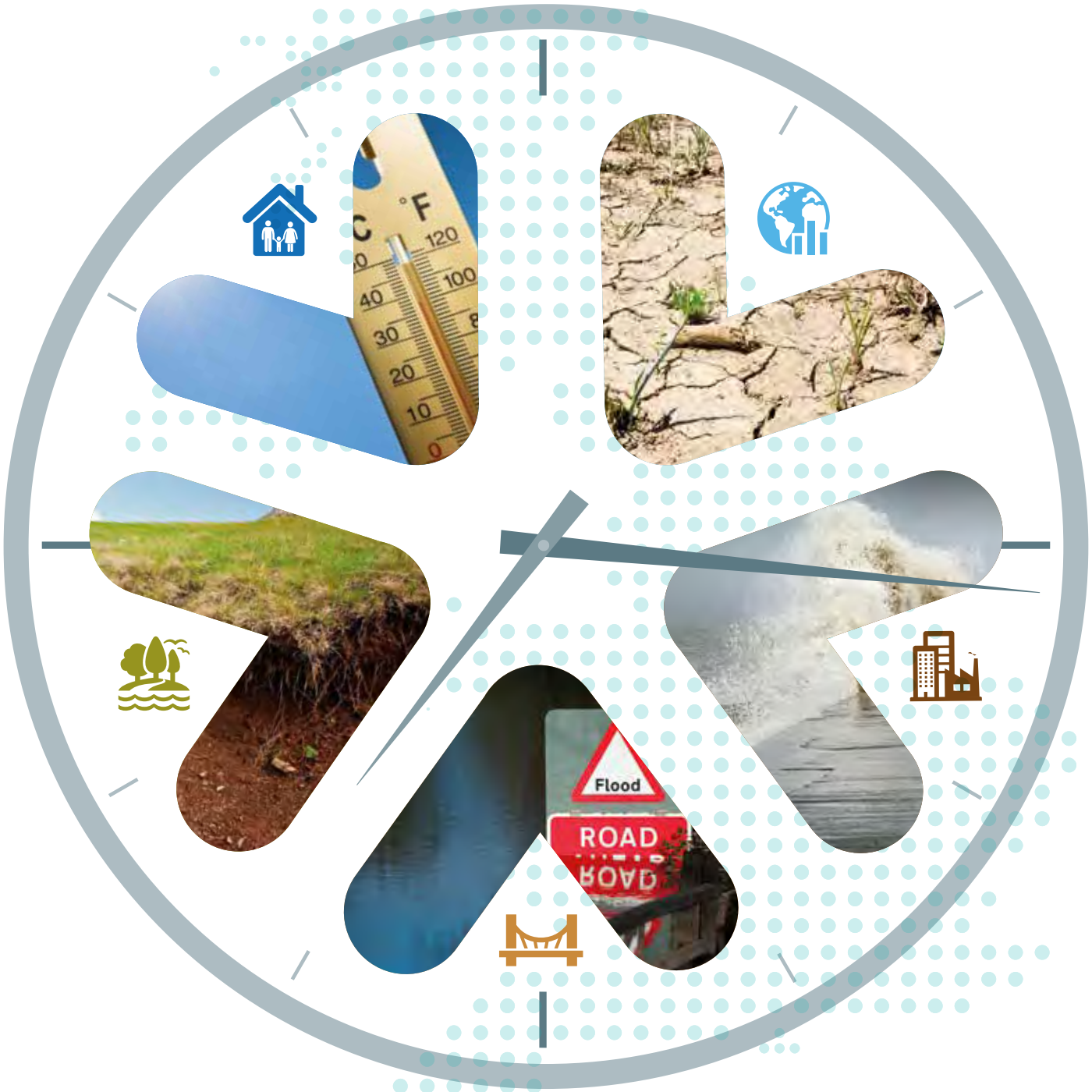
Committee on Climate Change

UK 2017 Climate Change Risk Assessment

UK Climate Change Risk Assessment 2017

Synthesis report: priorities for the next fi e years



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UK Climate Change Risk Assessment 2017

Synthesis report: priorities for the next five years

July 2016

Preface

The Committee on Climate Change (CCC) is an independent statutory body established under the Climate Change Act 2008 to advise the UK and devolved administration governments on setting and meeting carbon budgets, and preparing for climate change.

The Act also established the CCC's Adaptation Sub-Committee (ASC) specifically to provide advice to the UK and devolved governments on climate change risks and opportunities, and to report to the UK Parliament on the progress being made by the National Adaptation Programme.

The UK Climate Change Risk Assessment 2017

The Climate Change Act requires the Government to compile every five years its assessment of the risks and opportunities arising for the UK from climate change. The first UK Climate Change Risk Assessment (CCRA) was presented to Parliament by the Government in January 2012. The Government commissioned the ASC to produce an Evidence Report to inform the second Climate Change Risk Assessment (CCRA2) due in January 2017. This document provides a synthesis of the Evidence Report's key findings.

The full CCRA2 Evidence Report comprises eight chapters written by leading academics, consultants and other experts in the public and private sectors and civil society representing organisations across Great Britain and Northern Ireland. As well as gathering input and feedback at stakeholder events across the UK, the full report has benefited from a call for evidence in 2014 and two rounds of review by stakeholders, technical peer reviewers and other organisations in October 2015 and March 2016. The peer review panel was led by Professor Nigel Arnell, University of Reading.

Separate summaries of the Evidence Report are being published for England, Northern Ireland, Scotland and Wales to inform adaptation planning by the UK and devolved governments.

All of the above reports together with other CCRA2 materials can be found on the CCC's website at www.theccc.org.uk/uk-climate-change-risk-assessment-2017.

Implications of the EU Referendum

The recent vote in favour of leaving the European Union does not change the overall findings of this risk assessment. However, the magnitude of individual climate change risks and opportunities could be affected if legislation, policy and funding derived from the EU, relevant to climate change adaptation, are changed. Important areas include the Common Agricultural and Fisheries Policies, the Water Framework, Bathing Water, Birds, Habitats, Floods, Urban Waste Water Treatment and Solvency II Directives, and the European Structural Investment Fund. Compensatory UK measures may be stronger or weaker than their EU equivalents. The Adaptation Sub-Committee will consider the implications of the EU Referendum and the Government's response to the result in its next statutory progress report on the UK National Adaptation Programme, to be published in June 2017.

Key messages

The global climate is changing, with greenhouse gas emissions from human activity the dominant cause. The global increase in temperature of 0.85°C since 1880 is mirrored in the UK climate, with higher average temperatures and some evidence of more extreme weather events. Average annual UK temperatures over land and the surrounding seas have increased in line with global observations, with a trend towards milder winters and hotter summers in recent decades. Sea levels globally and around the UK have risen by 15-20 centimetres since 1900. Whilst natural variability in the climate will continue to have a large influence on individual weather events, the recent episodes of severe and sustained rainfall are consistent with projections of climate change.

The Paris Agreement is a significant step forward. 195 nations including the UK will "pursue efforts" to prevent more than a 1.5°C increase in global temperatures. Current commitments to reduce emissions however, even if fully implemented, will lead to an estimated 2.7°C rise. Global emissions would need to peak soon and then decline rapidly for the Paris Agreement goals to be feasible. Even in this scenario the uncertain sensitivity of the climate to greenhouse gases means there would remain at least a small chance of 4°C or more of warming by 2100. It is therefore prudent to prepare for further warming whilst pursuing more stringent emission reductions as part of the global effort.

The overall aim of the Evidence Report is to assess the urgency of further action to tackle current and future risks, and realise opportunities, arising for the UK from climate change. Almost sixty individual risks and opportunities have been assessed by leading academics and other experts as part of this second UK Climate Change Risk Assessment. Figure SR.1 presents the top six groups of risks. These are the most important because of their magnitude now and in the future, and because of the need for additional, co-ordinated steps to be taken within the next five years.

Figure SR.1: Top six areas of inter-related climate change risks for the United Kingdom

Source: ASC synthesis of the main areas of risk and opportunity within the chapters of the Evidence Report.
Notes: Future magnitude is based on a combination of climate change and other drivers of risk (e.g. demographic change), taking account of how current adaptation policies and plans across the UK are likely to reduce risks.

The greatest direct climate change-related threats for the UK are large increases in flood risk and exposure to high temperatures and heatwaves, shortages in water, substantial risks to UK wildlife and natural ecosystems, risks to domestic and international food production and trade, and from new and emerging pests and diseases (Table SR.1). A warmer atmosphere can hold more moisture, leading to heavier rainfall and more frequent flooding, including outside of recognised flood risk areas. Higher temperatures will affect public health, infrastructure, business, farming, forestry and the natural environment. Dry periods, when combined with higher temperatures, are likely to result in more severe and prolonged droughts. Projected sea level rise of 50-100 centimetres by 2100 will exacerbate flood risks and accelerate the process of coastal change for exposed communities.

In assessing the magnitude of risks, and the urgency of additional action, the Evidence Report takes account of the following:

- **Risks to the UK from climate change overseas.** Incremental changes in the global climate and extreme weather events elsewhere in the world can affect the UK through global trade, international supply chains, and the movement of people and capital. They can also threaten shared natural resources and shift comparative advantage between nations, with implications for inter-state rivalry and the balance of power.
- **Cross-cutting risks relating to the capacity of communities, businesses, infrastructure providers and national and local government across the UK to act early and effectively.** The true magnitude of risks and opportunities may be underestimated because each tends to be considered in isolation but in practice will act in combination. Actions to address risks need to be co-ordinated amongst the various responsible bodies to be effective. The adaptive capacity of organisations will be constrained by the knowledge, skills and resources available within key functions, and the level of understanding and appetite for risk amongst decision makers.
- **The changing vulnerability to climate change impacts.** Changes in the size and demography of the UK population will influence the scale of future impacts. The location and design of new buildings and infrastructure could either increase vulnerabilities or help to address them.
- **The steps already being taken, or expected to be, across the UK to adapt.** Whether as part of planned, or natural (autonomous), adaptation, actions such as increasing the height of sea walls and tackling unsustainable water abstraction will reduce the impacts of climate change.

As well as risks, the Evidence Report identifies some opportunities arising from climate change:

- **Milder winters should reduce the costs of heating homes and other buildings, helping to alleviate fuel poverty and reduce the number of winter deaths from cold.** However, cold weather is expected to remain a significant cause of death and more action is needed to address the poor thermal performance of housing if this opportunity is to be realised.
- **UK agriculture and forestry may be able to increase production with warmer weather and longer growing seasons.** Whilst uncertain, some crops and tree species may also benefit from increased CO_2 fertilisation. To realise this opportunity, the stewardship of important natural resources needs to be improved to prevent the availability of water and quality of soils constraining output. Farmers may also need advice to help them improve and adapt farm systems and exploit new markets.
- **Economic opportunities for UK businesses may arise from an increase in demand for adaptation-related goods and services.** The UK has relevant expertise in architecture and construction, finance and investment, business risk management, and water and environmental conservation. UK tourism and outdoor activity may also increase. Businesses can be expected to respond to market signals and develop new products and services in these areas.

Table SR.1: Summary of urgent climate change risks for the United Kingdom	
Flooding and coastal change risks to communities, businesses and infrastructure *HIGH MAGNITUDE NOW (high confidence)* *HIGH MAGNITUDE IN FUTURE (high confidence)* MORE ACTION NEEDED	**The impacts of flooding and coastal change in the UK are already significant and expected to increase as a result of climate change.** At the national level, more ambitious approaches to adaptation could offset increases in expected annual flood damage if global warming is limited to 2°C. However, within this national projection local impacts will vary considerably. Improving protection for some communities will be possible whilst others will face the prospect of significantly increased risks. This will affect property values, business revenues and in extreme cases the viability of communities. Risks to communities and local economies are closely linked to the resilience of local infrastructure, in particular energy, transportation and communications systems. Warming of 4°C or more implies inevitable increases in flood risk across all UK regions even in the most ambitious adaptation scenarios considered.
Risks to health, wellbeing and productivity from high temperatures *HIGH MAGNITUDE NOW (high confidence)* *HIGH MAGNITUDE IN FUTURE (medium confidence)* MORE ACTION NEEDED	**Heatwaves in the UK like that experienced in 2003 are expected to become the norm in summer by the 2040s.** The average number of hot days per year has been increasing since the 1960s, and currently 2,000 people die prematurely each year in the UK from heat-related conditions. The growing, ageing population means the number of vulnerable people at risk is increasing. In combination this means the number of premature heat-related deaths is expected to more than triple by the 2050s. The impacts will not be limited to southern England. There is evidence that newer homes are at a greater risk of overheating than older designs. Delayed introduction of policies to ensure homes, hospitals, care facilities, schools and prisons, and business premises, are safe and operable in high temperatures will increase risks and lead to longer-term wellbeing impacts.
Risk of shortages in the public water supply, and for agriculture, energy generation and industry, with impacts on freshwater ecology *MEDIUM MAGNITUDE NOW (medium confidence)* *HIGH MAGNITUDE IN FUTURE (high confidence)* MORE ACTION NEEDED	**Climate change is projected to reduce the amount of water in the environment that can be sustainably withdrawn whilst increasing the demand for irrigation during the driest months. At the same time the growing population will create additional demands on already stretched resources in some parts of the country.** Even low population growth and modest climate change scenarios suggest severe water supply deficits, and with high population growth and more severe climate change these deficits deepen and by the 2050s extend across the UK. Whilst there is significant action already underway, there is an urgent need for longer-term water resource planning to assess the scale of risks and consider strategic options, more co-ordinated action to ensure resilient supplies especially in times of drought, and further steps to achieve the ambitious reductions in water demand and leakage that are likely to be required. Otherwise there could be increasingly difficult trade-offs between the needs of industry, farming and the public water supply, and the ecological status of rivers, lakes, estuaries, and groundwater.

Table SR.1: Summary of urgent climate change risks for the United Kingdom

Risks to natural capital, including terrestrial, coastal, marine and freshwater ecosystems, soils and biodiversity *MEDIUM MAGNITUDE NOW (medium confidence)* *HIGH MAGNITUDE IN FUTURE (medium confidence)* MORE ACTION NEEDED	**Climate change presents a substantial risk to the UK's native wildlife and to the vital goods and services provided by natural capital, including food, timber and fibre, clean water, carbon storage, and the cultural benefits derived from landscapes.** Projected increases in soil aridity and wildfire risks, changes in the availability and temperature of freshwater, and the acidification and warming of UK seas, will exacerbate existing pressures including pollution, habitat loss, invasive species, and the over-exploitation of natural resources. Significant and potentially far-reaching changes are already underway, such as the observed shift from cold to warm water plankton species in the North Sea, which could have implications for the entire marine food chain.
Risks to domestic and international food production and trade *MEDIUM MAGNITUDE NOW (high confidence)* *HIGH MAGNITUDE IN FUTURE (medium confidence)* MORE ACTION NEEDED	**The affordability of food for the UK population is subject to domestic and international risks affecting production and prices.** Extreme weather events affecting international production, trade and supply chains could make food prices volatile with occasional spikes. Longer-term incremental changes in climate are likely to alter the agricultural productivity of regions that are important for global food production. The resilience of the UK food system in the long-term will depend on the stewardship of natural resources here and overseas, and how international markets respond to the pressures from climate change. There is the potential for domestic production to increase in a warmer climate but this will be constrained unless more action is taken to address the declining quality of soils and projected water deficits in the most productive UK regions.
New and emerging pests and diseases, and invasive non-native species, affecting people, plants and animals *MEDIUM MAGNITUDE NOW (medium confidence)* *HIGH MAGNITUDE IN FUTURE (low confidence)* RESEARCH PRIORITY	**The impacts of new and emerging pests and diseases are potentially high for otherwise healthy people, animals and plants. The warmer, wetter conditions expected with climate change will allow some pests and diseases to extend their range.** Disease outbreaks are difficult to predict, have widespread direct as well as indirect impacts on communities and economies, and are very expensive to manage once established. Though not necessarily caused by climate change, several vector-borne diseases (i.e. diseases spread by insects and ticks) have emerged and expanded in Europe in recent years. These include vivax malaria, West Nile fever, dengue fever, Chikungunya fever, leishmaniasis, Lyme disease (already present in the UK) and tick-borne encephalitis. There is an urgent need for further research to inform government policy and operational measures, such as additional surveillance of emerging pathogens and monitoring of existing problem species. Nationally and internationally there is a need for more research to understand how pest and disease outbreaks can be contained.

Source: ASC synthesis of the main areas of risk emerging from the chapters of the Evidence Report.

Notes: Risks are based on the likelihood of adverse (or beneficial) outcomes under a range of climate and other scenarios (e.g. population and economic growth). Risks are colour-coded according to urgency category:

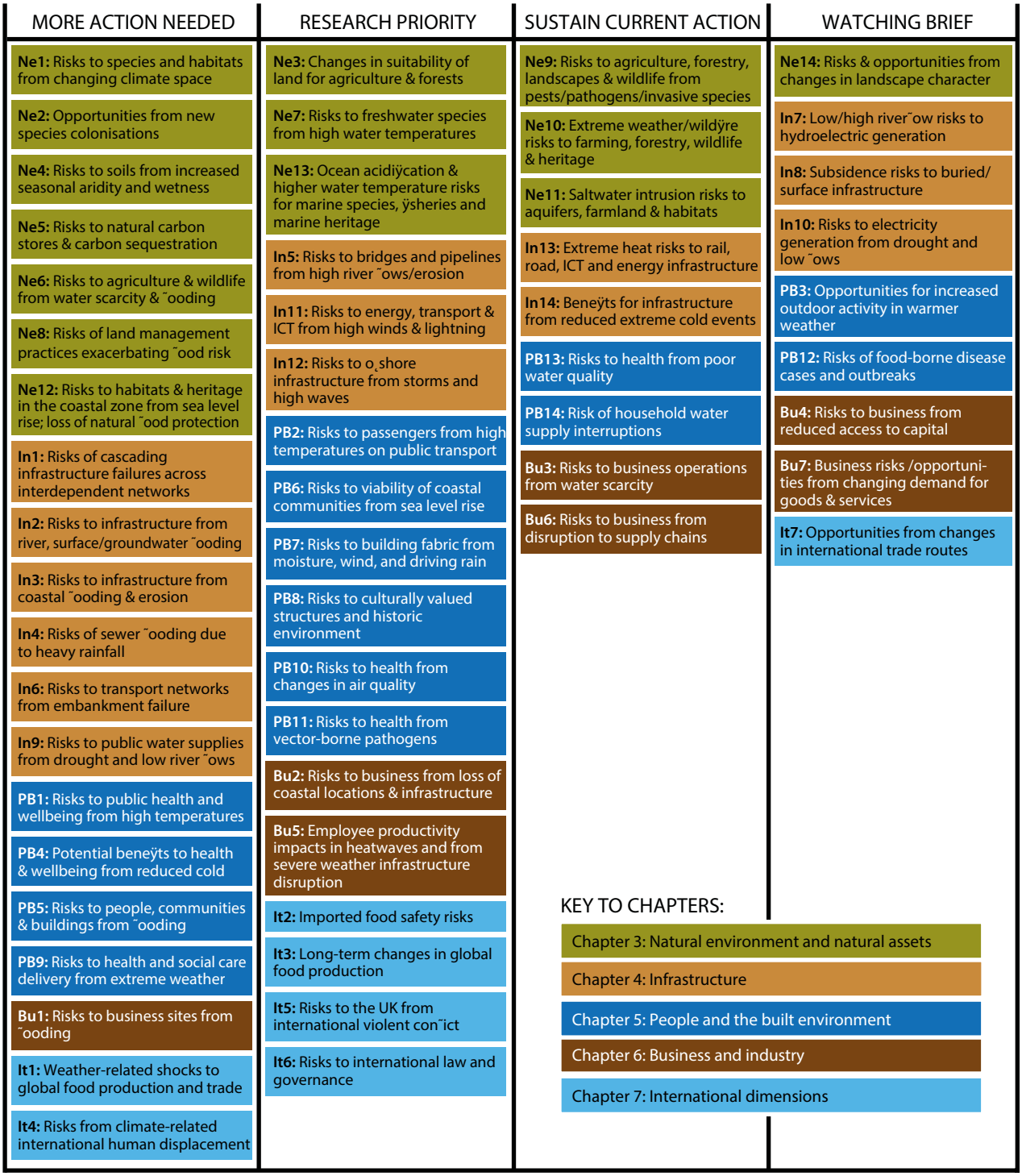
- ***More action needed:*** New, stronger or different government policies or implementation activities– over and above those already planned – are needed to reduce long-term vulnerability to climate change.
- ***Research priority:*** Research is needed to fill significant evidence gaps or reduce the uncertainty in the current level of understanding in order to assess the need for additional action.

The urgency categories take full account of the current policies and adaptation plans in place across the four UK nations to mitigate risks.

The above groupings attempt to capture the most important broad areas requiring further attention. Other specific risks have also been identified and should not be overlooked. Table SR.2 presents the full list of risks and opportunities discussed in the Evidence Report. Other risks arise from the exposure of interdependent infrastructure networks to multiple, correlated hazards (e.g. flooding and high winds), as well as the vulnerability of certain infrastructure types to specific hazards (e.g. road surfaces to high temperatures). Air quality in both urban and rural areas could deteriorate further though climate change will have less influence than pollution from transport, industry and farming. Risks will arise for culturally-valued buildings and landscapes from a combination of higher temperatures and rainfall intensities. There are also uncertain but potentially very significant international risks arising from climate-related human displacement, and the possibility of violent inter-state conflict over scarce natural resources.

The UK Government will consider these findings and present to Parliament in early 2017 their formal assessment of the climate change risks and opportunities for the UK. The UK and devolved governments are then each expected to update their national adaptation programmes to address the risks identified, beginning with the second UK National Adaptation Programme, expected in the summer of 2018.

Figure SR.2: Urgency of risks and opportunities identified and discussed in the vidence Report



Source: ASC judgement in discussion with lead contributors, based on the evidence of magnitude, current and potential adaptation, and benefits of further action in the next five years, presented within the Evidence Report chapters.

Notes: Individual risks and opportunities are presented in the order they are discussed in the chapters (not in priority order). The urgency categories are defined as follows:

- **More action needed:** New, stronger or different government policies or implementation activities– over and above those already planned – are needed to reduce long-term vulnerability to climate change.
- **Research priority:** Research is needed to fill significant evidence gaps or reduce the uncertainty in the current level of understanding in order to assess the need for additional action.
- **Sustain current action:** Current or planned levels of activity are appropriate, but continued implementation of these policies or plans is needed to ensure that the risk continues to be managed in the future. This includes any existing plans to increase or change the current level of activity.
- **Watching brief:** The evidence in these areas should be kept under review, with long-term monitoring of risk levels and adaptation activity so that further action can be taken if necessary.

See Chapter 2 of the Evidence Report for more details of the urgency scoring methodology used.

Acknowledgements

The Adaptation Sub-Committee would like to thank:

The team that prepared the analysis for this report: led by Kathryn Humphrey, Daniel Johns and Matthew Bell, and included Manuela Di Mauro, David Thompson, David Style, Rachel Buckle and Alex Townsend.

The lead contributors that compiled the Evidence Report:

Synthesis - Daniel Johns (ASC Secretariat).

Chapter 1: Introduction - Kathryn Humphrey (ASC Secretariat), James Murphy (Met Office).

Chapter 2: Approach and Context - Rachel Warren (University of East Anglia).

Chapter 3: Natural Environment and Natural Assets - Iain Brown (University of York).

Chapter 4: Infrastructure - Richard Dawson (Newcastle University).

Chapter 5: People and the Built Environment - Sari Kovats (London School of Hygiene & Tropical Medicine) and Dan Osborn (University College London).

Chapter 6: Business and Industry - Swenja Surminski (London School of Economics).

Chapter 7: International Dimensions - Andy Challinor (University of Leeds) and W. Neil Adger (University of Exeter).

Chapter 8: Cross-Cutting Issues - Roger Street (UK Climate Impacts Programme).

The authors of four research projects commissioned to inform this second CCRA:

Sayers and Partners et al. (2015) for the ASC, *Future projections of UK flood risk*.

HR Wallingford et al. (2015) for the ASC, *Updated projections of water availability in the UK*.

AECOM et al. (2015) for the ASC, *Aggregate assessment of climate change impacts on the goods and services provided by the UK's natural assets*.

Met Office et al. (2015) for the ASC, *Developing H++ climate change scenarios*.

These research projects were funded by the Natural Environment Research Council with contributions from Defra, the devolved administrations, and the Environment Agency.

Other members of the Secretariat who contributed to this report: Jo Barrett, Stephen Smith, Steve Westlake, Penny Seera and Stephanie Wildeshaus.

Members of the Advisory Board chaired by Lord Krebs, consisting of the customers and funders of the Evidence Report representing Defra, the Scottish Government, the Welsh Government, the Northern Ireland Executive, Environment Agency, and the Natural Environment Research Council.

The peer reviewers and a wide range of stakeholders who attended our expert workshops in London, Cardiff, Edinburgh and Belfast in 2014 and 2015, responded to our call for evidence, reviewed the four research reports, provided feedback on the draft chapters, and held discussions with committee members, lead and contributing authors, and members of the secretariat.

The committee would also like to thank the many contributing authors who gave their time and expertise to the project for free. See full acknowledgements in Chapter 1 of the Evidence Report.

This report should be referenced as:
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Contents

Foreword

The scientific consensus is that the global climate has already changed as a result of man made greenhouse gas emissions and that it will continue to do so. No-one can be sure about the exact pace and magnitude of change, but planning for the future means planning for a different climate.

There is no question that the primary response to climate change should be to reduce greenhouse gas emissions to limit further climate change, as agreed in Paris last December. But at the same time it is crucial to prepare for the inevitable changes that will result from the gases that have already been released into the atmosphere and that will continue to be emitted for some time to come.

This report draws together the available evidence relating to the risks and opportunities from the impacts of climate change in the UK. It has involved a very large team of contributors from the UK and overseas. The hundreds of authors, peer reviewers and stakeholders who have drafted and commented on the text give us confidence that this is an authoritative, comprehensive and up to date assessment of the evidence. The main report runs to several hundred pages, so the Adaptation Sub-Committee has produced this short synthesis report that captures the key messages.

The aim of the report is to assess the urgency of further action or research in the next five years, to help the UK and devolved governments and others prioritise their resources. Our analysis includes the effects of climate change, adaptation measures that are already underway, such as investment in flood defences, and the effects of economic and demographic trends. Even when the full impacts of climate change will not be felt for several decades, it may be a matter of urgency to act now, because of the long-term consequences of today's decisions.

The six immediate priority areas are related to risks of flooding and coastal change, the impact of high temperatures in the built environment, risks to natural capital, risks of future water shortages, impacts on the global food system, and risks arising from new and emerging pests and diseases.

It will now be for others, primarily the UK and devolved governments, to decide on what action to take in light of our evidence report. In June 2017, the Adaptation Sub-Committee will present its second assessment of the National Adaptation Programme, in which we will update our analysis of whether or not sufficient action is being taken to manage climate risks.

The next report will also take account of the recent vote to leave the European Union. EU-derived legislation has served to raise environmental and other standards in the UK over recent decades. If the vote to leave the EU changes the UK's legal framework it will be important for new laws and policies to be introduced that preserve the long-term outcomes that need to be achieved, to avoid the risks from climate change increasing. The ASC's next report will consider whether the relevant domestic policies and proposals coming forward are commensurate with the risks from climate change.

Lord Krebs
Chair, Adaptation Sub-Committee
of the Committee on Climate Change

The Adaptation Sub-Committee

Lord John Krebs, Chair

Professor Lord Krebs of Wytham Kt FRS was until recently Principal of Jesus College Oxford. Previously, he held posts at the University of British Columbia, the University of Wales, and Oxford, where he was lecturer in Zoology, 1976-88, and Royal Society Research Professor, 1988-2005. From 1994-1999, he was Chief Executive of the Natural Environment Research Council and, from 2000-2005, Chairman of the Food Standards Agency. He is a member of the U.S. National Academy of Sciences. He was chairman of the House of Lords Science & Technology Select Committee from 2010 to 2014 and President of the British Science Association in 2012.

Professor Jim Hall

Professor Jim Hall FREng is Director of the Environmental Change Institute at Oxford University, where he is Professor of Climate and Environmental Risks. A chartered engineer by background, Professor Hall has pioneered the use of probabilistic methods in flood risk assessment and water resource systems. He is Associate Editor of the Journal of Flood Risk Management and Fellow of the Institute of Civil Engineers.

Professor Dame Anne Johnson

Professor Dame Anne Johnson DBE FMedSci is a public health doctor. She is Professor of Infectious Disease Epidemiology, Chair of the Population and Lifelong Health Domain and Vice Dean International at University College London. She was a member of the UCL/Lancet Commission report on managing the health effects of climate change. She was previously Chair of the MRC Population Health Sciences Group. She is also a Wellcome Trust Governor.

Ece Ozdemiroglu

Ece Ozdemiroglu is an environmental economist and the founding director of eftec (Economics For the Environment Consultancy). At eftec she has undertaken, directed and quality assured over 450 projects generating and interpreting economic value evidence on natural capital, ecosystem services, green infrastructure, water and flood management, remediation of environmental damage, cultural heritage, chemicals and value of information. She is also the Economics Lead of the Valuing Nature Programme, steering group member of the Natural Capital Initiative, and associate editor of the Journal for Environmental Economics and Policy.

Rosalyn Schofield LLB

Rosalyn Schofield is a solicitor. She is currently Director of Company Secretariat at Associated British Foods plc where she has global responsibility for sustainability, including the environmental impact of its businesses. Formerly, she was Legal Director at JD Wetherspoon plc where she managed the development, construction and opening of up to 100 outlets a year. Her early career was as a commercial property lawyer in private practice.

Sir Graham Wynne CBE

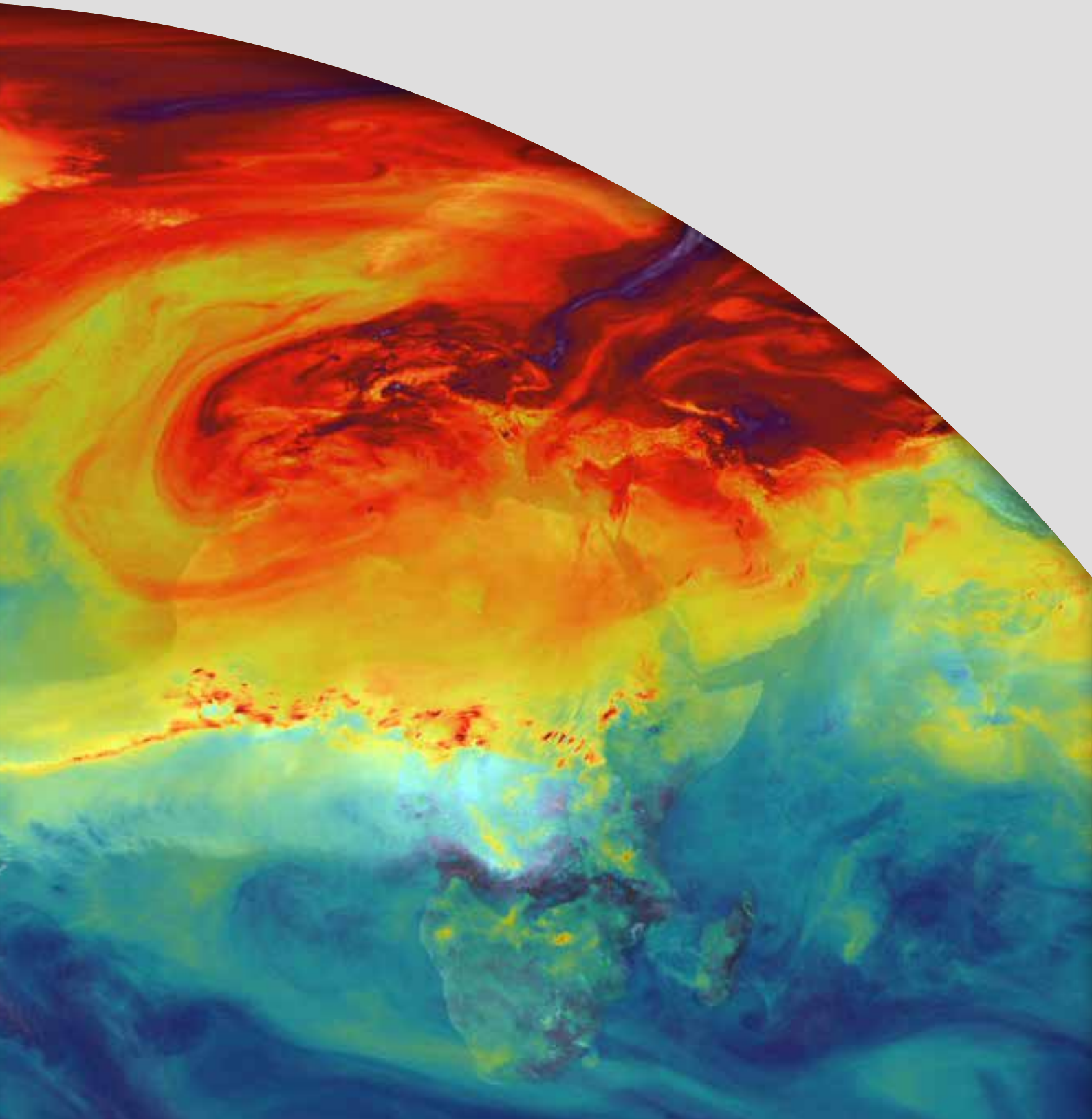
Sir Graham Wynne is a former Chief Executive and Director of Conservation of the RSPB. He is currently Senior Advisor to the Prince of Wales' International Sustainability Unit (ISU), a member of the Board of the Institute for European Environmental Policy and a Trustee of Green Alliance. He was a member of the Policy Commission on the Future of Farming and Food, the Sustainable Development Commission, the Foresight Land Use Futures Group and England's Wildlife Network Review Panel. His early career was in urban planning and inner city regeneration.

Professor Martin Parry (Imperial College) and Professor Samuel Fankhauser (London School of Economics) were also members of the Adaptation Sub-Committee until the end of December 2015.

Chapter 1: Introduction

The need for a UK Climate Change Risk Assessment

Purpose of this report



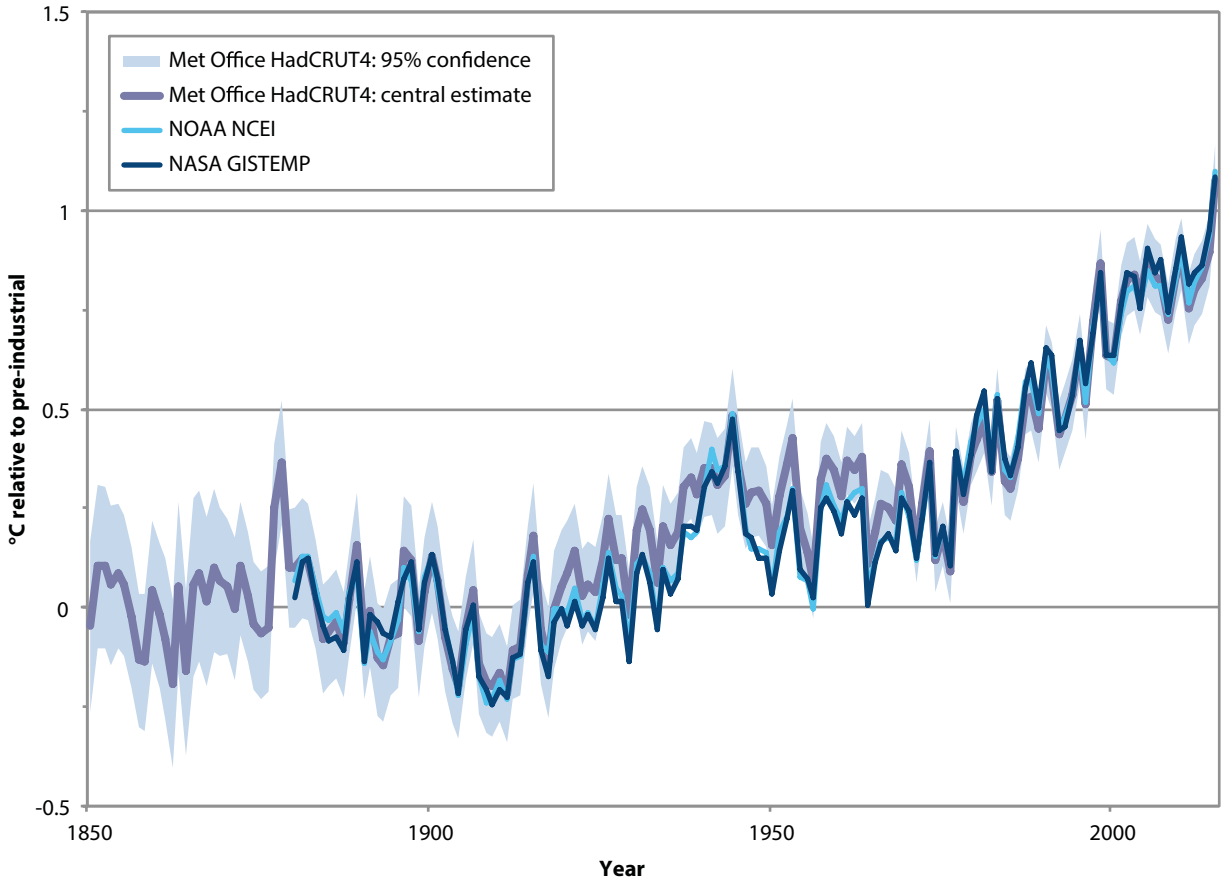
The need for a UK Climate Change Risk Assessment

The global climate is changing, leading to rising temperatures and sea levels, retreating ice, and an increase in the number of heavy precipitation events in a number of regions.

The average surface temperature of the globe, combined over land and ocean, increased by 0.85°C [0.65 - 1.06°C] between 1880 and 2012 (Figure SR.3 – including data up to and including 2015). The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2014) concluded that the warming trend in the climate system since the 1950s is unequivocal and the dominant cause is greenhouse gas emissions from human activity.

- The amplitude and spatial pattern of warming that has evolved over the 20th century matches the predictions of climate models that incorporate natural and human factors combined, but not natural factors alone (IPCC, 2014).
- Human-driven emissions of CO_2 and other greenhouse gases have stemmed primarily from burning fossil fuels, deforestation, and other land-use change. Accelerating economic activity over the 20th century means that half of the anthropogenic greenhouse gas emissions since the beginning of the industrial revolution occurred between 1970 and 2011 (IPCC, 2014).
- According to data extracted from ice cores, and other lines of evidence, concentrations of carbon dioxide, methane and nitrous oxide in the atmosphere are at their highest for at least the last 800,000 years (IPCC, 2014).

Figure SR.3: Global average surface temperature since the mid 19th century



Source: Met Office, NASA, NOAA.
Notes: Plot shows the global average surface temperature relative to the pre-industrial era (using the 1880 – 1899 period) from three independent monitoring groups.

Image on previous page: visualisation of carbon dioxide concentrations in the atmosphere, produced by the NASA Goddard Space Flight Center. See: https://svs.gsfc.nasa.gov/11719.

Fourteen of the sixteen warmest years on record have occurred since 2000, with 2015 confirmed as the warmest year globally on record. 2015 was more than 1°C higher than pre-industrial temperatures and 0.2°C above 2014 which was the previous warmest year. Such a run of high temperatures is extremely unlikely to have occurred in the absence of human-caused climate change (Mann et al., 2016). The global temperature record is highly likely to be broken again in 2016.[1]

The measured increases in global average surface temperature have been accompanied by other observed changes that are symptomatic of a shift in the Earth's energy balance:

- **Rising ocean heat content:** Over 90% of the excess heat trapped by greenhouse gases between 1971 and 2010 has been absorbed by the oceans. Warming has been measured to depths of 2,000 metres and half of the increase in the heat content of oceans since the industrial revolution has occurred in the last twenty years (Glecker et al., 2016). Globally, warming is highest at the surface (to a depth of 75 metres) with temperatures increasing by about 0.11°C [0.09 – 0.13°C] per decade since the 1970s (IPCC, 2014).
- **Sea level rise:** After little global change between AD 0 and 1900, global average sea levels have risen by 19 [17 – 21] centimetres since the beginning of the 20th century (IPCC, 2014). This has principally been caused by thermal expansion of the oceans (IPCC, 2014) but there have also been 31 successive years of net losses in glacier mass and other ice on land (NOAA, 2015). The rate of sea level rise has accelerated to more than 3mm per year since the 1990s (IPCC, 2014).
- **Reduction in Antarctic and Greenland ice sheets:** New observations show faster ice loss than reported in IPCC (2014), especially along the West Antarctic coast where the structure of the ice sheet makes it vulnerable to collapse (McMillan et al., 2014, Rignot et al., 2014). New modelling suggests such a collapse may already be under way (Joughin et al., 2014), but more detailed assessments are needed to support this. The process of collapse, if underway, would take centuries to complete but lead to higher rates of sea level rise than current best estimates.
- **Reduction in Arctic sea ice:** Whilst the extent of Arctic sea ice in summer fluctuates from year to year there has been a significant downward trend since satellites began measurement in the 1970s.[2] The lowest extent to date was recorded in September 2012, 3.29 million square kilometres (49%) below the 1979 – 2000 average (NSIDC, 2012).
- **Ocean acidification:** Oceans to date have absorbed about a quarter of the CO_2 released to the atmosphere from human activity (Gattuso et al., 2015) leading to ocean acidification (Jacobson, 2005). Ocean acidification causes coral bleaching and undermines the structure of other calcifying marine organisms such as starfish, crustaceans and molluscs, important for the global food chain (Mora et al., 2013).
- **An increase in extreme weather events:** Changes in many extreme weather and climate events have been observed since the 1950s (IPCC, 2014). Globally, the number of cold days has decreased and the number of warm days has increased. The frequency of heat waves has increased in large parts of Europe, Asia and Australia. Heavy precipitation events have increased in some regions (for example in North America and Europe) and decreased in others.

1 As reported here: http://www.climatecentral.org/news/99-percent-chance-2016-hottest-year-20359

2 See: http://nsidc.org/arcticseaicenews/charctic-interactive-sea-ice-graph/

Reducing greenhouse gas emissions will be key to limiting the impacts of climate change. The IPCC's Fifth Assessment Report concluded that to retain a likely (66%) chance of avoiding a 2°C rise only a further 1,000 [650 – 1250] gigatonnes of CO_2 could be released to the atmosphere after 2011. Achieving this implies annual greenhouse gas emissions peaking soon and then reducing by 40-70% by 2050, and near or below zero net emissions by 2100.[3]

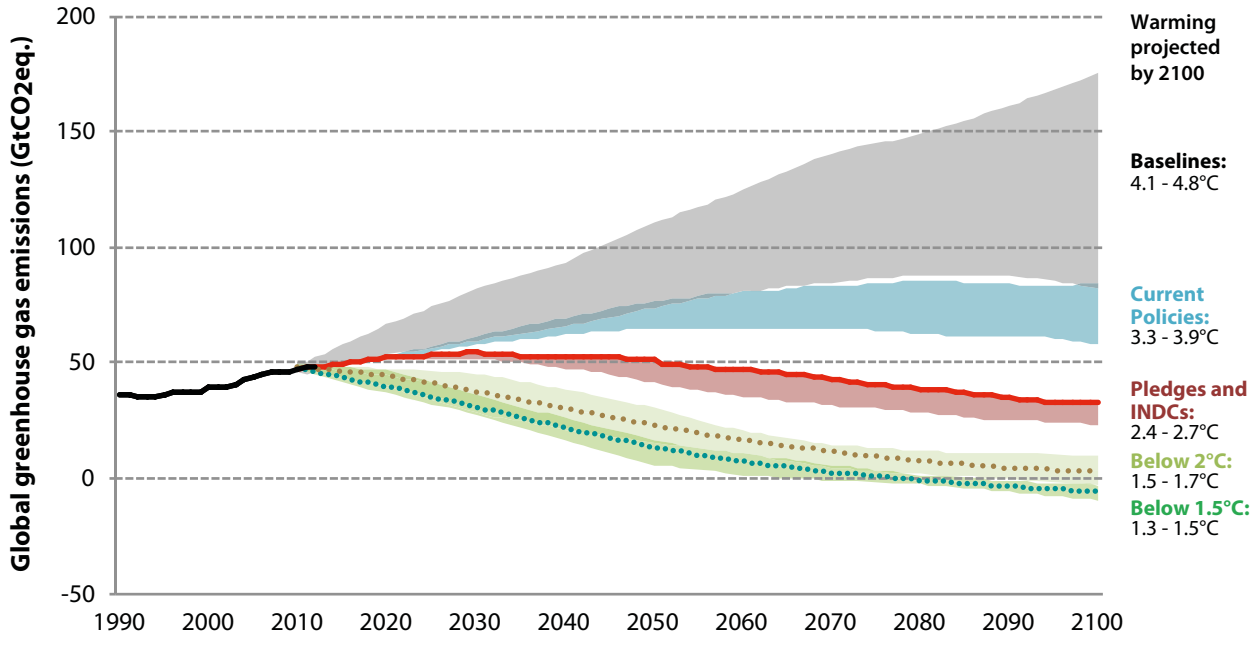
Due to the length of time that carbon dioxide and some other greenhouse gases remain in the atmosphere, it is the cumulative emissions over time that will largely determine the amount of warming that occurs. Emissions totalling 1,900 gigatonnes of CO_2 ($GtCO_2$) occurred between 1870 and 2011, with annual emissions currently standing at around 36 $GtCO_2$ per year. If this were to continue the 2°C carbon budget would be exhausted within two to three decades.

In any event, at some stage, emissions will need to fall to near zero to avoid further warming. However, even in this scenario rising sea levels and other changes to the Earth's natural systems would continue into the next century and beyond (IPCC, 2014).

The agreement at the Paris Conference of the Parties in December 2015 was a major step forward in tackling climate change. 195 nations have agreed to a legally-binding process in order to limit global surface warming to "well below" 2°C, "pursue efforts" to prevent more than a 1.5°C increase, and achieve net zero emissions later this century.

The agreement calls for a global stocktake of national commitments every five years. At present, full implementation of the current Nationally Determined Contributions (NDCs) would probably correspond to a rise in global surface temperature of well above two degrees with a central estimate of 2.7°C (Gütschow et al., 2015, Figure SR.4). If these national commitments are not fulfilled, global temperatures could rise by 4.1–4.8°C, with a temperature increase of 6°C remaining plausible (CCC, 2015).

Figure SR.4: Potential trajectories of long-term emissions and resulting global temperatures



Source: Gütschow et al. (2015).
Notes: LULUCF stands for land-use, land-use change, and forestry.

3 The 40-70% reduction by 2050 is relative to the 2010 level of 49 $GtCO_2$-equivalent (IPCC, 2014). The remaining 1,000 $GtCO_2$ in the global 'carbon budget' is for CO_2 only, but takes account of other greenhouse gas emissions. However, if emissions of other greenhouse gases increase, the budget for CO_2 would reduce.

The combination of the warming that has already occurred, together with at least some further warming that is inevitable, means further adaptation to climate change will be required.

Even with strong mitigation policies implemented globally, some further changes in the climate are inevitable including for the UK. There remains significant uncertainty in the magnitude of future warming and its impacts for given levels of cumulative greenhouse gas emissions and CO_2 concentrations in the atmosphere. Even in the best case scenario, of warming limited to 1.5 to 2°C, there are likely to be significant national as well as global impacts beyond those already observed. Therefore, it is critical that appropriate and cost-effective steps are taken as a matter of urgency to prepare the country for climate change.

There also remains a chance of disruptive shifts in the climate, with an increasing chance of severe, pervasive and irreversible impacts associated with higher magnitudes of warming. Severe and widespread impacts could include substantial species extinctions, large risks to global and regional food production, and a combination of high temperatures and humidity compromising normal human activity. The thresholds for abrupt and irreversible change remain uncertain, but the risk associated with crossing multiple tipping points increases with rising temperature (IPCC, 2014).

Purpose of this report

This report summarises the Adaptation Sub-Committee's statutory advice on the risks and opportunities arising for the United Kingdom from climate change, as part of a climate change risk assessment required by Parliament every five years.

The UK is vulnerable to the global changes described above. In passing the Climate Change Act in 2008, Parliament created a long-term statutory framework for assessing and managing the risks to the UK from the changing climate. The Act established the Committee on Climate Change and its Adaptation Sub-Committee as statutory advisors to the UK and devolved governments.

The Act requires the Government to assess the risks and opportunities relevant to the UK every five years and present a report to Parliament. The first such UK Climate Change Risk Assessment (CCRA1) was published by the UK Government in January 2012. The Adaptation Sub-Committee (ASC) is required under the Act to give advice on the production of each CCRA.

Based on the risks identified, the Government is required to set objectives and introduce policies and activities to manage their impacts. The first UK National Adaptation Programme (NAP) was published in July 2013, covering devolved policy areas in England and UK-wide reserved matters. Similar adaptation programmes have also been published in Scotland (as required under the Climate Change (Scotland) Act 2009), Wales and Northern Ireland.

This report summarises a much more detailed Evidence Report, prepared by the ASC by working with leading academics and experts from the public and private sectors and civil society.

For the first CCRA, Defra instructed a consortium led by the consultancy HR Wallingford to compile an evidence report. This was published in January 2012 together with the Government's report to Parliament. The ASC provided methodological advice on the first CCRA, helped peer review its findings, and gathered lessons for subsequent CCRAs.

For this second CCRA, the Adaptation Sub-Committee was asked to compile an independent Evidence Report to inform the Government's report to Parliament, due in January 2017. This synthesis report summarises the conclusions of the full Evidence Report.

Chapters of the Evidence Report have been compiled by teams of leading academics and other experts working with the Adaptation Sub-Committee. Members of the ASC and its secretariat have helped steer the production of each chapter but they remain owned by the relevant authoring team.

The focus for this second CCRA is to advise the UK and devolved governments on the most urgent priorities to be addressed in the next round of adaptation programmes.

The first CCRA assessed the long-term risks to the UK mainly in terms of their potential magnitude but it did not, in a consistent way, take account of the policies and adaptation plans already in place to manage the risks. The first CCRA also focused primarily on risks arising in the UK, and did not include in its findings those international risks that could have national consequences.

The second CCRA is based on a literature review of the available evidence regarding climate change risks and opportunities that affect the UK. However, with the support of the Natural Environment Research Council, the ASC commissioned four research projects published in autumn 2015:

- Sayers and Partners et al. (2015) for the ASC, *Future projections of UK flood risk*.
- HR Wallingford et al. (2015) for the ASC, *Updated projections of water availability in the UK*.
- AECOM et al. (2015) for the ASC, *Aggregate assessment of climate change impacts on the goods and services provided by the UK's natural assets*.
- Met Office et al. (2015) for the ASC, *Developing H++ climate change scenarios*.

The urgency of further action has been assessed by the Adaptation Sub-Committee based on the evidence presented within each chapter, taking in to account the views of the chapter authors. In concluding on the urgency of each risk, the ASC has considered the magnitude of the risk both now and in the future, the potential for current policies or other actions to manage the risk, and the additional benefit of taking further action in the next round of national adaptation plans.

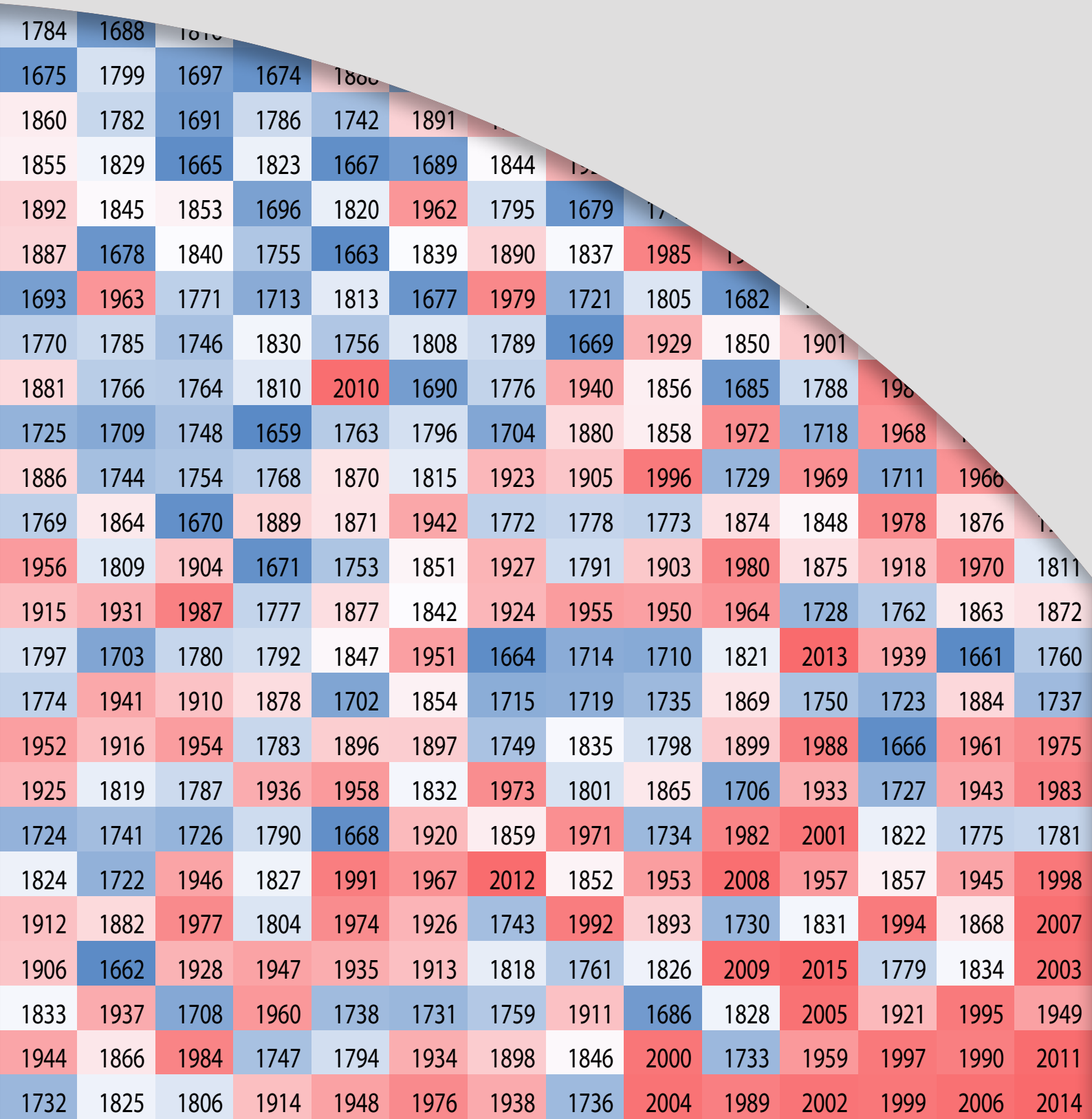
Chapter 2: Climate change in the United Kingdom

Observed changes in the UK climate

Projections of the UK climate for this century

Impacts from 2°C and 4°C of warming

Understanding the potential for climate extremes



Observed changes in the UK climate

UK average temperatures and sea levels have risen in line with global changes. There has been a significant increase in rainfall in western Scotland since the 1960s, with upward though non-significant trends in rainfall across the whole of the UK. More winter rainfall has been falling in heavy rainfall events. These patterns are consistent with projections of more and heavier rainfall for the UK in a warmer atmosphere.

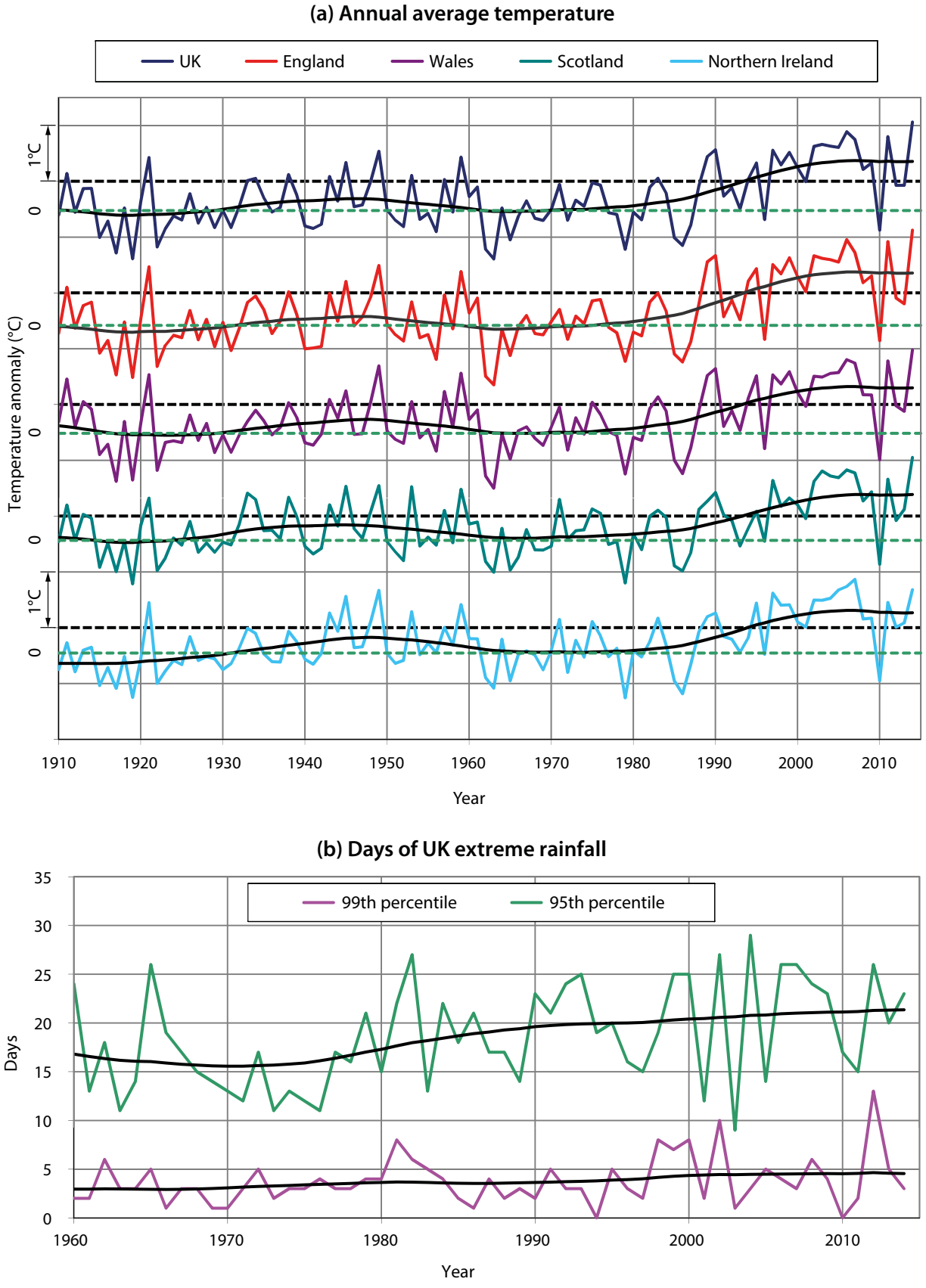
- **Temperature over land:** Annual average UK land temperature was 0.9°C higher during the period 2005-2014 compared to 1961-1990, with 2014 being the warmest individual year. The majority of UK warming has occurred since the 1970s. This recent warming is consistent with increasing greenhouse gases in the atmosphere and is very unlikely to be due to natural climate variations (Karoly and Stott, 2006). All ten of the warmest years in the UK annual average temperature record have occurred since 1990, with the eight warmest occurring since 2002 (Kendon et al., 2015).
- **Sea levels:** Average UK sea levels have risen at a rate of around 1.4 +/- 0.2 mm per year since 1901 (Kendon et al., 2015, Wadey et al., 2014), close to the global average rate of change. The rate of change has accelerated since 1990 (Jenkins et al., 2008), which globally now averages more than 3 mm per year (IPCC, 2014). The UK is also influenced by vertical movements in the land mass due to isostatic rebound, with a general pattern of sinking in the south and lifting in the north.
- **Rainfall:** There has been a significant upward trend in annual rainfall over Scotland, to a level more than 10% above the average during the early decades of the 20th century. Smaller, non-statistically significant increases in annual rainfall have also occurred over Northern Ireland, England and Wales in recent decades (Kendon et al., 2015). More winter rainfall has fallen as heavy precipitation during the last thirty years, and there have been increases in winter run-off and high river flows (Watts et al., 2015). These changes are consistent with projected global rainfall patterns in a warming climate but it is not possible at this stage to attribute them unambiguously to climate change. The relatively short rainfall and river gauge records in the UK may also understate the current risk of extreme rainfall.[4]
- **Wind storms:** The frequency of severe autumn and winter wind storms increased between 1950 and 2003 although storminess in recent decades is not considered unusual in the context of longer European records dating back to the early 20th century (Allen et al., 2009). Wind speeds show a very slight decline across the UK in all regions except the south-east, which shows a slight increase. These changes are consistent with climate projections for the UK but uncertainties are large (Watson et al., 2013).

Figure SR.5 shows the observed changes in annual average temperatures for each UK nation together with the number of days of extreme rainfall in each year since the 1960s.

4 The Met Office has been commissioned to reassess the potential for extreme rainfall in England (in the current climate). This advice will form part of the Government's National Flood Resilience Review, due to report in July 2016, initiated after severe rainfall and widespread flooding occurred in December 2015.

Image on previous page: annual average temperatures ranked according to the Central England Temperature record. Warmest years are in the bottom right hand corner and coolest towards the top-left (though some years are obscured in this extract of the full image). More recent years are colour coded red, with earlier years in blue, to reflect the trend towards warmer average temperatures in recent decades.

Figure SR.5: Observed changes in UK temperature and rainfall



Source: Kendon et al. (2015).
Notes: Plot (a) shows annual average temperature from 1910 to 2014 compared with the 1981-2010 average (dashed black lines) for each UK nation. The dashed green lines are the 1961-1990 long-term averages. Plot (b) shows the number of days per year with UK average daily rainfall exceeding 9.5mm (95th percentile of values during 1960-2014, green line) and 14.0mm (99th percentile, pink line). Black (smoothed) lines are weighted moving averages. See Kendon et al. (2015), Annex 2 for method used.

It is increasingly possible to quantify whether the chance of a particular weather event has changed as a result of greenhouse gas emissions from human activity and the warming that has already occurred (Box SR.1).

The science of attribution has developed rapidly in recent years in terms of the approaches taken, the types of weather event considered, and the regions of the world studied. Advances in methods and computational power have led to a corresponding increase in the confidence in results.

Natural variability in the climate system, for example from changes in atmospheric circulation, can be responsible in full or in part for extreme weather. It has therefore been difficult in the past to attribute any single extreme weather event to climate change. However, a recent assessment by the US National Academies of Science (2016) concluded that "this is no longer true as an unqualified blanket statement".

Box SR.1: Can UK extreme weather events be attributed to climate change?

Climate change attribution studies attempt to detect whether the chance of particular weather events has changed due to elevated levels of greenhouse gases in the atmosphere. Changes in mean and extreme temperatures and sea level are easier to identify and attribute than changes in rainfall, flooding, storms and drought. Examples of positive attribution include:

- **Heatwaves:** Climate change has already at least doubled the chance of a severe heatwave in Europe, such as the 2003 heatwave that killed 2,000 people in the UK and tens of thousands across Europe (Stott et al., 2004). More recent assessments suggest the risk of an extremely hot summer has increased significantly even in the last ten years (Christidis et al., 2015).
- **Flooding:** Studies suggest flood events like in autumn 2000 (Pall et al., 2011), and extremely wet winters like the winter of 2013/14 (Shaller et al., 2016), have become more likely. This is consistent with the increasing moisture levels that a warmer atmosphere can hold. There is some evidence that heavily moisture-laden air currents (atmospheric rivers), linked with the flooding in England in November 2009 and December 2015, are more likely to form and can hold more moisture with climate change (Lavers et al., 2013).
- **Droughts:** Evapotranspiration of moisture from soils and plants will increase with temperature. This makes moisture deficits more likely during periods of dry weather. However, rainfall projections are uncertain and a change in likelihood of drought in the UK has not been detected. Changes in the frequency of drought have been detected in other parts of the world, for example in the Mediterranean region (Hoerling, 2012).
- **Cold snaps:** Cold December temperatures in the UK are now half as likely as they were in the 1960s (Massey et al., 2012). Cold weather in the UK is likely to be less severe, occur less frequently, and last for a shorter period of time than was historically the case. However, cold conditions will still occur due to natural variability in the weather from year to year.

Not all extreme weather can be linked to climate change. For example, the run of wet summers in the UK from 2007 to 2012 is one recent example in which natural variability in the Earth's atmosphere is thought to have played an important role.

Source: See individual references.

Projections of the UK climate for this century

The most up-to-date land and marine climate scenarios available for the UK are from the 2009 UK Climate Projections (UKCP09). Until at least 2018, these will remain the best available evidence for projected changes in the UK climate.

Since UKCP09 was launched, a newer set of climate models has been developed to inform the Intergovernmental Panel on Climate Change's Fifth Assessment Report. A comparison between UKCP09 and the newer CMIP5 multi-model simulations conducted as part of preparing CCRA2 concluded that the results are generally consistent (Sexton et al., 2016). UKCP09 therefore continues to provide a valid assessment of the 21st century UK climate, and in general its outputs remain appropriate for adaptation planning (Figure SR.6). However, CMIP5 results suggest there is a smaller chance of summer rainfall totals reducing in England and Wales than was projected in 2009.

A project to update the projections is underway and is expected to release results in 2018 (UKCP18).

Figure SR.6: UKCP09 projections for temperature and rainfall

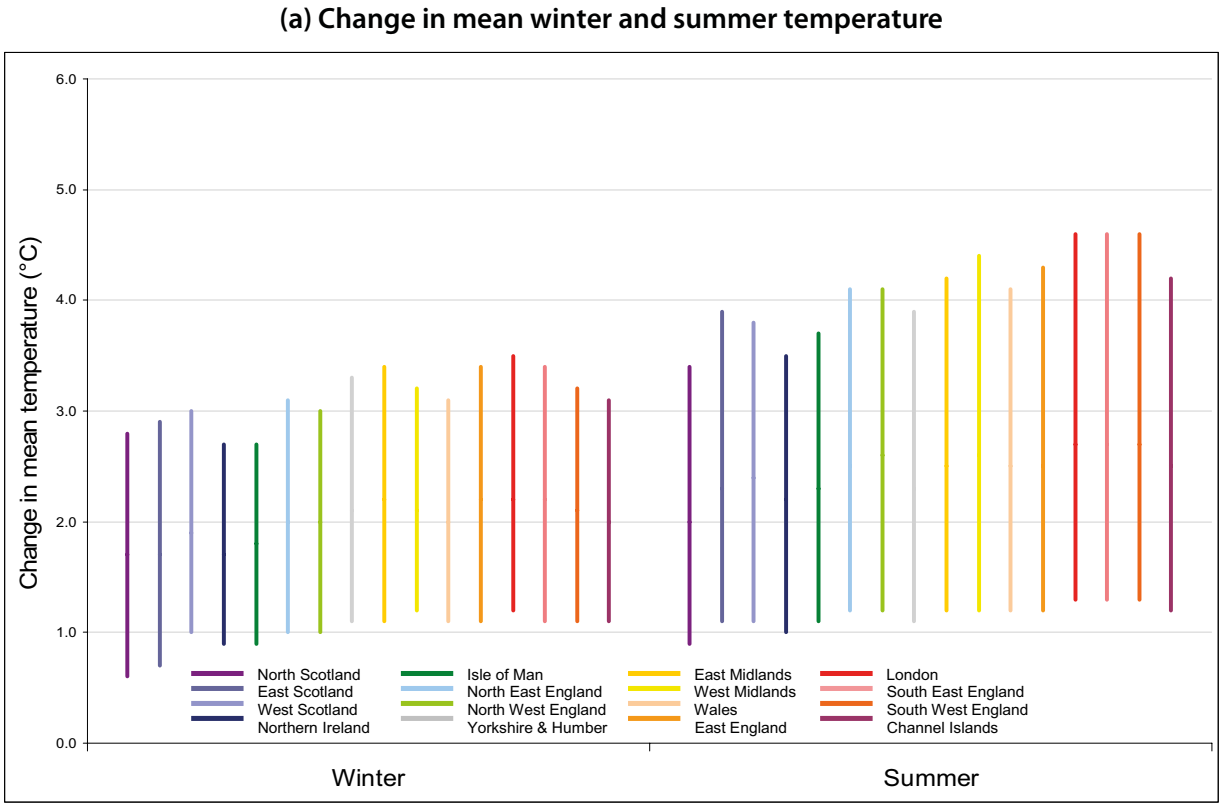
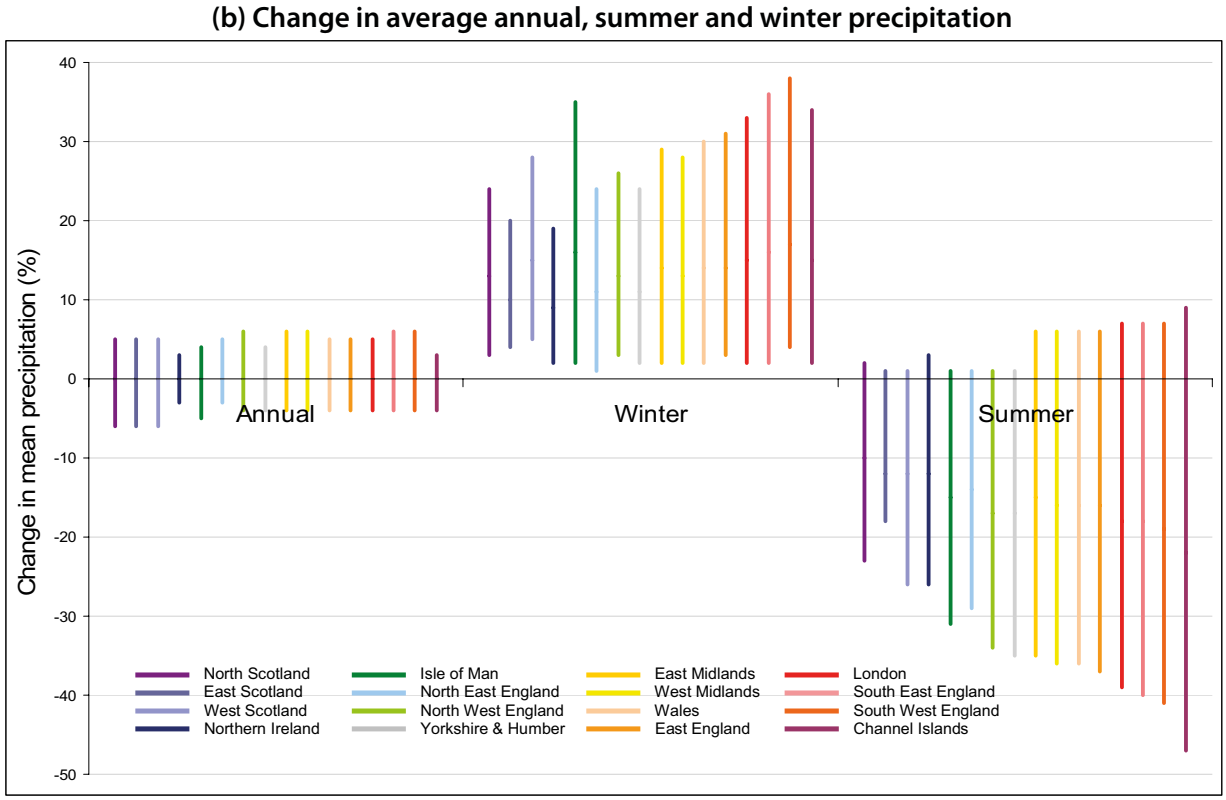


Figure SR.6: UKCP09 projections for temperature and rainfall



Source: 2009 UK Climate Projections, under a medium emissions scenario.
Notes: Both charts are projections for the period 2040-2069 relative to 1961-1990. Each vertical line shows the 10% - 90% probability distribution.

Impacts from 2°C and 4°C of warming

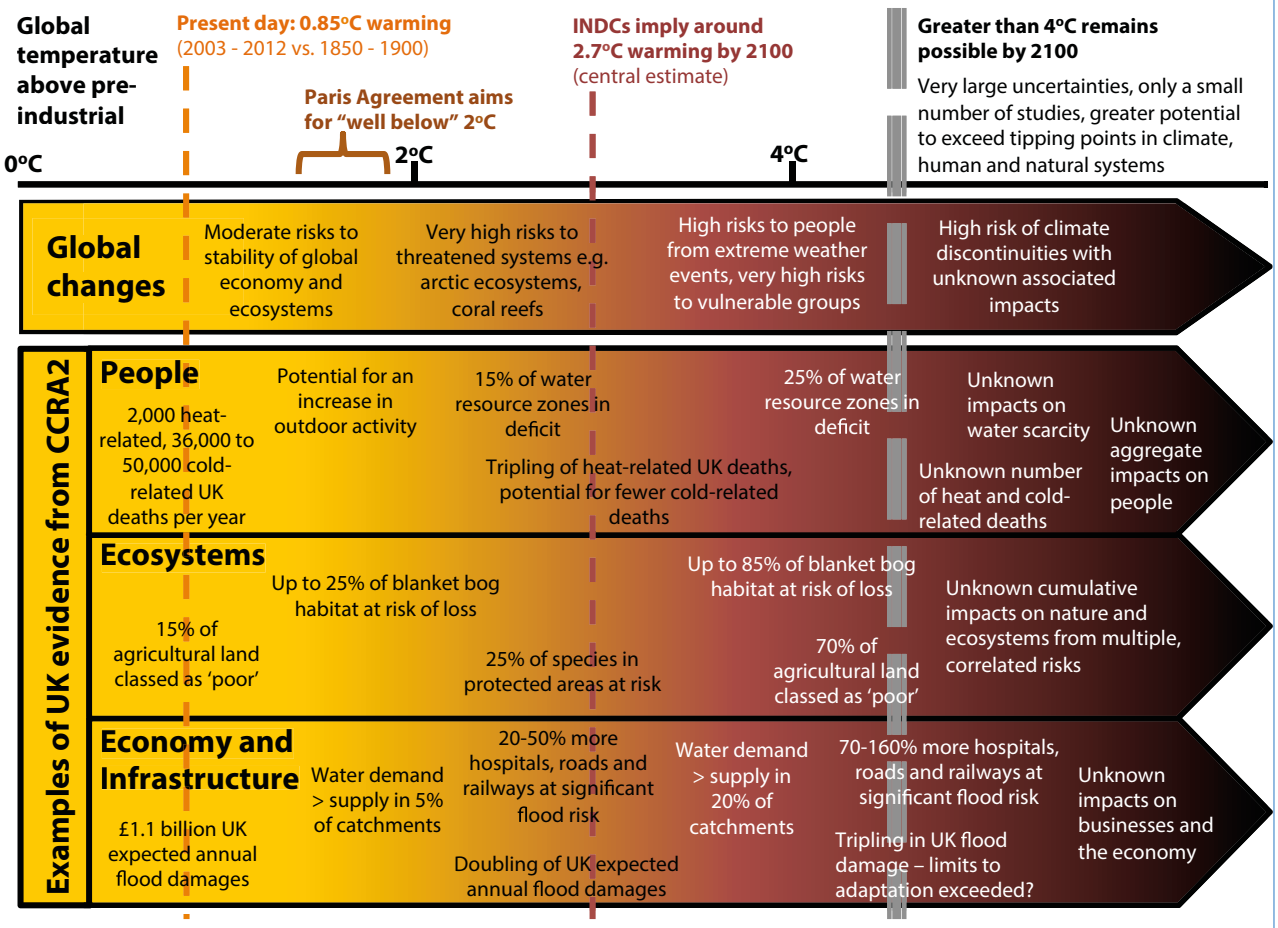
UKCP09 and other studies make it possible to explore how the impacts of climate change might vary depending on the actual amount of warming that takes place.

A study commissioned by the ASC (Warren et al., 2016), draws together evidence from a number of studies that describe the impacts of climate change in the UK for different degrees of global temperature increase. Figure SR.7 presents examples. More generally:

- **Even if global temperature increases are limited to 2°C or less, there are projected to be high magnitude impacts for the UK.** Temperatures over land, and at northern latitudes such as in the UK, would be expected to increase by more than the 2°C global average. In this scenario, compared to today, there could be a 30% decrease in river flows during 'dry' periods, a 5-20% increase in river flows during 'wet' periods, and between 700 and 1,000 more heat-related deaths per year in south-east England.
- **At global average temperature rises approaching 4°C, impacts become increasingly severe and may not be avoidable through adaptation.** For example, damages caused by river, coastal and surface water flooding all increase markedly with 4°C of warming. Residual flood risks remain high under all adaptation scenarios considered, suggesting limits in the amount of risk that can be avoided through investment in flood defences and other responses. Potentially irreversible impacts to the natural environment are projected with 4°C of warming, including risks to blanket bog, species in protected areas, and internationally important UK bird populations.

It is important to note that few studies consider impacts beyond 4°C of global warming (Warren et al., 2016) and impacts are increasingly uncertain for higher levels of warming. This is particularly the case for extreme weather events, which can have the greatest societal impacts. The potential for major discontinuities in the climate also increases greatly, where warming accelerates due to feedback processes in the Earth's natural systems. In the absence of evidence to suggest when safe warming thresholds or climate tipping points might be surpassed, most of the studies referenced in this report assume there are no such discontinuities. This assumption becomes increasingly untenable for warming in excess of 2°C.

Figure SR.7: Magnitude of UK climate change impacts for various degrees of global warming



Source: Warren et al. (2016) for the ASC.
Notes: This chart shows a selection of impacts drawn from the CCRA2 chapters for different degrees of global temperature increase above a pre-industrial baseline. The methodology, references and precise temperature estimates for each of the impacts shown can be found in Warren et al. (2016) for the ASC, including for a wider range of impacts than shown above. Colours in bars denote changes in global temperature only, and do not indicate the magnitude or severity of the impacts shown (and therefore this should not be compared to the 'burning embers' diagram in IPCC (2014, Assessment Box SPM.1, Figure 1)). The temperature scale refers to the possible changes in global temperature by the end of the century but not the rate of change. Many impacts will be sensitive to the speed, as well as the magnitude, of global temperature change.
Water resource zones (WRZs) are those used for the public water supply.
Intended Nationally Determined Contributions (INDCs) towards reducing global greenhouse gas emissions are as proposed by countries in advance of the Paris Conference of the Parties (Gütschow et al., 2015).

Understanding the potential for climate extremes

Climate projections such as UKCP09 focus on how the average seasonal climate is expected to change over extended periods of time. This averaging masks the potential for weather extremes within individual years, caused by the 'noise' of natural variability combining with the long-term climate change 'signal'. How climate change and natural variability will combine to create weather extremes in the UK is important to consider as part of long-term adaptation planning.

Global warming will shift both the average climate in the UK as well as the nature of extreme weather. UKCP09 provides projections of both seasonal average conditions and more extreme values such as summer maximum temperatures and rainfall on the wettest days of the year. However, even these results are presented as averages over wide geographic areas and several decades. The results say little about the variation in weather that might be experienced in any one location during any one year.

New research allows the UKCP09 projections to be expressed for individual years rather than 30-year averages, to help understand how climate change and natural variability might combine to create seasonal anomalies from year to year (Sexton and Harris, 2015). Doing so allows recent extreme seasons to be placed in the context of projected long-term changes. These results show that cold winters like in 2009-10, and wet summers like in 2012, will continue to occur from time to time and this is not inconsistent with the general projection for the UK of milder average winters and drier average summers.

Efforts are also being made to improve the ability of climate models to simulate weather processes that occur at a small geographical scale, such as intense rainfall caused by convective summer storms. Using the latest generation of Met Office climate models, Kendon et al. (2014) indicates that bursts of heavy convective rainfall that cause flash flooding (typically more than 30 millimetres per hour) may be more likely with climate change than UKCP09 suggested.

Unlikely, yet still possible, disruptive shifts in the UK climate also need to be considered in any robust climate change risk assessment.

The consideration of low probability, high impact risks is a fundamental component of good risk management, and this applies as much to climate change as it does to other types of risks (King et al., 2015). Extreme scenarios can be used to test the sensitivity and robustness of different adaptation options and decisions.

To inform this CCRA, Met Office et al. (2015) for the ASC provides a range of 'high++' scenarios representing unlikely but plausible extreme changes in the UK climate. These complement the existing high++ scenario for sea level rise developed as part of UKCP09, of up to 1.9 metres by 2100 for the UK coastline.

The scenarios created are typically climate change scenarios on the margins or outside of the 10th to 90th percentile range presented in the UKCP09 projections. These scenarios are not thought likely to occur, at least this century, but cannot be ruled out on the basis of current understanding. They are therefore useful when it is important to understand the most extreme circumstances that could reasonably occur, such as when developing water company drought plans, or in considering upgrade options for flood defences. These results have been incorporated where appropriate into the other research projects commissioned for CCRA2, and are discussed in the individual chapters of the Evidence Report.

Chapter 3: UK climate change risks and opportunities

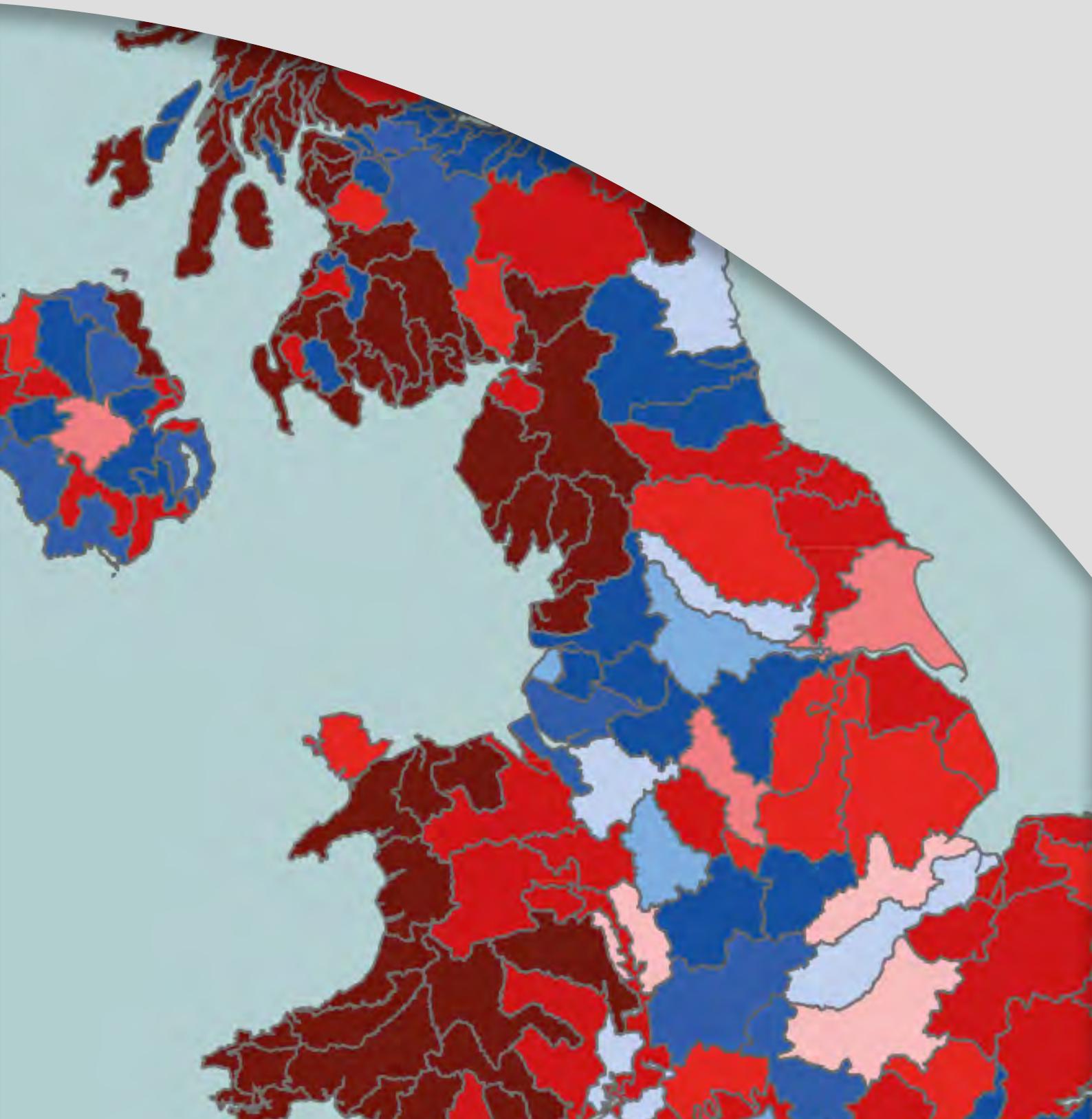
Approach to the second UK Climate Change Risk Assessment

Key climate change risks for the United Kingdom

Climate change opportunities

Assessment of risk and uncertainty

New knowledge and understanding developed since the first CRA



Approach to the second UK Climate Change Risk Assessment

The aim of the second Evidence Report is to address a single, specific question about the urgency of further action to tackle current and future risks, and realise opportunities, arising for the United Kingdom from climate change.

To fulfil the CCRA requirement in the Climate Change Act the UK Government asked the ASC to consider:

"Based on the latest understanding of current, and future, climate risks/opportunities, vulnerability and adaptation, what should the priorities be for the next UK National Adaptation Programme and adaptation programmes of the devolved administrations?"

In answering this question, the method used to compile the Evidence Report involved assessing each risk or opportunity in three stages:

1. What is the current scale of climate-related risk or opportunity, and how much action is already underway?
2. What is the potential scale of future risks and opportunities, and to what extent will planned actions or autonomous adaptation address these?
3. Would there be benefit from further action being taken in the next five years within each of the four countries of the United Kingdom?

The Evidence Report uses the concept of urgency to summarise the findings of the analysis. One of four 'urgency categories' has been assigned to each risk and opportunity (Figure SR.8). The urgency categories are designed to be mutually exclusive, so that each risk and opportunity falls into a single urgency category.

Whilst there will be specific evidence gaps and uncertainties in almost every area, the 'research priority' category is reserved for those risks and opportunities where further evidence is needed to determine whether more action is needed, current levels of action should be sustained, or for now things can be kept under review (watching brief).

Image on previous page: projected availability of water in the 2050s under a high population growth and high climate change scenario, assuming no additional action beyond current water resource management plans (scenario 15). See HR Wallingford et al. (2015) for the ASC.

Figure SR.8: Urgency categories used in the UK CCRA 2017 Evidence Report

Source: See Chapter 2 of the Evidence Report for a fuller description of the urgency scoring method.

Key climate change risks for the United Kingdom

Following a systematic review of the available evidence by leading academics and other experts, the Adaptation Sub-Committee has identified six key areas of climate change risk that need to be managed as a priority.

There is an urgent case for stronger policies to tackle five of these risk areas, and a further area where there is a pressing need for more research in order to inform future policy approaches.

More action needed:

- Flooding and coastal change risks to communities, businesses and infrastructure.
- Risks to health, wellbeing and productivity from high temperatures.
- Risk of shortages in the public water supply, and for agriculture, energy generation and industry, with impacts on freshwater ecology.
- Risks to natural capital including terrestrial, coastal, marine and freshwater ecosystems, soils and biodiversity.
- Risks to domestic and international food production and trade.

Research priority:

- New and emerging pests and diseases, and invasive non-native species, affecting people, plants and animals.

These groupings bring together more specific risks discussed in the sections that follow. In addition, the **Annex to this Synthesis Report** provides short summaries of each of the Evidence Report chapters. A more detailed **Appendix of Urgency Scoring Tables** has also been produced that brings together the evidence underpinning all of the urgency scores assigned by the ASC. Lastly, the ASC is publishing separate **national summaries** of the Evidence Report for England, Wales, Scotland and Northern Ireland. Whilst not exhaustive, Figure SR.9 attempts to characterise the spatial distribution of climate change risks and opportunities across the UK.

It should be recognised that the six risk groups are inter-related to a greater or lesser degree. Actions to address risks also need to be co-ordinated to be effective.

Chapter 8 of the Evidence Report considers the cross-cutting nature of climate change risks and opportunities, and the common factors involved in successful adaptation strategies. Unless such cross-cutting issues are considered, actions could be ineffective, sub-optimal in terms of their costs and benefits, or worse lead to unintended consequences. In planning adaptation strategies governments should consider:

- **Interactions among risks:** Some climate hazards are highly correlated (e.g. storms and high seas), and even where not the combined impact of climate change risks acting in parallel (e.g. a combination of higher temperatures and heavier rainfall patterns) needs to be considered.
- **Indirect and macroeconomic impacts:** The evidence suggests that indirect economic losses to the UK from extreme weather are likely to be at least as high as the identified direct losses. For example, in the surrounding as well as affected areas, infrastructure disruption and loss of custom may be more damaging to businesses than the direct impacts of flood water.
- **Distributional impacts:** Climate change will affect different people differently, depending on their social, economic and cultural background and environment.
- **Institutional barriers:** Obstacles to success include misaligned organisational or policy goals, the need to co-ordinate action by many partners, and the lack of effective monitoring and evaluation strategies that allow lessons to be learned and best practice to be disseminated.
- **Adaptive capacity:** Considerable knowledge and skills are required to assess and respond to climate change risks and opportunities. Adaptation strategies can lead to multiple co-benefits but only if organisations make action a priority and allocate the necessary resources.

MORE ACTION NEEDED: Flooding and coastal change risks to communities, businesses and infrastructure

Current magnitude:	**HIGH**	Future magnitude:	**HIGH**	In the 2050s in a range of climate change, population growth and adaptation scenarios.
Confidence:	***HIGH***	Confidence:	***HIGH***	

Risks from flooding and coastal change have been identified for all nations and all sectors considered in the Evidence Report. Damages from fl oding and coastal change are already high, averaging an estimated £1 billion per year in the UK.

A number of separate but related risks will arise due to increases in heavy rainfall, river flows, sea level rise and a corresponding increase in the height of tidal surges, and an increased rate of coastal erosion along vulnerable coastlines.

Current levels of adaptation are projected to be insufficient to avoid flood and coastal erosion risks and damages increasing with further warming. With 4°C of warming and high population growth, the number of households at a significant chance of flooding[6] is projected to increase from 860,000 today to 1.9 million by the 2050s. Additional adaptation may be able to counter the increase in flood damages anticipated with 2°C of global warming, at least in some parts of the UK, but in others increasing flood risks appear inevitable especially with 4°C or more of global warming.

Priorities for further action and research include:

- **Residual risks:** even with current investment plans the residual risk of flooding will remain high across the UK. Improved flood defences will not be possible or affordable in every area, and with climate change a greater disparity in risk between protected and non-protected areas may emerge. Some individual coastal communities are vulnerable to coastal erosion and sea level rise. More action is needed to support communities facing increasing risks, especially in areas where formal flood defences are unlikely and long term viability is at risk.
- **Urban water management:** climate change is expected to lead to significant increases in heavy rainfall, with sewers in many urban areas already at or over capacity. More action is needed protect individual properties whilst also beginning to redesign urban landscapes (such as through the use of sustainable drainage approaches) to be able to cope with more intense patterns of rainfall.
- **People and communities:** as well as residential homes and other buildings, a significant number of hospitals and other care facilities are located in exposed areas. The evidence suggests that the long-term health and wellbeing impacts of flood events are considerable and more research is needed to assess and understand how best to manage these.
- **Infrastructure:** electricity sub-stations, road and rail networks, water treatments works, ports and airports, and fixed line and mobile communications assets, are all exposed to increasing flood risks. Further work is needed to assess and address vulnerabilities, including as a result of interdependencies between networks.[7] This includes the risk of sewer failure and consequential flooding.
- **Agricultural production:** strategic choices need to be made about the value of protecting agricultural production in flood risk areas when this could further increase run-off rates, silt deposition in rivers, and downstream flood risk.[8]

6 In areas at a 1-in-75 annual chance or greater of flooding.

7 Note the Government's National Flood Resilience Review is underway at the time of writing, led by the Chancellor of the Duchy of Lancaster and due to report in July 2016. Among other things, the review is considering options to improve the resilience of important infrastructure assets to flooding.

8 These trade-offs are currently being considered as part of the work of the Cumbrian Floods Partnership, led by Defra ministers, and in a number of other catchment-based pilots across the UK.

- **Business:** companies operating in flood risk areas are exposed to direct damages to buildings and assets, and indirect impacts on sales, production, supply chains and reputations. Businesses not directly at risk but located in affected towns may suffer knock-on impacts from disrupted infrastructure and custom being postponed or lost to competitors elsewhere.

Risks where more action is needed (including reference to Evidence Report sections)			
PB5: Risks to people, communities, and buildings from flooding (5.2.5, 5.3.4, 5.5.1)	In2: Risks to infrastructure services from river, surface water and groundwater flooding (4.4 to 4.9)	In3: Risks to infrastructure services from coastal flooding and erosion (4.4 to 4.9)	In4: Risks of sewer flooding due to heavy rainfall (4.5)
In6: Risks to transport networks from slope and embankment failure (4.7)	Bu1: Risks to business sites from fl oding (6.2.2, 6.2.3)	Ne8: Risks of land management practices exacerbating fl od risk (3.3, 3.4)	Ne12: Risks to habitats and heritage in the coastal zone from sea-level rise; and loss of natural flood protection (3.5)
Research priorities			
PB6: Risks to the viability of coastal communities from sea level rise (5.2.6, 5.2.7)	In5: Risks to bridges and pipelines from high river fl ws and bank erosion (4.5, 4.7, 4.8)	Bu2: Risks to business from loss of coastal locations and infrastructure (6.2.2, 6.2.3)	

MORE ACTION NEEDED: Risks to health, wellbeing and productivity from high temperatures

Current magnitude:	**HIGH**	Future magnitude:	**HIGH**	In the 2050s, under a medium emissions scenario, assuming a continuation of current policies and plans.
Confidence:	***HIGH***	Confidence:	***MEDIUM***	

High temperatures are associated with mortality and wellbeing impacts across all regions of the UK. The average number of hot days per year is increasing as is the chance of a severe heatwave – both are projected to rise further with climate change. At present, there are no comprehensive policies in place to adapt existing homes and other buildings to high temperatures, manage urban heat islands, nor safeguard new homes. The level of risk from overheating across the UK is unknown for hospitals, care homes, schools, prisons, and places of work.

Average and extreme temperatures across the UK are expected to increase further in the coming decades. Heatwave events such as in 2003 are projected to become the norm in the UK by the 2040s. For a 2°C rise in global mean temperature, the increase in temperatures under heatwave conditions in Europe is projected to increase by between 1.4 - 7.5°C.

The proportion of the UK population aged over 75 is projected to increase from 8% in 2015 to 18% by 2085. Older people are more likely to be adversely affected by high temperatures, but above 35°C, all age groups are at risk of health impacts. It is plausible that some degree of autonomous physiological acclimatisation will take place in response to gradual increases in mean temperature. However, the evidence suggests people are less able to adapt to sudden increases in temperature over a short period of time, particularly if overall temperature variability increases.

Priorities for further action and research include:

- **Overheating within new and existing homes.** In the absence of adaptation, annual UK heat-related mortality is projected to increase by two-thirds by the 2020s, by around 250% by the 2050s, and by more than 500% by the 2080s from a current baseline of 2,000 heat-related deaths per year. This is due to the effects of climate change and the growing, ageing population, with warmer temperatures having the larger impact (assuming a medium emissions scenario). There is evidence that people lack a basic understanding of the risks to health from indoor high temperatures, and are therefore less likely to take measures to safeguard their and their dependents' wellbeing. Insulating homes to improve thermal efficiency needs to be undertaken carefully to avoid increasing the risk of overheating.
- **The urban heat island effect.** UK planning strategies do not currently make specific recommendations for reducing the heat island effect such as through planning and urban design, beyond promoting urban green space.
- **Overheating within public buildings.** The current impacts and future risks of overheating in hospitals, care homes, schools and prisons across the UK are not known. Further research will be important to assess the level of risk in all types of building to determine the action necessary.
- **Productivity impacts on employees.** Past events suggest extreme outdoor temperatures can have significant effects on production. The 2003 European heatwave is estimated to have resulted in a reduction in manufacturing output in the UK of £400 to £500 million. More research is needed to understand the potential health impacts for outdoor as well as indoor workers.

Risks where more action is needed (including reference to Evidence Report sections)	
PB1: Risks to health and wellbeing from high temperatures (5.2.2, 5.3.2, 5.5.3)	
Research priorities	
Bu5: Risks to business from reduced employee productivity, due to infrastructure disruption and higher temperatures in working environments (6.4.2, 6.4.3, 6.4.4, 6.4.5)	PB2: Risks to passengers from high temperatures on public transport (5.3.9)
Sustain current action	
In13: Risks to transport, digital and energy infrastructure from extreme heat (4.6, 4.7, 4.8)	
Watching brief	
PB3: Opportunities for increased outdoor activities from higher temperatures (5.2.3)	

MORE ACTION NEEDED: Risk of shortages in the public water supply, and for agriculture, energy generation and industry, with impacts on freshwater ecology

Current magnitude:	**MEDIUM**	Future magnitude:	**HIGH**	By the 2050s, in high emissions and population scenarios. Assumes current plans and policies are delivered in full.
Confidence:	***MEDIUM***	Confidence:	***HIGH***	

The Evidence Report identifi s risks arising from water scarcity for England, Scotland and Wales. A number of separate but related water scarcity risks will arise due to changes in rainfall, increases in potential evaporation and soil aridity, coupled with projections of continuing population growth.

By the 2050s under high climate change and high population growth scenarios, demand for water could be more than 150% of the available resource in many catchments across the UK. The analysis shows that in numerous catchments in the north and the west (as well as in the south and east) of England, in parts of Scotland as well as Wales, it will not be possible to abstract water up to 25% of the time without causing ecological damage. This could require more frequent water restrictions such as temporary hosepipe bans and limits on abstraction by water companies, farmers and industry.

Rising average temperatures are expected to increase evapotranspiration and summer aridity. However, there remains a high degree of uncertainty over future seasonal rainfall projections and what this might mean for the frequency and intensity of water shortages and drought. It is therefore important that there is flexibility to adjust policies and approaches to changing weather patterns and the pace of population growth.

Priorities for further action and research include:

- **Public water supplies:** without additional action, Great Britain overall is projected to be in deficit by 800 to 3,000 megalitres per day by the 2050s (5 to 16% of the total demand for water at that time). Water companies have been taking steps to manage this risk, with climate change factored in to their 25-year water resource management plans. Steady progress has been made in reducing water demand over the last decade. Reforms to the abstraction regime in England and Wales are planned, and Scotland and Northern Ireland have published or consulted on water scarcity strategies within the last two years. However, there remains a significant risk of water shortages in some parts of the UK. This will require more ambitious and co-ordinated action by water companies, other abstractors and governments to significantly reduce demand. Given the long lead times involved, longer-term planning of supply-side options is also needed.
- **Agriculture:** projections suggest that, without further action, the availability of water for irrigation will become a serious limiting factor to agricultural production and quality, particularly for growing cereals and potatoes. Many of the most productive regions of Great Britain at present, for example in Kent and the East Anglia fens, are also where projections of both soil aridity and water scarcity are severe.
- **Natural environment:** reduced water availability in the summer will impact the ecology of rivers and lakes, unless there is further action to improve the condition of water bodies and to encourage the wider uptake of measures to reduce the impacts of low flows. More research is required on the implications of climate change for setting minimum environmental flow levels.

- **Energy generation and industry:** some scenarios for energy generation suggest freshwater use for cooling will rise significantly, especially if there were widespread deployment of carbon capture and storage in inland areas (for example if CCS were fitted to existing power stations in the River Trent catchment). Some water-intensive industries are clustered in areas at risk of water scarcity, such as paper manufacturing in Kent and chemicals manufacturing in the north west of England.
- **Freshwater species:** increasing water temperatures could have negative effects on sensitive species like salmon and arctic charr, especially in locations with reduced water quality or when combined with low flows. Further monitoring and research are needed to guide appropriate policy responses.

Risks where more action is needed (including reference to Evidence Report sections)		
Ne4: Risks to soils from increased seasonal aridity and wetness (3.3)	Ne6: Risks to agriculture and wildlife from water scarcity and fl oding (3.4)	In9: Risks to public water supplies from drought and low river fl ws (4.5)
Research priorities		
Ne7: Risks to freshwater species from higher water temperatures (3.4)		
Sustain current action		
PB14: Risk of household water supply interruptions (5.2.4)	Bu3: Risks to business operations from water scarcity (6.2.4, 6.2.5)	Ne11: Risks to aquifers, agricultural land and habitats from saltwater intrusion (3.5)
Watching brief		
In7: Risks to hydroelectric generation from low or high river fl ws (4.8)	In10: Risks to electricity generation from drought and low river fl ws (4.8)	

MORE ACTION NEEDED: Risks to natural capital including terrestrial, coastal, marine and freshwater ecosystems, soils and biodiversity

Current magnitude:	**MEDIUM**	Future magnitude:	**HIGH**	By mid-century under a range of emission scenarios assuming current polices and plans continue.
Confidence:	***MEDIUM***	Confidence:	***MEDIUM***	

The impacts of climate change are already discernible across terrestrial, freshwater, coastal and marine ecosystems. Many species are shifting their range in response to warmer conditions both on land and in the seas. The capacity of species and ecosystems to adjust and adapt will, however, be increasingly constrained by existing pressures, including habitat loss and fragmentation, pollution of land, air and water, over-exploitation of terrestrial, freshwater and marine resources, and the spread of invasive species. The warming climate is also likely to create risks, as well as provide some potential benefits, for agriculture and forestry.

Key risks from climate change to natural capital include:

- **Deterioration of high-grade agricultural land:** due to increasing soil aridity, reduced water availability for irrigation, the depletion of soil organic matter, and sea level rise. The proportion of agricultural land in England and Wales classed as 'best and most versatile' (Grades 1, 2 and 3a) is projected to decline from 38% to 9% by the 2050s under a high climate change scenario. Current crop production in areas of eastern England and Scotland could become unviable due to the combination of drying soils and lack of dependable water supplies for use on farms.
- **Degradation of upland peat habitats:** due to warmer temperatures and changing rainfall patterns. These habitats are vital for nationally scarce plants and wildlife, and for storing carbon. They also help provide clean drinking water to millions of people, but are highly vulnerable as a result of damaging management practices and air pollution.
- **Loss of coastal habitats:** due to rising sea levels. Habitats such as saltmarsh and sand dunes provide valuable natural buffering from wave energy as well as their importance for wildlife. The widespread loss of these habitats, as they become squeezed between rising sea levels and man-made defence structures, will have implications for the long-term viability of coastal defences and the communities they protect.
- **Loss of marine fisheries and wildlife:** due to ocean acidification and increasing sea temperatures. In the North Sea warm water plankton species are replacing previously dominant cold water species. These changes may have significant implications for other parts of the marine food-chain.

Priorities for further action and research include:

- **Increase current efforts** to reduce existing pressures (see above), improve the ecological condition of protected wildlife sites and water bodies, and restore degraded ecosystems, such as peatlands, wetlands and native woodlands.
- **Take more flexible and integrated approaches to managing natural capital**, including further realignment of the coast, catchment management, and landscape-scale initiatives to increase habitat extent and improve habitat condition and connectivity.
- **Assess the nature and scale of changing land suitability and its impacts,** including by conducting further research into more resilient crop varieties, tree species, livestock regimes and farming systems.
- **Better understand the magnitude and scale of risks to marine ecosystems** from climate change.

Risks where more action is needed (including reference to Evidence Report sections)				
Ne1: Risks to species and habitats due to inability to respond to changing climatic conditions (3.2)	Ne2. Opportunities from new species colonisations (3.2)	Ne4: Risks to soils from increased seasonal aridity and wetness (3.3)	Ne5: Risks to natural carbon stores and carbon sequestration (3.3, 3.7)	Ne6: Risks to agriculture and wildlife from water scarcity and fl oding (3.4)
Research priorities				
Ne7: Risks to freshwater species from higher water temperatures (3.4)		Ne13: Risks to, and opportunities for, marine species, fisheries and marine heritage from ocean acidifi ation and higher water temperatures (3.6)		
Sustain current action				
Ne9: Risks to agriculture, forestry, landscapes and wildlife from pests, pathogens and invasive species (3.7)	Ne10: Risks to agriculture, forestry, wildlife and heritage from changes in frequency and/or magnitude of extreme weather and wildfire events (3.3)	Ne11: Risks to aquifers, agricultural land and habitats from saltwater intrusion (3.5)		
Watching brief				
Ne14: Risks and opportunities from changes in landscape character (3.7)				

MORE ACTION NEEDED: Risks to domestic and international food production and trade

Current magnitude:	**MEDIUM**	Future magnitude:	**HIGH**	In the 2050s, assuming 2°C warming by the 2080s and no additional adaptation.
Confidence:	***HIGH***	Confidence:	***MEDIUM***	

Access to safe, nutritious and affordable food in the UK is subject to domestic and international risks. Climate change may present new opportunities to increase domestic production, but unless more action is taken the condition of soils and scarce water resources are likely to be limiting factors. The resilience of the UK food system will depend on effective management of natural resources both here and overseas and on understanding and managing the response of international markets to climate risks.

About 60% of UK food comes from domestic production and the rest is imported, for some crops from a limited number of trading partners. Risks to the UK food system arise from an increasing risk of extreme weather events affecting both production and supply chains. Incremental changes in temperature, rainfall patterns and ocean acidification are also likely to shift the global pattern of food production posing risks to the price of food in the UK.

Areas for further action include:

- **Weather-related shocks to global food production:** droughts can disrupt production within regions whilst other events such as flooding can cause supply chain problems. Longer-term, incremental climate change will shift the balance of global food production between regions. The changes will influence markets, trade and domestic prices and in turn impact UK businesses - especially farmers - and lower income households.
- **Risks to soils and agricultural production from changes in rainfall:** domestic agricultural production is likely to be constrained by reduced water availability and increased soil aridity and erosion. Parts of southern, eastern and central England are likely to become unviable for some current farming activity due to their intensive water requirements. Conversely, a trend towards wetter winters is likely to increase problems such as soil compaction and erosion, unless good management practices are adopted.

More research is also needed to understand and manage the potential for long term shifts in global food production:

- **International risks:** longer-term incremental changes in climate are likely to alter the agricultural productivity of important regions. Climate change will also place additional pressure on international law and governance. These pressures are likely to negatively affect both the production of food and how markets respond.
- **Agriculture:** longer growing seasons and increased CO_2 fertilisation may create an opportunity to increase domestic food production of some crops. However, this opportunity is likely to be limited by (and could further exacerbate) pressures on soils and water resources in the currently most productive UK regions.
- **Commercial fisheries and aquaculture:** are likely to be negatively affected by the combination of ocean acidification and higher water temperatures acting on the aquatic food chain, both in the UK and overseas. The magnitude of these changes is uncertain.

Risks where more action is needed (including reference to Evidence Report sections)			
It1: Risks from weather-related shocks to international food production and trade (7.2)	Ne4: Risks to soils from increased seasonal aridity and wetness (3.3)	Ne6: Risks to agriculture and wildlife from water scarcity and fl oding (3.4)	
Research priorities			
Ne3: Risks and opportunities from changes in agricultural and forestry productivity and land suitability (3.3)	Ne13: Risks to, and opportunities for, marine species, fisheries and marine heritage from ocean acidifi ation and higher water temperatures (3.6)	It2: Imported food safety risks (7.2)	It3: Risks and opportunities from climate-related changes in global food production (7.2)
Sustain current action			
Ne9: Risks to agriculture, forestry, landscapes and wildlife from pests, pathogens and invasive species (3.7)	Ne10: Risks to agriculture, forestry, wildlife and heritage from changes in frequency and/or magnitude of extreme weather and wildfire events (3.3)	Ne11: Risks to aquifers, agricultural land and habitats from saltwater intrusion (3.5)	

RESEARCH PRIORITY: New and emerging pests and diseases, and invasive non-native species, affecting people, plants and animals

Current magnitude:	**MEDIUM**	Future magnitude:	**HIGH**	Based on a range of climate scenarios, assuming no additional adaptation beyond current policies and plans.
Confidence:	***MEDIUM***	Confidence:	***LOW***	

New and emerging diseases have the potential to cause severe and increasing impacts on people, animals and plants as the climate changes in the UK and overseas. Pests and invasive non-native species may also increase in number and range in a warmer, wetter atmosphere. There are risks from an increase in the prevalence of pathogens that are already present in the UK, and from new pathogens arriving from overseas, though there are very large uncertainties.

Quantitative projections of the impact of climate change on human diseases are uncertain. However, it is likely that the range, activity and vector potential of some tick and mosquito species will increase across the UK with the risk of high magnitude impacts. For example, Lyme disease is present and increasing in occurrence across the UK, and changes in temperature and precipitation may increase this further. Future trends in agriculture and trade, land use, wild animal populations and tourism will also be important.

Priorities for further research include:

- **Vector-borne diseases affecting human health:** higher temperatures will lead to an increased risk of invasion to the UK of the Asian tiger mosquito, *Aedes albopictus* – the vector of Chikungunya virus, dengue fever and Zika virus. The current risk remains low, but may increase in the future. There is also a risk of expansion of the range of *Culex modestus*, already present in south-east England, which is a known vector of West Nile virus. Projections for the 2080s, under a variety of emission scenarios, only indicate a small risk of malaria transmission in the UK.
- **Pests and diseases affecting plants (including trees) and livestock:** there is an increased risk from expansion of animal disease vectors for bluetongue and of airborne spread of Foot and Mouth. Small changes in climatic conditions around critical thresholds may result in dramatic changes in parasitic nematodes in livestock. Insect pests are generally expected to become more abundant due in part to higher overwinter survival rates. Wetter winters may increase the risk of liver fluke, which is transmitted to cattle and sheep by water-sensitive lymneid snails. Tree diseases also have potentially large impacts under climate change, including *Phytophthora ramorum* and evergreen diseases such as needle blight and green spruce aphid that are already present and increasing in extent.
- **Surveillance and monitoring:** activities are underway in all four UK countries, but it is not clear to what extent surveillance is effective in identifying risks, and also whether resources are prioritised towards those vectors and pathogens that pose the biggest challenge in the changing climate. Current efforts to monitor and control pests and diseases should be maintained, and further research is urgently needed to better understand the drivers of change in transmission and effects of adaptation strategies. Better ongoing surveillance for the importation of exotic arthropod vectors and pathogens would also be beneficial. Measures to enhance natural resilience, including species diversification in production systems, also need to be more fully evaluated.

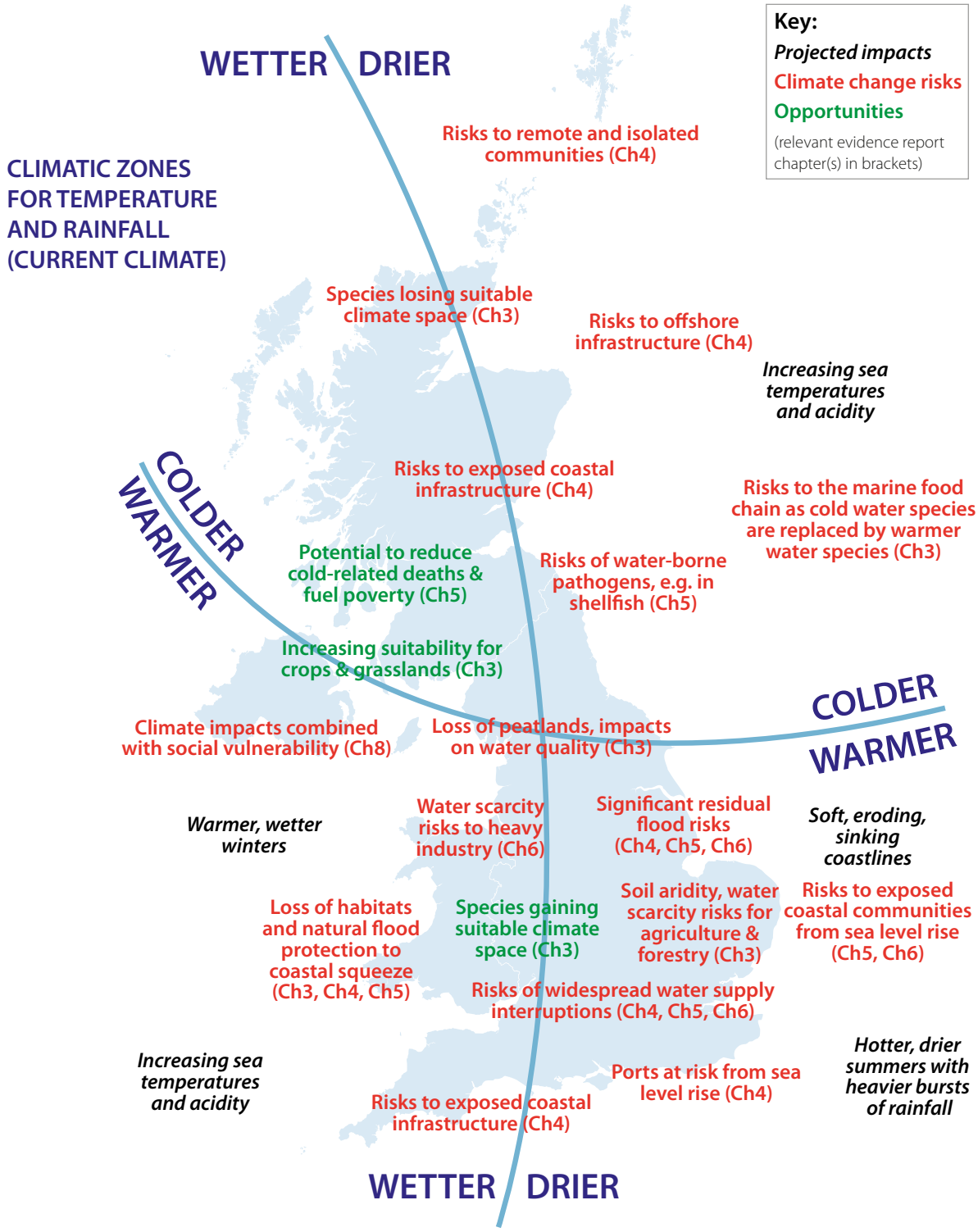
Risks where more action is needed (including reference to Evidence Report sections)	
N/A	
Research priorities	
PB11: Risks to health from vector-borne pathogens (5.5.2)	It2: Imported food safety risks (7.2)
Sustain current action	
Ne9: Risks to agriculture, forestry, landscapes and wildlife from pests, pathogens and invasive species (3.7)	PB13: Risks to health from poor water quality (5.5.6)
Watching brief	
PB12: Risk of food borne disease cases and outbreaks (5.5.6)	

Climate change opportunities

The Evidence Report highlights that as well as risks, there will be opportunities arising for the UK from climate change. Opportunities include increased agricultural production, new species colonising the UK, and for businesses to develop new products and create new markets. With further action there is also potential to reduce the number of people dying unnecessarily in cold weather.

- **Agricultural and forestry production:** a warmer climate will extend the growing season and improve the viability of some high value crops (for example tomatoes, olives, grapes and other soft fruits). However, as previously highlighted, such opportunities will only arise if important natural resources are conserved, in particular fertile soils and water for irrigation. This requires a broad-based assessment of changing land suitability in the context of strategic land-use planning.
- **Biodiversity:** parts of the UK and the surrounding seas are already being colonised by species that thrive in warmer air and water temperatures. However, some local extinctions of native flora and fauna can be expected. Colder, upland areas most likely to experience the greatest change, together with locations that have distinctive climate and environmental conditions not available elsewhere. Species will only become established in new areas if they find sufficient, suitable habitat in good condition.
- **Cold-weather impacts:** Milder winters should diminish the need to heat homes and other buildings in winter, and potentially reduce the impact and burden of fuel poverty across the UK. However, especially when the growing, ageing population is factored in, cold is expected to remain the largest climate-related contributor to death in the UK by some margin. More action is needed to improve the thermal efficiency of buildings if the benefits of milder average winters are to be translated into significant reductions in cold weather mortality. Cold weather impacts on infrastructure should also reduce but cold winters are still expected to occur from time to time through the century. Infrastructure providers will therefore still need to be ready for a cold winter, and their reducing frequency may lead to complacency.
- **Business:** climate change will affect the production costs and demand for certain goods and services, increasing the profitability of some and decreasing others. Businesses that anticipate changing markets may be able to gain an advantage, as well as profit from specific adaptation-related goods and services such as water engineering, climate risk insurance, adaptation finance, and precision farming technologies. Businesses can be expected to respond to market signals and exploit these opportunities as they arise.
- **Health, wellbeing and tourism:** warmer temperatures may encourage more active transport (such as cycling and walking) and increased numbers of visitors to the UK's national parks, beaches and open spaces. It may affect peoples' choice of travel destination, both in displacing UK foreign travel and encouraging tourists from overseas. However, these effects are likely to be dominated by wider socio-economic trends such as household disposable income and currency exchange rates.

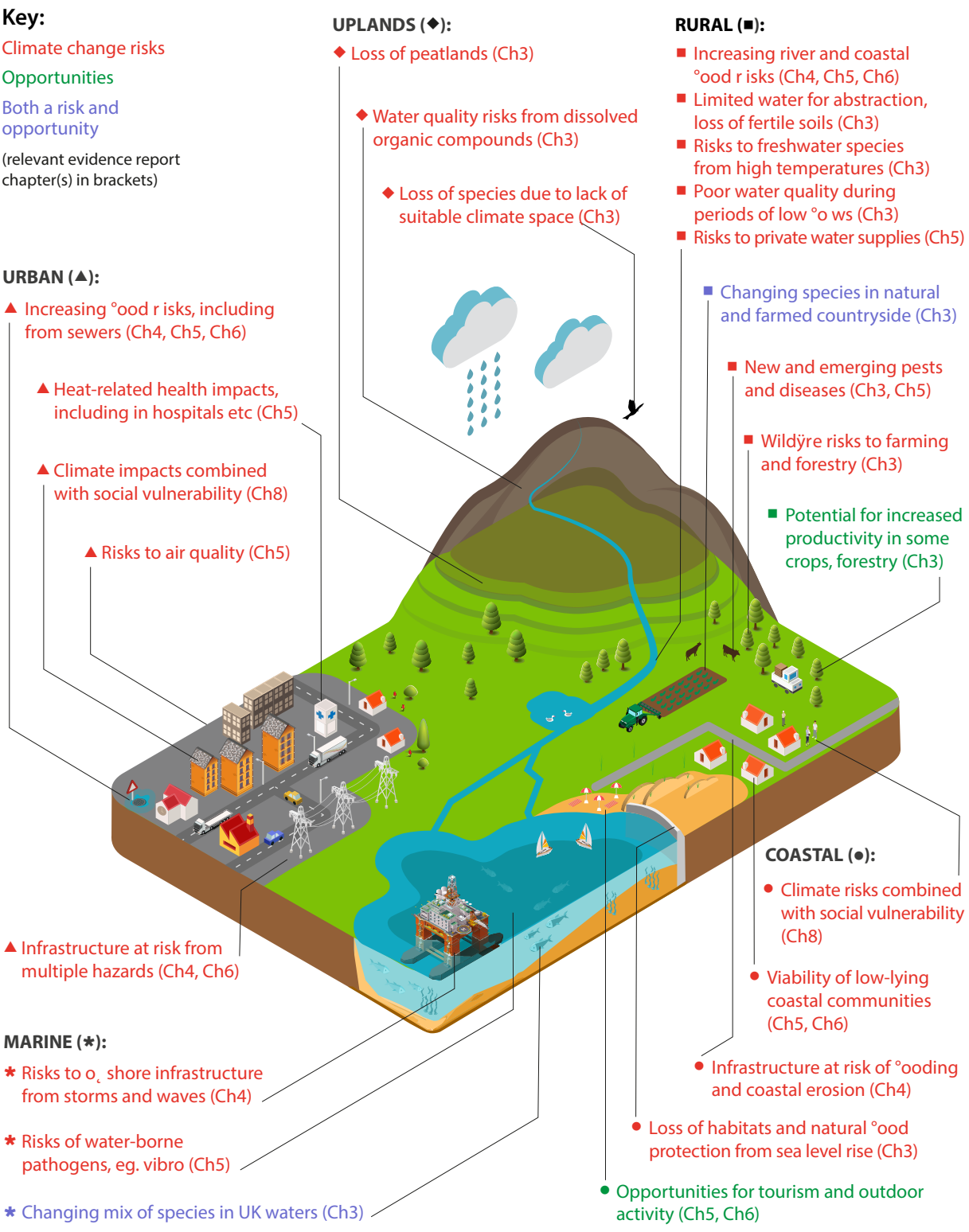
Figure SR.9: Spatial distribution of climate change risks and opportunities for the United Kingdom



Source: ASC synthesis of the Evidence Report chapters.

Notes: The risks presented are not exhaustive and will not be confined to the area(s) shown. The climate zones indicated are based on the current climate (see: http://www.metoffice.gov.uk/public/weather/climate/). Whilst all parts of the UK are expected to warm, and to become wetter (at least in winter), heat-related impacts are expected to be more pronounced in southern UK areas, and water scarcity and aridity stronger in the east.

Figure SR.10: UK climate change risks and opportunities for different types of area



Source: ASC synthesis of the Evidence Report chapters.

Notes: The risks presented are not exhaustive and will not be confined to the types of area shown. See chapters of the Evidence Report for more details.

Assessment of risk and uncertainty

In the Evidence Report, 'risk' is taken to mean *the potential for consequences where something of value is at stake*. While the authors have in many cases been able to provide information on the magnitude of the impact arising from a given change, the resulting impacts do not for the most part have probabilities associated with them.

Assessing the risks from climate change is inherently uncertain, and precise estimates for the likelihood of different events and impacts cannot always be given. Studies that assess future risks, including climate change studies, have to cope with a large amount of uncertainty. This assessment uses the IPCC's definition of risk, which notes that risk arises from the interaction of climate hazards with exposure and vulnerability to impacts. All risks imply some measure of likelihood and impact, but these cannot always be defined.

Not all future possibilities are discussed in this report. Uncertainties can be as important to understand and manage as the risks themselves.

Many of the studies considered in this report explore only a small number of future scenarios. Scenarios are based on a particular set of assumptions about the future climate and changes in socio-economics, and describe the expected impacts associated with these. For example, in Sayers et al. (2015) flood risks are considered under scenarios involving 2°C and 4°C of global warming by the 2080s and various projections of population growth.

The published literature does not consider the full span of uncertainty related to future greenhouse gas emissions, nor the full uncertainty associated with how sensitive the climate and global temperatures will be to these emissions. The inability to cover all possible eventualities is a limitation common to all studies that consider uncertain future events.

The presence of uncertainty in the results should not be taken to mean that impacts are very unlikely to occur. They are considered very likely to occur at least in some form. The uncertainty lies in the magnitude of the change in risk, and the associated impacts. The risks and opportunities discussed are those with the potential to cause the greatest damage, or benefit, to the UK. Other than where associated with high++ scenarios, the impacts have a reasonable chance of occurring this century. To aid the reader, confidence scores – high, medium or low - have been provided in the Evidence Report chapters to summarise the strength and consistency of the evidence in each case.

New knowledge and understanding since the first CRA was published

The analysis in the Evidence Report has benefited from improvements in the understanding of certain risks and opportunities made since 2012.[9] The results also diverge from CCRA1 because this study seeks to answer a different and more specific, policy-relevant question.

Chapter 1 of the Evidence Report outlines the major methodological differences between CCRA1 and CCRA2. This second CCRA:

- has targeted a smaller number of risks and opportunities;
- takes account of the effects of current and planned future adaptation activity on risk levels;
- includes a chapter on climate change overseas and how these risks could result in UK impacts; and

9 For example, through the production of the Living With Environmental Change (LWEC) series of climate change impacts report cards, available here: http://www.nerc.ac.uk/research/partnerships/lwec/products/report-cards/

- presents the results primarily in terms of the urgency of further action in the short-term as well as the magnitude of risks and potential impacts in the long-term.

This means the results of the first two CCRAs are not directly comparable. The authors of each of the Evidence Report chapters have summarised the main changes in approach and advances in knowledge compared with CCRA1. These can also be found in the summaries of the Evidence Report chapters contained in the **Annex** to this Synthesis Report.

Chapter 4: Next steps

Taking adaptation policy forward in the UK

Taking adaptation policy forward in the UK

The UK Government must present its second Climate Change Risk Assessment report to Parliament by January 2017.

Under the Climate Change Act, the Government's assessment of UK climate change risks and opportunities needs to be updated every five years, with the first report presented to Parliament in January 2012. The first report was a synthesis of the evidence and a statement of the adaptation policies in place at the time. This report has been commissioned by the UK Government to inform the second statutory assessment of climate change risks and opportunities due to be presented to Parliament in January 2017.

Following the publication of the formal CCRA report in January, updated national adaptation programmes are expected from the UK and Scottish Governments, and in Wales and Northern Ireland. An updated UK NAP is expected in the summer of 2018, and updated programmes in Scotland and Northern Ireland are expected in 2019. In Wales the CCRA will be used to inform a Future Trends report required under the Wellbeing of Future Generations Act.

Meanwhile, plans are underway to enhance the evidence base in advance of the third Climate Change Risk Assessment due to report in 2022. Key to this will be the production of updated UK climate projections in 2018.

The Met Office is leading the work to update the UK climate projections, under the direction of a governance board chaired by Defra's Chief Scientist. The Adaptation Sub-Committee is represented on the UKCP18 Governance Board and a member of the ASC's Secretariat chairs a user group of government departments.

The UKCP18 projections will enhance understanding in three key areas:

- new uncertainty distributions of plausible future changes in temperature, precipitation and other key climate variables;
- new spatially-coherent global to sub-national projections that combine climate change and natural weather variability; and
- new fine-grain models of localised extreme weather events such as heavy rainfall.

It should be noted that the new projections are being developed within significant resource constraints and the number of emission scenarios and model runs are likely to be limited.

The Adaptation Sub-Committee is working with the Government's Chief Scientific Advisor, Defra's Chief Scientist, and the UK Research Councils, to explore how the research priorities and other evidence gaps highlighted by this second CCRA might be taken forward.

A joint conference with the academic community will be held in November 2016 to present the list of research gaps found by each of the chapter authoring teams, with the aim of developing co-ordinated plans to address them.

This may lead to a programme of research funded by the research councils that would present results in time to be incorporated in to the third CCRA in 2022.

Dummy outputs and preliminary results may emerge from UKCP18 early in order to accelerate the production of pilots and studies using the new data. Otherwise there is a risk that studies that explore UK sectorial impacts arising from the updated climate projections will not be completed, peer-reviewed and published in time for the third CCRA Evidence Report.

The Adaptation Sub-Committee will continue to review what is being achieved by the UK National Adaptation Programme and present its second statutory progress report to Parliament in June 2017. The ASC's second statutory progress report will be informed by the second round of adaptation reports currently being produced and published by infrastructure operators and other important bodies (under the Adaptation Reporting Power within the Climate Change Act). The ASC's report will be the last one before the UK National Adaptation Programme is updated in 2018. Separately, the ASC will publish an initial assessment of the Scottish Climate Change Adaptation Programme in September 2016.

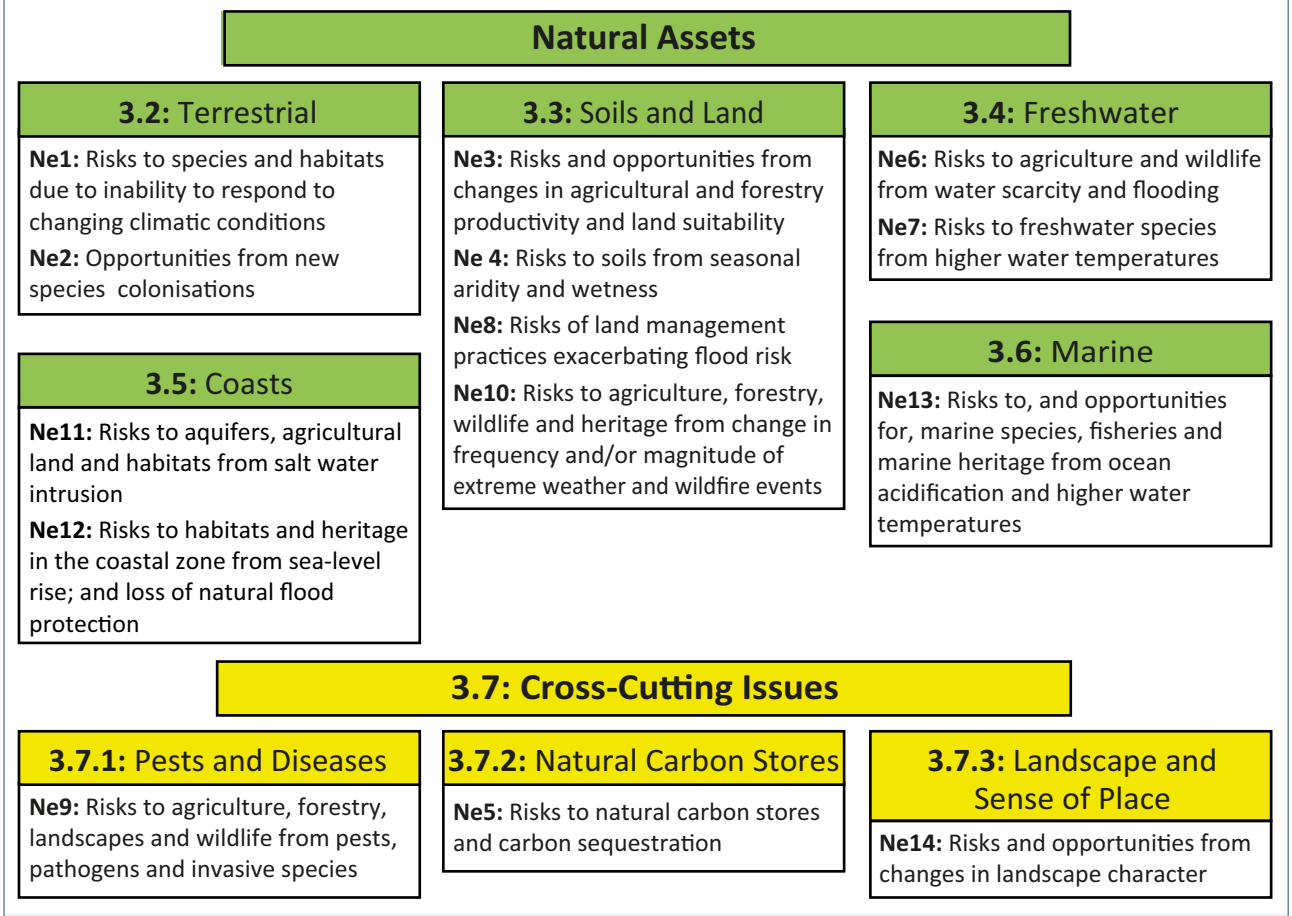
Annex: Evidence Report chapter summaries

Chapter 3: Natural environment and natural assets

Climate change is already having an impact upon natural systems in the UK. Evidence of long-term shifts in the distribution and abundance of some terrestrial, freshwater and marine species due to higher temperatures is now discernible, despite complex interactions. These shifts can be expected to continue and become more widespread, with some species potentially benefiting, but others losing suitable climate space.

Climate change presents a substantial risk to the vital goods and services provided to people by the natural environment (Figure SR.A1). The continued provision of key goods and services traditionally associated with the natural environment, including clean water, food, timber and fibre, are at risk from climate change. Other goods and services that are less well accounted for, although increasingly being recognised, are also at risk including pollination, carbon storage, natural flood alleviation and the cultural benefits provided by landscapes and wildlife.

Figure SR.A1: Climate change risks and opportunities for the natural environment



Source: CCRA2 Evidence Report, Chapter 3.
Notes: Numbers denote the sections of Chapter 3 discussing the issues presented.

The risks from climate change are heightened because the natural environment is already stressed. Historic and on-going pressures include pollution, habitat loss and fragmentation, the continuing drainage of wetlands and the unsustainable use of soil, water and marine resources. These pressures constrain the natural resilience of species and ecosystems and their ability to adjust and adapt. There is therefore a risk that climate change will lead to further species declines and habitat degradation.

There are also potential opportunities that could arise from a modest level of climate change, through extended growing seasons and improved productivity in agriculture, forestry and fisheries. These opportunities will only be realised, however, if limiting factors such as water availability, soil health and pests and diseases are managed.

Key risks for natural capital from climate change include:

- The majority of agricultural land in the eastern side of the UK is projected to become less suitable for some current farming systems due to a combination of reduced water availability, increased soil aridity, the continued loss of soil organic matter, and sea level rise. Some current production may have to shift to the wetter north and west of the country, although increased flooding and waterlogging of farmland in these areas maybe a limiting factor.
- Reduced water availability in the summer, combined with increased water demand from a growing population, is likely to challenge the ecological health of rivers and lakes.
- The UK coast and associated species, habitats and land uses are particularly vulnerable to sea level rise, exacerbated by existing pressures. The loss of habitat and sediment in the coastal zone will have implications for the long-term viability of coastal defences, which often rely on the natural buffering provided by inter-tidal habitats to absorb wave energy.
- Similarly, change in the marine environment is also inevitable. A combination of ocean acidification and higher temperatures is already having an impact on UK waters and could result in fundamental changes to marine food-chains and the fisheries they support.
- New and emerging pests, diseases and invasive species could pose additional risks to trees, crops, livestock and native wildlife.

Priorities for further action and research include:

- Increase current efforts to end damaging management practices, improve the ecological condition of the UK's network of protected sites, and deliver the widespread restoration of degraded habitats.
- Take more flexible and integrated approaches to managing natural capital, including further realignment of the coast, catchment management, and landscape-scale initiatives to increase habitat extent and improve habitat condition and connectivity.
- Assess the nature and scale of changing land suitability and its impacts, including by conducting further research into more resilient crop varieties, tree species, livestock regimes and farming systems.
- Better understand the magnitude and scale of risks to marine ecosystems and fisheries from climate change.

Table SR.A1: Urgency of additional action to support the natural environment

Risk/opportunity	Urgency score	Rationale for scoring
Ne1: Risks to species and habitats due to inability to respond to changing climatic conditions (Section 3.2)	More action needed	More action needed to reduce existing pressures, improve condition and size of habitats, restore degraded ecosystems, and deliver coherent ecological networks. More action to factor climate change into conservation planning and site management.
Ne2: Opportunities from new species colonisations (3.2)	More action needed	More action needed to deliver coherent ecological networks. More action to factor climate change into conservation planning and site management.

Table SR.A1: Urgency of additional action to support the natural environment		
Ne3: Risks and opportunities from changes in agricultural and forestry productivity and land suitability (3.3)	Research priority	More research needed into developing integrated land-use planning based upon changing land suitability. More research needed on the nature and scale of changing land suitability and its impacts. More research needed into crop varieties, tree species and agricultural systems that are resilient to climate change.
Ne4: Risks to soils from increased seasonal aridity and wetness (3.3)	More action needed	More action needed to reduce existing pressures on soils, increase uptake of soil conservation measures and restore degraded soils.
Ne5: Risks to natural carbon stores and carbon sequestration (3.3, 3.7)	More action needed	More action needed to restore degraded carbon stores, particularly peatlands. More research needed to account for climate change impacts on carbon stores in the UK GHG projections.
Ne6: Risks to agriculture and wildlife from water scarcity and flooding (3.4)	More action needed	More action needed to reduce pollution and over-abstraction and improve the ecological condition of water bodies. Ensure decisions on use of water allow for necessary environmental flows and take account of climate change.
Ne7: Risks to freshwater species from higher water temperatures (3.4)	Research priority	More research needed on the scale of risk and effectiveness of adaptation measures.
Ne8: Risks of land management practices exacerbating flood risk (3.3, 3.4)	More action needed	Deliver wider uptake of natural flood management in high-risk catchments especially where there are likely to be carbon storage, water quality and biodiversity benefits. Implement catchment-scale planning for flood risk management. Review potential for adverse flood risk outcomes from land management subsidies.
Ne9: Risks to agriculture, forestry, landscapes and wildlife from pests, pathogens and invasive species (3.7)	Sustain current action	Continue to implement surveillance and bio-security measures. Continue current research efforts into the impact of climate change on long-term risks. Develop cross-sectoral initiatives for risk assessment and contingency planning.
Ne10: Risks to agriculture, forestry, wildlife and heritage from changes in frequency and/or magnitude of extreme weather and wildfire events (3.3)	Sustain current action	Continue to build resilience of ecosystems to drought, flood and fire. Continue current efforts to manage and respond to wildfires. Monitor heat stress impacts on livestock. Continue current efforts to manage impacts of high winds on forestry.
Ne11: Risks to aquifers, agricultural land and habitats from saltwater intrusion (3.5)	Sustain current action (watching brief in Northern Ireland & Scotland)	Continue action to manage salinity risks to freshwater habitats. Monitor impacts on aquifers to assess whether risks are increasing.

Table SR.A1: Urgency of additional action to support the natural environment		
Ne12: Risks to habitats and heritage in the coastal zone from sea-level rise; and loss of natural flood protection (3.5)	More action needed	More action needed to deliver managed realignment of coastlines and create compensatory habitat.
Ne13: Risks to, and opportunities for, marine species, fisheries and marine heritage from ocean acidification and higher water temperatures (3.6)	Research priority	More research needed to better understand magnitude of risk to marine ecosystems and heritage.
Ne14: Risks and opportunities from changes in landscape character (3.7)	Watching brief	Monitor impacts and ensure climate change is accounted for in future landscape character assessments.

Source: CCRA2 Evidence Report, Chapter 3.
Notes: Urgency scores have been determined by the ASC on the basis of the evidence presented in the chapter. See Chapter 2 of the Evidence Report for a description of the urgency scoring methodology.

Box SR.A1: Advances in understanding since CCRA1

Chapter 3 – Natural environment and natural assets

- CCRA2 focusses more on the cross-sectoral nature of risks and opportunities. In particular, cross-cutting risks linked to the availability of land, water and marine resources have been highlighted using an ecosystem services framework.
- The analysis of terrestrial species, habitats and soils has benefited from a large expert-based analysis of climate impacts through the LWEC Report Card process and from updated bioclimatic envelope modelling for the whole of the UK.
- Specific emphasis has been placed on assessing risks to pollinators, reflecting the direct benefits they deliver for farming and the natural environment.
- Assessment of crop production has been refined to provide a broader interpretation of the effects of climate change on crop yields than in CCRA1.
- Risks relating to grassland and livestock productivity, which are important for large areas of the UK, receive more comprehensive coverage than in CCRA1.
- Freshwater ecosystems and water-related services (such as flood alleviation) are evaluated together to highlight synergies and the role of ecosystem-based adaptation.
- Similarly, risks from sea level rise to coastal ecosystems important for buffering flooding and coastal erosion have been evaluated.
- A cross-cutting approach to assessing risks to, and opportunities for, the marine environment has been taken.
- New ensemble models of climate change in the marine environment have been used, including an assessment of uncertainty that was not available for CCRA1.
- A cross-sectoral approach has been taken to evaluate risks associated with pests and diseases, wildfire, and natural carbon stores, in order to bring together the available evidence.

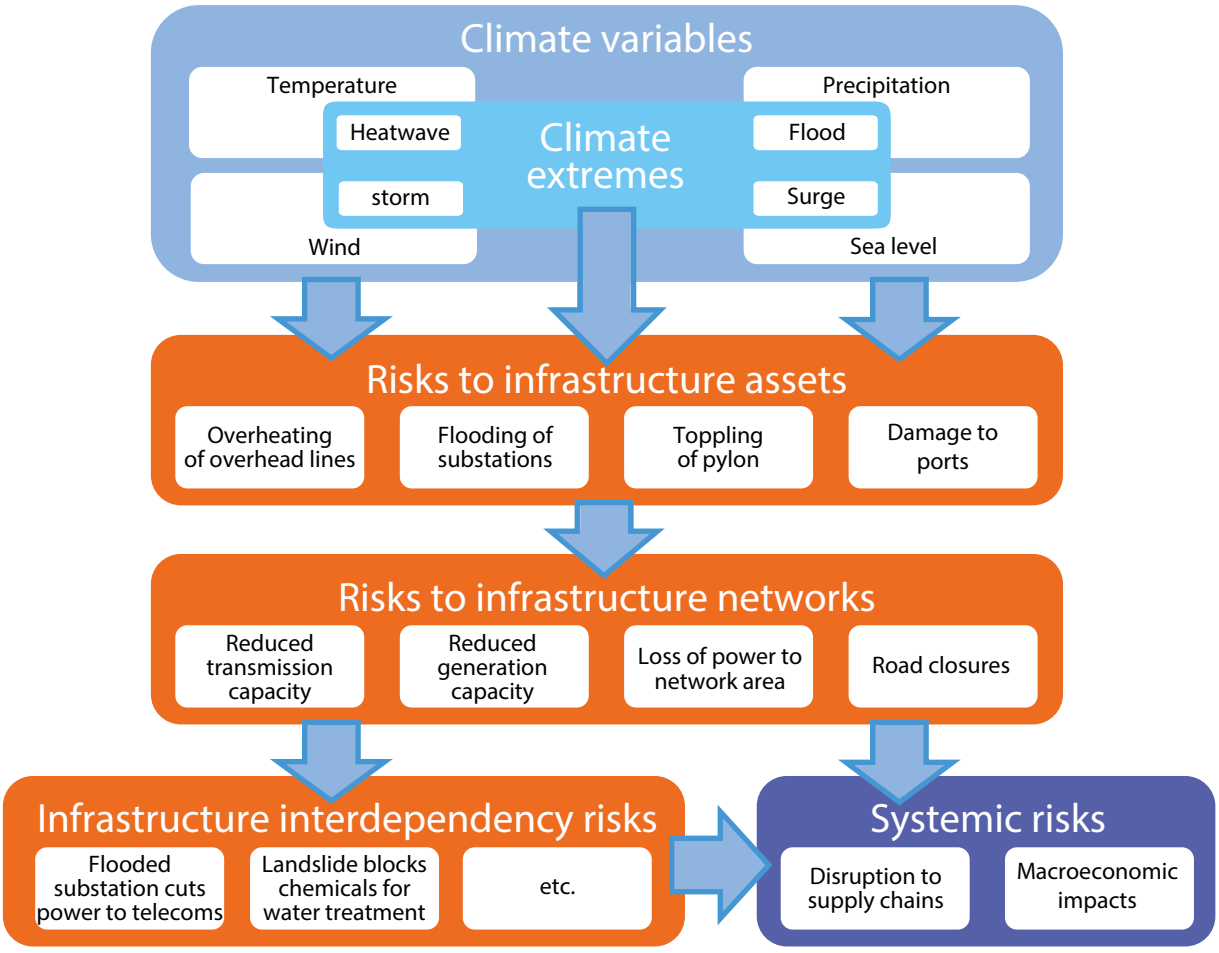
Source: CCRA2 Evidence report, Chapter 3.

Chapter 4: Infrastructure

Extreme events, such as the winter storms of 2013/14 and 2015/16, are associated with disruption to or even the complete loss of essential services such as water and energy supplies, and transportation and communication networks. As well as being costly to recover, the loss of infrastructure services can have significant impacts on people's health and wellbeing, and local economic activity.

Infrastructure services such as heating, lighting, mobility and sanitation are essential for modern society. Current variability in weather already impacts the performance of the UK's infrastructure. Climate change is expected to lead to an increase in the frequency and severity of severe weather including flooding, higher temperatures and possibly drought.

Figure SR.A2: Example relationships between climate variables and infrastructure impacts



Source: CCRA2 Evidence report, Chapter 4.

An increasing frequency and severity of flooding from a range of sources represents the most significant climate change risk to UK infrastructure.

Assets and networks across all infrastructure sectors are already exposed to multiple sources of flooding, and the number of assets exposed to significant levels of flood risk could double by the 2080s with projected changes in the UK climate.

- Coastal infrastructures, particularly ports, are at risk from rising sea levels and a consequential increase in the height of onshore waves and storm surges.

- High onshore waves will also accelerate rates of coastal erosion and put increasing lengths of the UK rail network at risk, as well as sea walls that protect coastal settlements.
- Infrastructure networks near rivers, especially bridges, electricity and communication cables, and gas pipelines, will become more vulnerable to higher flows and erosion of bridge foundations.

The collapse of ageing bridges in recent flood events highlights the potential for knock-on impacts. As well as allowing passage of people and goods, bridges often carry gas pipelines, and electricity, telephone and data cables.

Changes in temperature and rainfall will place additional pressures on infrastructure, in particular the rail, road, water and energy sectors.

High temperatures increase the risk of buckling railway track, cause electricity cables to sag, and road tarmac to soften and rut. Components such as signalling equipment can overheat and fail.

Changing rainfall patterns and increased evapotranspiration, coupled with population growth, are projected to lead to water demand exceeding the available supply in water resource zones across England and in some other parts of the UK by the 2050s. Widespread deficits are projected by the 2080s in most climate and population scenarios. Increasing investment and adaptation by water companies will be needed to manage this risk, starting with the full implementation of current water resource management plans (WRMPs) between now and the 2030s. There would be merit in WRMPs having a longer than 25-year time horizon, to make sure water companies take full account of the uncertainty in future projections through to the middle of the century and beyond. In some cases early steps may need to be taken to assess and retain long-term water supply options.

Projected extended periods of rainfall will also increase the risk of slope and embankment failure. Approximately 8% of the UK's transport and road network is at a material risk of landslide disruption. Risks of subsidence to buried infrastructure, such as high pressure pipelines and high voltage electricity cables, could also potentially increase.

Any increases in maximum wind speeds with climate change experienced during storms would have significant implications for many infrastructure networks.

Whilst projections remain uncertain, overhead power and data network cabling, offshore infrastructure and transport networks could become increasingly disrupted.

Vulnerability to this risk is expected to increase. Higher temperatures imply increased rates of vegetation growth, resulting in more damage from fallen trees and large branches during storm events.

There is evidence that significant adaptation steps have been implemented, or are underway, across most infrastructure sectors.

This is primarily in response to extreme events, most notably in summer 2007, winter 2013/14 and more recently the major flooding in northwest England and southern Scotland in the winter of 2015/16.

Reporting has improved, but could be made more transparent across the board – through better recording and provision of data on climate risks to infrastructure, and how adaptation investment contributes towards risk reduction. Current reporting is incomplete and inconsistent.

Whilst understanding of sectorial risks has improved over the last few years, the impacts of climate change could be amplified by interdependencies between infrastructure sectors.

Understanding of these is less comprehensive, and current governance arrangements mean that responsibilities for assessing and managing risks from interdependencies are unclear.

Table SR.A2: Urgency of additional action to support infrastructure resilience		
Risk/opportunity	**Urgency score**	**Rationale for scoring**
In1: Risks of cascading failures from interdependent infrastructure networks (Sections 4.4 to 4.9)	More action needed	More action needed to enhance arrangements for information sharing in order to improve understanding of critical risks arising from interdependencies.
In2: Risks to infrastructure services from river, surface water and groundwater flooding (4.4 to 4.9)	More action needed	More action needed to manage increasing risk to existing assets and networks and ensure increased risk is accounted for in design and location of new infrastructure.
In3: Risks to infrastructure services from coastal flooding and erosion (4.4 to 4.9)	More action needed (research priority in Northern Ireland & Scotland)	More action needed to manage increasing risk to existing networks (including flood and coastal erosion risk management infrastructure), from sea-level rise and increased rate of erosion.
In4: Risks of sewer flooding due to heavy rainfall (4.5)	More action needed	More action needed to deliver sustainable drainage systems, upgrade sewers where appropriate, and tackle drivers of increasing surface runoff (e.g. impermeable surfacing in urban areas).
In5: Risks to bridges and pipelines from high river flows and bank erosion (4.5, 4.7, 4.8)	Research priority	More research needed on implications of projected changes in river flows on future risk of scour/erosion.
In6: Risks to transport networks from slope and embankment failure (4.7)	More action needed	More action needed to locate and remediate slopes, embankments and cuttings at risk of failure.
In7: Risks to hydroelectric generation from low or high river flows (4.8)	Watching brief	Monitor impacts and be ready to adapt operations as necessary.
In8: Risks to subterranean and surface infrastructure from subsidence (4.5, 4.6, 4.7, 4.8)	Watching brief	Monitor changes in temperature and rainfall patterns to update assessments of subsidence risk.
In9: Risks to public water supplies from drought and low river flows (4.5)	More action needed (sustain current action in Northern Ireland & Scotland)	New policies and stronger co-ordinated, cross-sector effort needed to deliver more ambitious reductions in water consumption and establish strategic planning of new water-supply infrastructure. More action needed to put in place reforms of the water abstraction licencing regime.
In10: Risks to electricity generation from drought and low river flows (4.8)	Watching brief	Continue to monitor risks including as a result of deploying carbon capture and storage. Ensure appropriate siting of new infrastructure including use of suitable cooling technologies.
In11: Risks to energy, transport and digital infrastructure from high winds and lightning (4.6, 4.7, 4.8)	Research priority	More research needed on the implications of increased vegetation growth rates on future risks of damage from falling trees in storms.

Table SR.A2: Urgency of additional action to support infrastructure resilience		
In12: Risks to offshore infrastructure from storms and high waves (4.7, 4.8)	Research priority (watching brief in Northern Ireland & Wales)	More research needed to assess climate risks to existing and planned off-shore renewable energy infrastructure.
In13: Risks to transport, digital and energy infrastructure from extreme heat (4.6, 4.7, 4.8)	Sustain current action	Continue current actions to reduce risks, including maintenance and renewal of infrastructure networks.
In14: Potential benefits to water, transport, digital and energy infrastructure from reduced extreme cold events (4.5, 4.6, 4.7, 4.8)	Sustain current action	Continue current actions to reduce risks, including to maintain current cold-weather planning and response capabilities.

Source: CCRA2 Evidence Report, Chapter 4.
Notes: Urgency scores have been determined by the ASC on the basis of the evidence presented in the chapter. See Chapter 2 of the Evidence Report for a description of the urgency scoring methodology.

Box SR.A2: Advances in understanding since CCRA1

Chapter 4 – Infrastructure

- CCRA1 reported on risks to transport, energy and water infrastructure separately. In CCRA2 all infrastructure risks are brought together within one chapter.
- Additionally, CCRA2 reviews risks to solid waste, ICT and Flood and Coastal Erosion Risk Management infrastructure.
- New insights into risks resulting from infrastructure interdependence are also reported.
- Research since CCRA1 has improved analysis of risks from flooding, bridge scour, rail buckling and windstorms. However, there has been no change in our understanding of the trends in key risks.

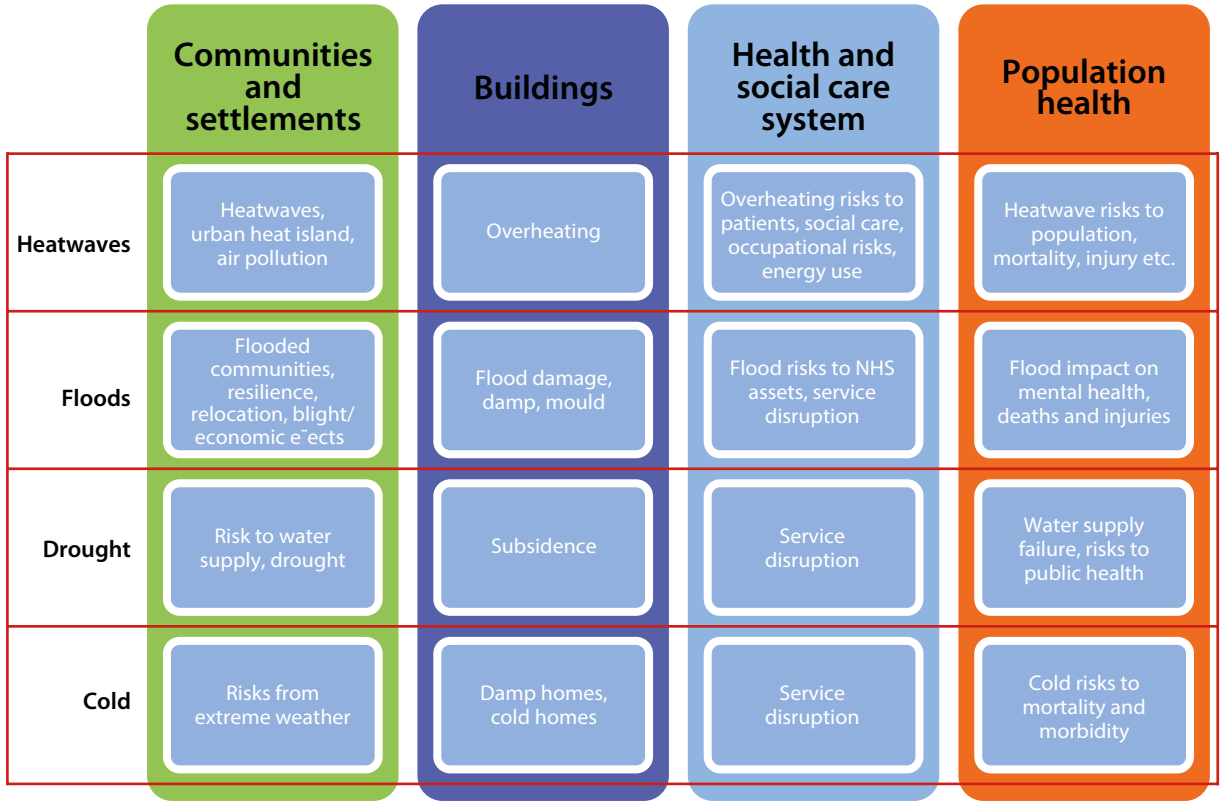
Source: CCRA2 Evidence report, Chapter 4.

Chapter 5: People and the built environment

Increasing temperatures, rising sea-levels and modified rainfall patterns will change the climate-related risks to people and the built environment. Climate change will create new challenges for those working in planning, community development, emergency response, and the health and social care system. There are also potential opportunities for health and wellbeing from warmer weather.

Flooding and high temperatures pose the greatest risks to people and the greatest need for action in the next five years. These risks interact across multiple levels – communities, buildings, health systems and individuals (Figure SR.A3).

Figure SR.A3: Climate change hazards affecting people and the built environment



Source: CCRA2 Evidence Report, Chapter 5.

Flooding already poses a severe threat to people, communities and buildings. Climate change is expected to increase the frequency, severity and extent of flooding.

According to research conducted to support the CCRA, at present an estimated 1.8 million people are living in areas of the UK at significant risk of river, surface water or coastal flooding.[10] The population living in such areas is projected to rise to 2.6 million by the 2050s under a 2°C scenario and 3.3 million under a 4°C scenario, assuming low population growth and a continuation of current levels of adaptation. As well as risks to life and property, flooding causes long term damage to health, wellbeing, livelihoods, and social cohesion. Significant and increasing investment will be required over time to address the projected increase in flood risk associated with climate change. Even then, flood defences will provide limited and diminishing standards of protection as sea levels rise and patterns of

10 Areas with a 1-in-75 or greater annual chance of flooding.

rainfall intensify. Other communities, where the economic justification for investment in flood defences is less strong, face the prospect of growing and unmanaged flood risk.

As a result, the focus of adaptation activity must also be on adapting buildings, catchments and landscapes to make them more resilient to flood waters, as well as improving flood defence standards and surface water drainage where possible.

Analysis conducted for the CCRA suggests that 0.5 to 1 metre of sea level rise could make some 200km of coastal flood defences in England highly vulnerable to failure in storm conditions. Sea level rise and increased wave action will make it increasingly difficult and costly to maintain current sea defence lines in some areas.

Significant additional investment is likely to be required to maintain these defences or to retreat defence lines to more sustainable locations. It is not known how much of the coast is economically viable to protect in the future. Affected communities are likely to be exposed to economic blight long before the physical risks manifest, in the absence of plans to manage long-term coastal change. Impacts are already arising for individual isolated communities.

Higher average and extreme temperatures throughout the year are likely to have a range of impacts on the UK population. Some of these could be benefic al, but as specific thresholds are exceeded, the adverse effects of excessive heat will increasingly be felt.

The number of heat-related deaths in the UK are projected to increase by around 250% by the 2050s (median estimate), due to climate change, population growth and ageing, from a current annual baseline of around 2,000 heat-related deaths per year. There are as yet no comprehensive policies in place aimed at reducing the risk of overheating in new and existing homes.

All types of buildings are at risk of overheating, including hospitals, care homes, offices, schools, and prisons. Modern healthcare facilities, designed to be thermally-efficient in cold weather, can have problems with thermal comfort during heatwaves for both patients and staff. Overheating on public transport including buses and trains is also likely to increase although some management is already being put in place for example in London.

There are also potential opportunities associated with higher temperatures. For example, outdoor activities may become more attractive, with perhaps an increase in active travel such as cycling and walking. Other aspects of physical activity may also increase with benefits for health and wellbeing. Very little quantitative evidence exists that considers these benefits.

Cold is currently a signifi ant public health problem, with between 35,800 and 49,700 cold-related deaths per year on average in the UK. Cold will remain an important climate risk even with milder average winter temperatures. This is due to the poor thermal performance of the UK housing stock combined with a growing, ageing population.

Climate change is projected to reduce the health risks from cold, but the number of cold-related deaths is projected to decline only slightly due to the effects of a growing, ageing population increasing the number of vulnerable people at risk. The latest estimates at UK-level suggest a reduction in cold-related mortality of 2% by the 2050s (medium emissions and including demographic change). Further measures need to be taken in the next five years to tackle the large numbers of cold homes and reduce the impacts of cold weather on health, even as the climate warms. Household energy efficiency measures will be important, including to reduce energy bills and greenhouse gas emissions from heating and hot water. However, increasing air tightness and levels of insulation can cause buildings to overheat unless steps are taken to mitigate this.

Health services will be vulnerable to an increase in the frequency and intensity of extreme weather events. The capacity of the system to cope with shocks is unknown but could decrease given pressures on the health service and local authorities.

Floods and storms cause significant disruption to health and social systems. Across England and Wales, the number of hospitals, GP surgeries, emergency service stations or care homes located in areas of significant flood risk are projected to increase by the 2050s by between 3 and 24% under a 2°C scenario, and between 27 and 110% under a 4°C scenario (assuming a continuation of current levels of adaptation). The risks are somewhat lower in Scotland and Northern Ireland.

Globally, human infectious disease risks are influenced by the movement of people, animals and goods. Climate change may increase the capacity of existing UK mosquito species to transmit certain arboviruses that are harmful to human health.

Higher temperatures in the future may lead to the expansion of insect vectors for certain diseases. For example, *Culex modestus* has recently been found in south-east England and is a vector for West Nile virus. Higher temperatures in the future will also increase the suitability of the UK's climate for invasive mosquito species. The risk of dengue and the Chikungunya virus remains low in the near term but may increase under a 4°C scenario. The risk of malaria in the UK remains low.

Table SR.A3: Urgency of additional action to support people and the built environment		
Risk/opportunity	**Urgency score**	**Rationale for scoring**
PB1: Risks to health and wellbeing from high temperatures (Sections 5.2.2, 5.3.2, 5.5.3)	More action needed (research priority in Northern Ireland, Scotland & Wales)	The risk to health is likely to increase in the future as temperatures rise. There is some evidence that the risks of overheating in hospitals, care homes, schools and offices will increase in the future. There is more evidence for England than for the devolved administrations. Policies do not exist at present to adapt homes or other buildings to higher temperatures.
PB2: Risks to passengers from high temperatures on public transport (5.3.9)	Research priority (sustain current action in England, watching brief in Northern Ireland & Scotland)	The action underway in London to assess and manage risks of overheating on public transport should continue, together with similar action as needed elsewhere in the UK.
PB3: Opportunities for increased outdoor activities from higher temperatures (5.2.3)	Watching brief	Leisure and other activities are likely to be taken up autonomously by people as the climate warms.
PB4: Potential benefits to health and wellbeing from reduced cold (5.3.3, 5.5.4)	More action needed	Climate change is projected to reduce the health risks from cold, but the number of cold-related deaths is projected to decline only slightly due to the effects of an ageing population increasing the number of vulnerable people at risk. Further measures need to be taken in the next five years to tackle large numbers of cold homes and reduce cold effects on health, even with climate warming.
PB5: Risks to people, communities and buildings from flooding (5.2.5, 5.3.4, 5.5.1)	More action needed (research priority in Northern Ireland, Scotland & Wales)	Under the most optimistic flood defence investment scenario for England, the level of risk declines but remains high by mid-century, and future spending plans for the devolved administrations are unclear. Increases in flood risk cannot be avoided under a 4°C climate scenario even if the most ambitious adaptation pathway considered in this report were in place.
PB6: Risks to the viability of coastal communities from sea level rise (5.2.6, 5.2.7)	Research priority	Research is needed to better characterise the impacts from sea level rise on coastal communities, thresholds for viability, and what steps should be taken to engage and support affected communities.
PB7: Risks to building fabric from moisture, wind and driving rain (5.3.4, 5.3.6, 5.3.7)	Research priority	More research is needed to better determine the future level of risk and what further steps might be appropriate.
PB8: Risks to culturally valued structures and the wider historic environment (5.3.8)	Research priority	Climate-related hazards damage historic structures and sites now, but there is a lack of information on the scale of current and future risks, including for historic urban green spaces and gardens as well as structures.
PB9: Risks to health and social care delivery from extreme weather (5.4)	More action needed (research priority in Northern Ireland, Scotland & Wales)	There is some evidence of inconsistent planning for extreme weather across the UK. Surveys indicate that many Clinical Commissioning Groups, NHS providers, GPs and Local Authorities may not have appropriate plans in place.

Table SR.A3: Urgency of additional action to support people and the built environment		
PB10: Risks to health from changes in air quality (5.2.2, 5.3.5, 5.5.5)	Research priority	More research is needed to understand the influence of climate change on ground level ozone and other outdoor air pollutants (especially particulates), and how climate and other factors (e.g. individual behaviour) affect indoor air quality.
PB11: Risks to health from vector-borne pathogens (5.5.2)	Research priority	Further research is needed to improve the monitoring and surveillance of vector species and related infectious disease, and to assess the extent to which current efforts are focussed on those infections that pose the greatest long-term risks.
PB12: Risk of food borne disease cases and outbreaks (5.5.6)	Watching brief	Regulations in place to monitor and control food-related hazards should be kept under review.
PB13: Risks to health from poor water quality (5.5.6)	Sustain current action	Current policies and mechanisms to assess and manage risks to water quality in the public water supply should continue to be implemented.
PB14: Risk of household water supply interruptions (5.2.4)	Sustain current action	Policies are in place to safeguard the continuity of public water supplies during droughts and from burst pipes in cold weather. These risks should be kept under review to make sure long-term risks continue to be managed appropriately.

Source: CCRA2 Evidence Report, Chapter 5.
Notes: Urgency scores have been determined by the ASC on the basis of the evidence presented in the chapter. See Chapter 2 of the Evidence Report for a description of the urgency scoring methodology.

Box SR.A3: Advances in understanding since CCRA1

Chapter 5 – People and the built environment

- Risks from flooding set out in this chapter are of a similar magnitude to CCRA1 but now cover all four types of flooding (river, coastal, surface water and groundwater), rather than just river and coastal flooding. The chapter presents consistent projections for the whole of the UK for the first time, whereas in CCRA1 only England and Wales could be covered as suitable data was not available for Northern Ireland and Scotland.
- This chapter also contains more information than was available for the CCRA1 on the health, social and economic impacts from flooding, and flood risks to communities.
- CCRA1 did not consider the risks to coastal communities for rises in sea level beyond 1 metre.
- CCRA1 projected a large benefit arising from a reduction in cold-related mortality. A more comprehensive assessment published in 2014 makes this large benefit less certain due to the compounding effects of population ageing.
- Unlike the first CCRA, this chapter reviews the evidence regarding the capacity of the health and social care system to cope with climate risks.
- New risks and opportunities assessed here that were missing from CCRA1 include the risks to historic buildings, structures, and gardens, risks to passengers on public transport and opportunities for health and wellbeing from warmer weather.

Source: CCRA2 Evidence report, Chapter 5.

Chapter 6: Business and industry

Recent empirical evidence highlights the growing impact that climate risks have on business and industry in the UK (Figure SR.A4). Flooding and extreme weather events which damage assets and disrupt business operations pose the greatest risk now and in the future.

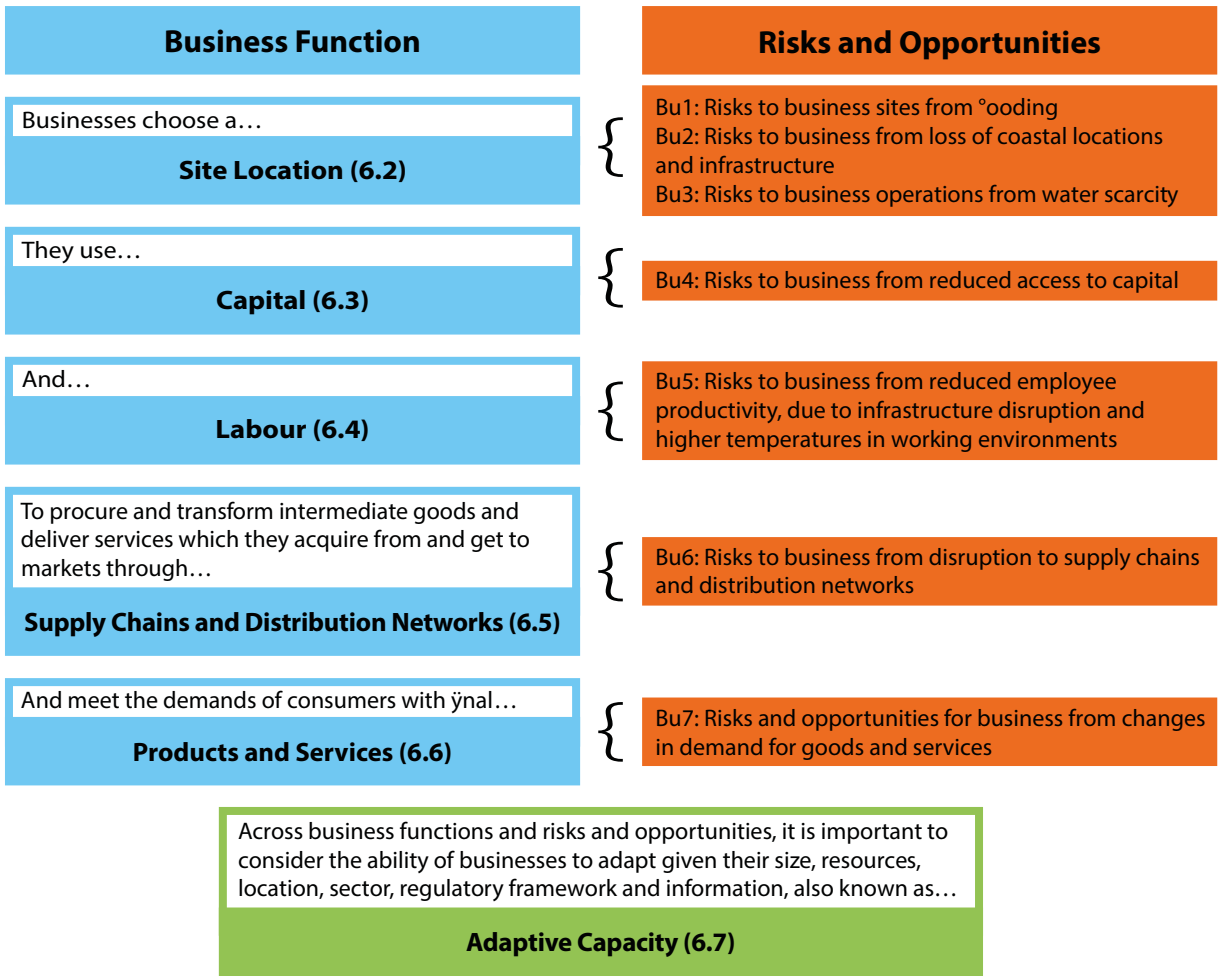
The level of disruption to business operations will depend, in part, on the resilience of local infrastructure including energy, transportation and telecoms. The knock-on impacts of severe weather include disruptions to supply chains and distribution channels, and impacts on staff, leading to lost business and reputational damage. These can be as damaging particularly for small businesses as the direct impacts of severe weather.

- Currently, the risk to businesses from flooding is high in many parts of the UK. Local levels of risk will vary in terms of exposure and as a result of existing protection measures at a community or site level. Whilst managing flood risks will be possible and affordable in some areas in others risks are expected to rise. Businesses therefore need to understand their exposure and not assume that authorities will manage risks on their behalf.
- Severe flooding and coastal erosion can lead to loss of coastal business locations and the infrastructure they rely on. This may affect sectors dependent on the cultural value of these locations, such as tourism, and those reliant on vulnerable infrastructure for example to provide access, power and communications.

With the exception of only the northern-most catchments of Scotland and some central and western central catchments in England, projections suggest larger routine deficits in the availability of water for abstraction, constituting a risk especially to water-intense industries.

Through their international supply chains, distribution networks and global markets, UK businesses are exposed to the risks of extreme weather around the world. Climate change is expected to increase the risk of weather-related disruptions, particularly for supply chains and distribution networks that involve more vulnerable countries, such as in south and south-east Asia, and in sub-Saharan Africa.

Figure SR.A4: Climate change risks and opportunities for business



Source: CCRA2 Evidence Report, Chapter 6.

Climate change will provide both risks and opportunities to business through changes in demand for existing and new products and services.

This appears to be particularly relevant for adaptation-related goods and services within the following sectors: engineering and consulting, tourism, insurance and other finance products, and agriculture and food.

The UK has expertise in many areas to develop climate-related products and services. To date evidence is limited on how the UK is performing in emerging adaptation-related markets at home and abroad. Opportunities to grow exports may be being missed.

It is ultimately for each business to determine their strategy for adapting to climate change. However some key interdependencies are beyond the control of individual businesses.

Adaptation measures taken by one sector might impact on other businesses. Insurance companies can exit the market, adjust premiums or limit terms when the level of risk increases. While this can create incentives for more adaptive behaviour by businesses - including to mitigate risks on-site or move assets to lower risk locations - it also may raise questions of affordability, particularly for smaller businesses.

Regulatory responses by the Government to climate change - particularly for heavily regulated sectors such as finance, food and utilities - can present both risks and opportunities.

Government has a role in enabling, facilitating and supporting private sector adaptation through policies, regulation, and measures such as information sharing and raising awareness.

Most adaptation action for communities and society will be delivered by the private sector. A range of case studies conclude that businesses and industry play an important role, from building adaptive capacity within sectors to delivering specific adaptation action at individual business, community, regional and national levels.

If and how businesses can respond to climate risks and opportunities depends on their adaptive capacity. This is currently low for small businesses; a key issue requiring urgent attention.

Table SR.A4: Urgency of additional action to support business

Risk/opportunity	Urgency score	Rationale for scoring
Bu1: Risks to business sites from flooding (6.2.2, 6.2.3)	More action needed (research priority in Northern Ireland, Scotland & Wales)	More effort is needed in England to address flood risks and inform businesses of their current and future exposure and what steps they might take to limit impacts. More research needed elsewhere in the UK to understand uptake of flood protection measures by businesses and how spending plans on defences and other measures may or may not protect individual businesses.
Bu2: Risks to business from loss of coastal locations and infrastructure (6.2.2, 6.2.3)	Research priority	More research needed on costs and benefits of adaptation options for different coastal areas.
Bu3: Risks to business operations from water scarcity (6.2.4, 6.2.5) NB: Also see related infrastructure risk In9.	Sustain current action	Sustain current actions to create more flexible abstraction regimes and promote water efficiency among businesses.
Bu4: Risks to business from reduced access to capital (6.3)	Watching brief	Monitor and research action by regulators, banks and insurance firms, and information disclosures by UK companies.
Bu5: Risks to business from reduced employee productivity, due to infrastructure disruption and higher temperatures in working environments (6.4.2, 6.4.3, 6.4.4, 6.4.5)	Research priority	More research needed on disruption to ICT, power and transport infrastructure which prevents workers accessing premises or working remotely, and on impacts of higher temperatures on employee safety and productivity.
Bu6: Risks to business from disruption to supply chains and distribution networks (6.5) NB: Also see related international risks It1 and It3.	Sustain current action	Sustain and monitor the uptake of existing guidance which helps businesses improve the resilience of supply chains and distribution networks, particularly at the international level.
Bu7: Risks and opportunities for business from changes in demand for goods and services (6.6)	Watching brief	Monitor sales of adaptation goods and services within the UK, and by UK companies.

Source: CCRA2 Evidence Report, Chapter 6.
Notes: Urgency scores have been determined by the ASC on the basis of the evidence presented in the chapter. See Chapter 2 of the Evidence Report for a description of the urgency scoring methodology.

Box SR.A4: Advances in understanding since CCRA1

Chapter 6 – Business

- The assessment in CCRA1 was focused on the following sub-sectors: financial services; tourism; food and beverage manufacturing; oil, gas and mining; and chemical manufacturing.
- CCRA2 uses a business function approach to identify and assess risks and opportunities across different business types, different economic sectors and industry sub-sectors, as well as across regions.
- The evidence highlights that there are particular sectors for which the risks and opportunities from climate change are more relevant (engineering and consulting, tourism, insurance and other finance products, agriculture, food and utilities), the majority of which were part of the CCRA1 assessment.
- CCRA2 incorporates new research on insurance and other finance products.
- CCRA 2 also considers risks and opportunities from new regulation introduced to manage climate risks, and limited adaptive capacity, in addition to those risks arising directly from climate hazards such as higher temperatures, flooding and water scarcity.
- There has been greater engagement with individual businesses and industry representatives during the process of compiling the chapter.
- Overall, the risks and opportunities for business and industry identified are broadly in line with those from CCRA1.

Source: CCRA2 Evidence report, Chapter 6.

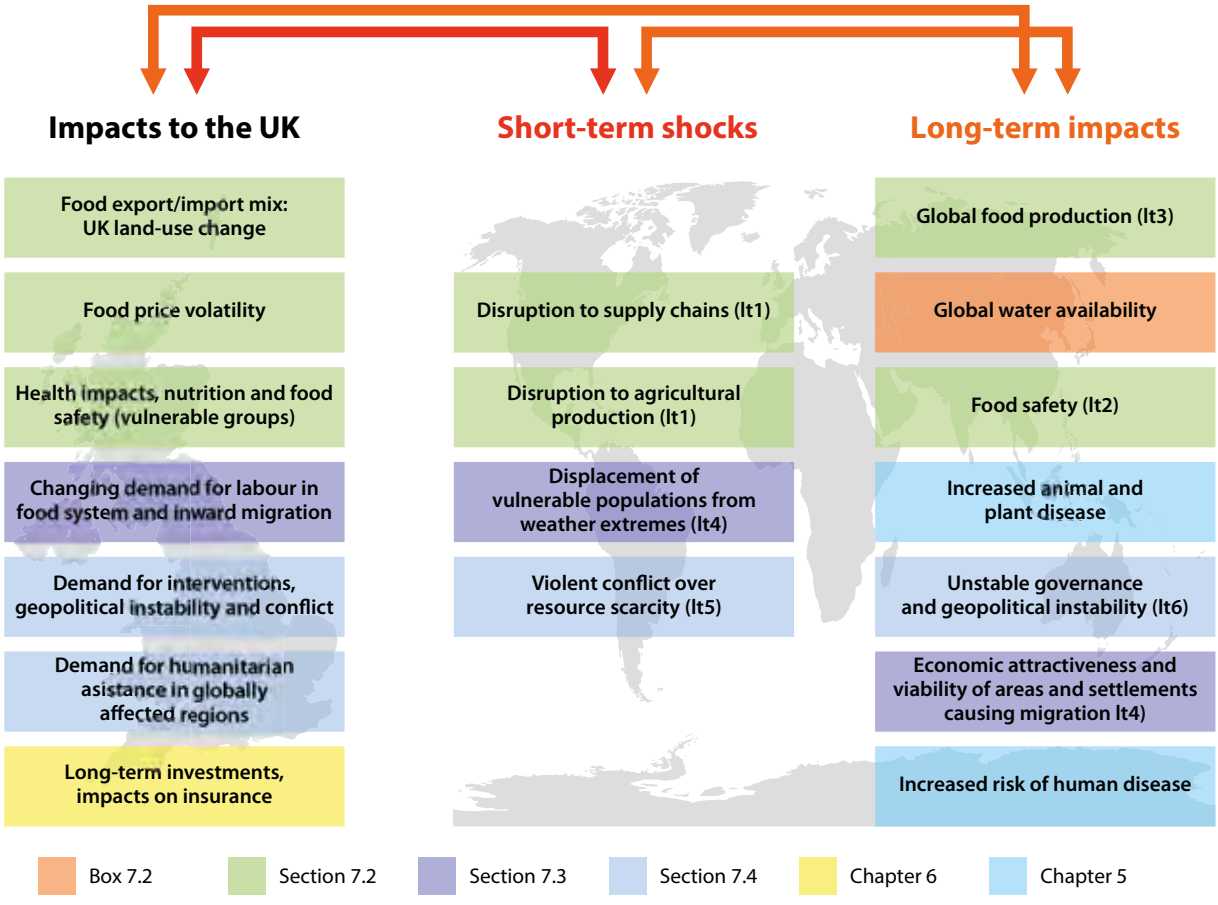
Chapter 7: International dimensions

Climate change will impact populations, economies and livelihoods around the world. An increase in extreme weather impacts can be expected to cause widespread loss of life and severe humanitarian crises. Increasing pressure will be placed on scarce natural resources, patterns of agricultural production will change and be disrupted, and when combined with other factors this could cause individual states to fail.

Impacts will be imported to the UK through the price and safety of food and other commodities, changes in the patterns of trade, disruption to global supply chains, and risks to overseas investments (Figure SR.A5).

- Climate change is expected to increase the frequency of weather extremes, disproportionately affecting low income populations. The UK is likely to be called upon to provide more resources for humanitarian assistance, and efforts to build state stability and long-term resilience could be undermined.
- Extreme weather events can also cause production shocks and supply chain disturbance, with impacts on the world food market, to which UK prices are particularly sensitive.
- UK business is also affected by these shocks. For example, the 2012 US drought contributed to increasing the price of soya which, in turn, led to some UK pig farmers being forced out of business.
- Climate change will cause shifts in the global production of food. This could positively or negatively affect the price, availability and nutritional value of food in the UK. Research is needed to build a more complete understanding of these risks in order to inform policy.

Figure SR.A5: International dimensions of climate change risk



Source: CCRA2 Evidence Report, Chapter 7.

When combined with other factors, weather-related events can cause people to migrate, mostly within or to neighbouring countries but it can also lead to movement further afi ld. There is the potential to increase cooperation with EU states on migration and build mechanisms to facilitate assistance, settlement or return of displaced populations.

Climate change will also over time affect the economic attractiveness of specific regions within countries, and across continents, improving agricultural prospects and creating jobs in some areas whilst others suffer declines. Populations are likely to shift and migrate in response.

Geopolitical risks impact the UK by increasing demand for humanitarian assistance and aff cting UK economic interests abroad. Research is needed to understand whether current approaches to aid and development are building the long-term resilience and stability needed.

- An increasing frequency of extreme weather events would shift international aid away from long-term development aid (resilience building, disaster risk reduction, state stability) toward responsive interventions (peace-keeping, humanitarian aid).
- Research is needed to understand the impact of existing funding mechanisms, such as the Conflict, Stability and Security Fund.

Table SR.A5: Urgency of additional action to manage international dimensions of risk

Risk/opportunity	Urgency score	Rationale for scoring
It1: Risks from weather-related shocks to international food production and trade (Section 7.2)	More action needed	At present there is no co-ordinated national approach to ensure the resilience of the UK food system. Coordinated approaches require broad participation across policy, industry and research.
It2: Imported food safety risks (7.2)	Research priority	There is a gap in surveillance systems to monitor food safety at source and through complex international supply chains.
It3: Risks and opportunities from long-term, climate-related changes in global food production (7.2)	Research priority	The UK may increase its comparative advantage in specific areas of agricultural production in the future. Trends in global agricultural production and consumption need further monitoring and assessment.
It4: Risks to the UK from climate-related international human displacements (7.3)	More action needed	A more pro-active strategy to work in partnership with other countries is needed to provide rapid legal and basic assistance to migrants and to build long-term resilience in exposed regions. Otherwise overseas development efforts will increasingly be diverted to provide humanitarian (i.e. emergency) aid.
It5: Risks to the UK from international violent conflict (7.4)	Research priority	Further evidence is needed to understand the appropriate balance between long-term development aid (resilience building, disaster risk reduction, state stability) and responsive interventions (peace-keeping, humanitarian aid).
It6: Risks to international law and governance (7.4)	Research priority	There is a lack of systematic monitoring and strategic planning to address the potential for breakdown in foreign national and international governance, and inter-state rivalry, caused by shortages in resources that are sensitive to climate change.
It7: Opportunities from changes in international trade routes (7.4)	Watching brief	Potential changes in trade routes are already being assessed and the issue should continue to be monitored.

Source: CCRA2 Evidence Report, Chapter 7.
Notes: Urgency scores have been determined by the ASC on the basis of the evidence presented in the chapter. See Chapter 2 of the Evidence Report for a description of the urgency scoring methodology.

Box SR.A5: Advances in understanding since CCRA1

Chapter 7 – International dimensions

- CCRA1 did not explicitly address international dimensions of climate change risks but was complemented by a separate report, the Foresight Report of 2011 *International Dimensions of Climate Change*.
- New research and analysis in the last five years has highlighted the importance of systemic food system resilience. For example, CCRA2 goes further than the Foresight report in considering sustainable intensification of food production in the UK as a policy option. The chapter recognises that increasing UK domestic production will only have limited success in avoiding food system shocks, due to the interconnected nature of global food markets, and existing pressures on domestic natural capital such as water and soils.
- CCRA2 includes a broader discussion of conflict and migration risks.
- CCRA2 also includes a more comprehensive assessment of risks related to migration flows globally that were highlighted in a separate Foresight Report *Migration and Global Environmental Change: future challenges and opportunities* in 2011.
- CCRA2 assesses geopolitical risks exacerbated by climate change, including the demand for humanitarian assistance, global conflict risks, and the biosecurity dimensions of disease risks. These have previously been addressed by separate government reviews, such as the Ashdown Review on humanitarian assistance conducted for DFID in 2011.

Source: CCRA2 Evidence report, Chapter 7.

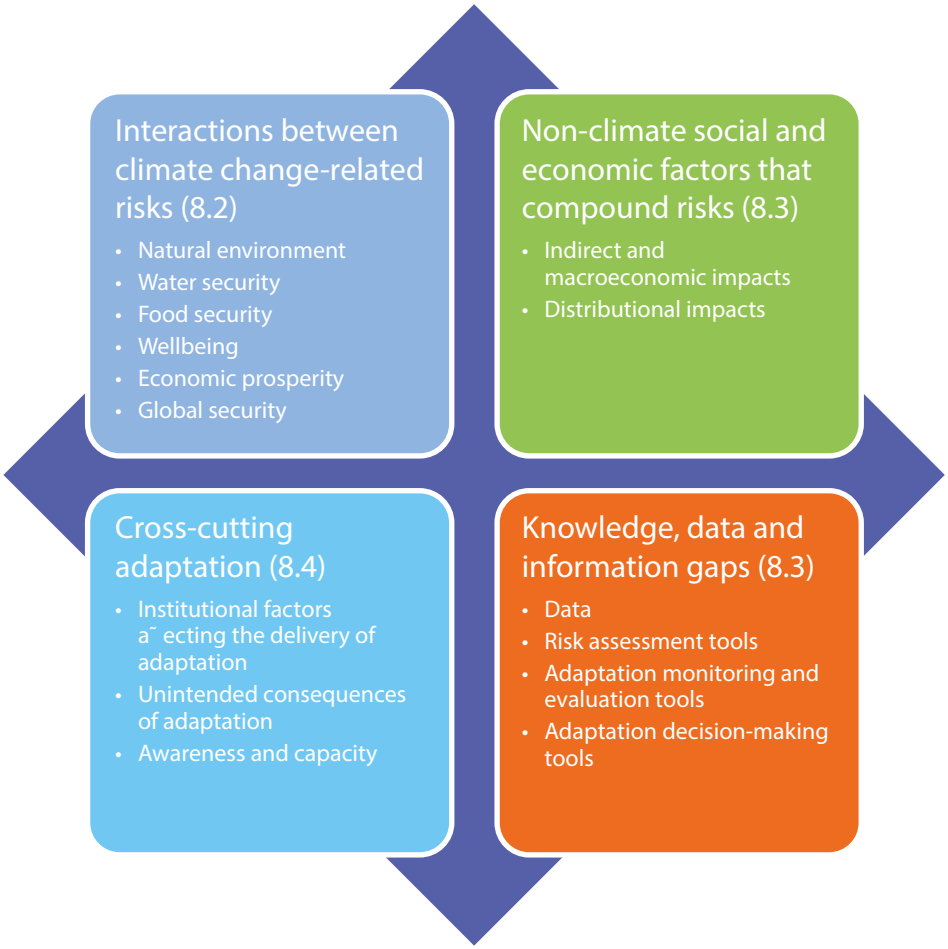
Chapter 8: Cross-cutting issues

Eff ctive adaptation cannot be undertaken without careful consideration of the cross-cutting nature of risks and synergies between adaptation activities. Unless cross-cutting issues are considered, actions could be ineffective, sub-optimal in terms of their costs and benefits, or worse lead to unintended consequences.

The main cross-cutting factors relating to **climate change risks** in the UK are:

- **Interactions among risks:** climate change risks act together to impact upon natural capital, water security, food security, wellbeing, economic prosperity and ultimately global security (Figure SR.A6).
- **Indirect and macroeconomic impacts:** the evidence suggests that indirect economic losses to the UK from climate risks are likely to be at least of the same order of magnitude as the identified direct losses. To date there has been little assessment of the potential macroeconomic impact of climate change for the UK.
- **Distributional impacts:** climate change will affect different people differently, depending on their social, economic and cultural background, and local environment. Low income households are particularly susceptible to climate change impacts, as impacts would disproportionately affect their disposable income. These groups also have lower capacity and resources to adapt.

Figure SR.A6: Cross-cutting issues affecting climate change risks



Source: CCRA2 Evidence Report, Chapter 8.

Cross-cutting issues relating to **adaptation planning and policy responses** are:

- **Institutional barriers:** current institutional frameworks for adaptation in the UK have the potential to deliver outcomes that achieve multiple benefits. However, obstacles to success include unclear or unmeasurable adaptation policy goals across correlated risks; a large number of partners involved in delivering adaptation activity; the limited alignment between related policy goals (e.g. flood risk management with housing and planning policies); and capacity gaps, including as a result of funding and resource constraints, particularly at the local level.
- **Unintended consequences:** taking interacting risks in to account, together with non-climate drivers of risk (e.g. changing demographics or technology), and addressing institutional barriers, can help policies succeed and avoid the risk of unintended consequences. Such a cross-cutting approach, as advocated in the HM Treasury Green Book, is not always followed in practice.
- **Adaptive capacity:** addressing climate change risks systematically requires considerable knowledge, skills and resources. Shortages in capacity can lead to a focus solely on 'incremental change at the margin', with more fundamental and ultimately beneficial ('transformational') change considered too difficult, expensive or risky in the absence of detailed appraisal and exploration. Opportunities to achieve co-benefits are lost as a result.

A number of **knowledge, information and data gaps** to assess and manage cross-cutting risks have also been identified:

- **Data:** data gaps include social vulnerabilities and their relationship with climate change impacts. The data that are available are often incomplete or incompatible with other data sources. Data collection in specific areas could be strategically planned at a multi-organisation level. Data access, including in some cases the desire to generate revenue from publicly-funded data, remains a significant obstacle to research and innovation in the UK.
- **Risk assessment models and other tools:** although there have been some advances in models, tools and other resources to support risk assessments, there are particular gaps that need further attention. These include the assessment of aggregate annual risks from multiple hazards and to multiple receptors; assessing the intangible impacts of climate change; macroeconomic models that can be applied at city or regional level; and tools to assess community resilience.
- **Decision-making tools:** although not widely accessible nor used, there are a growing number of decision-making tools to support adaptation related activity. However, many of these tools have been developed by the research community and may not meet the needs of practitioners.
- **Adaptation monitoring and evaluation tools:** many of the available indicators to measure adaptation progress are based on what data are available rather than what would be most useful. There appears to be little routine collection of data and other evidence to assess whether adaptation policies are effective in achieving their stated objectives.

Box SR.A6: Advances in understanding since CCRA1

Chapter 8 – Cross-cutting issues

- CCRA1 did not include a chapter looking specifically at cross-cutting issues. It did however include commentary on other dimensions of risk, including distributional impacts and cascading effects.
- CCRA1 undertook a systematic mapping exercise to try to assess the number and type of interactions between different risks and opportunities. CCRA2 instead considers what the most important risk groupings might be and why and how policy makers should consider such interactions.
- CCRA2 also includes a more detailed commentary on institutional and decision making frameworks for adaptation.

Source: CCRA2 Evidence report, Chapter 8.

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Committee on Climate Change
7 Holbein Place
London
SW1W 8NR

www.theccc.org.uk

@theCCCuk