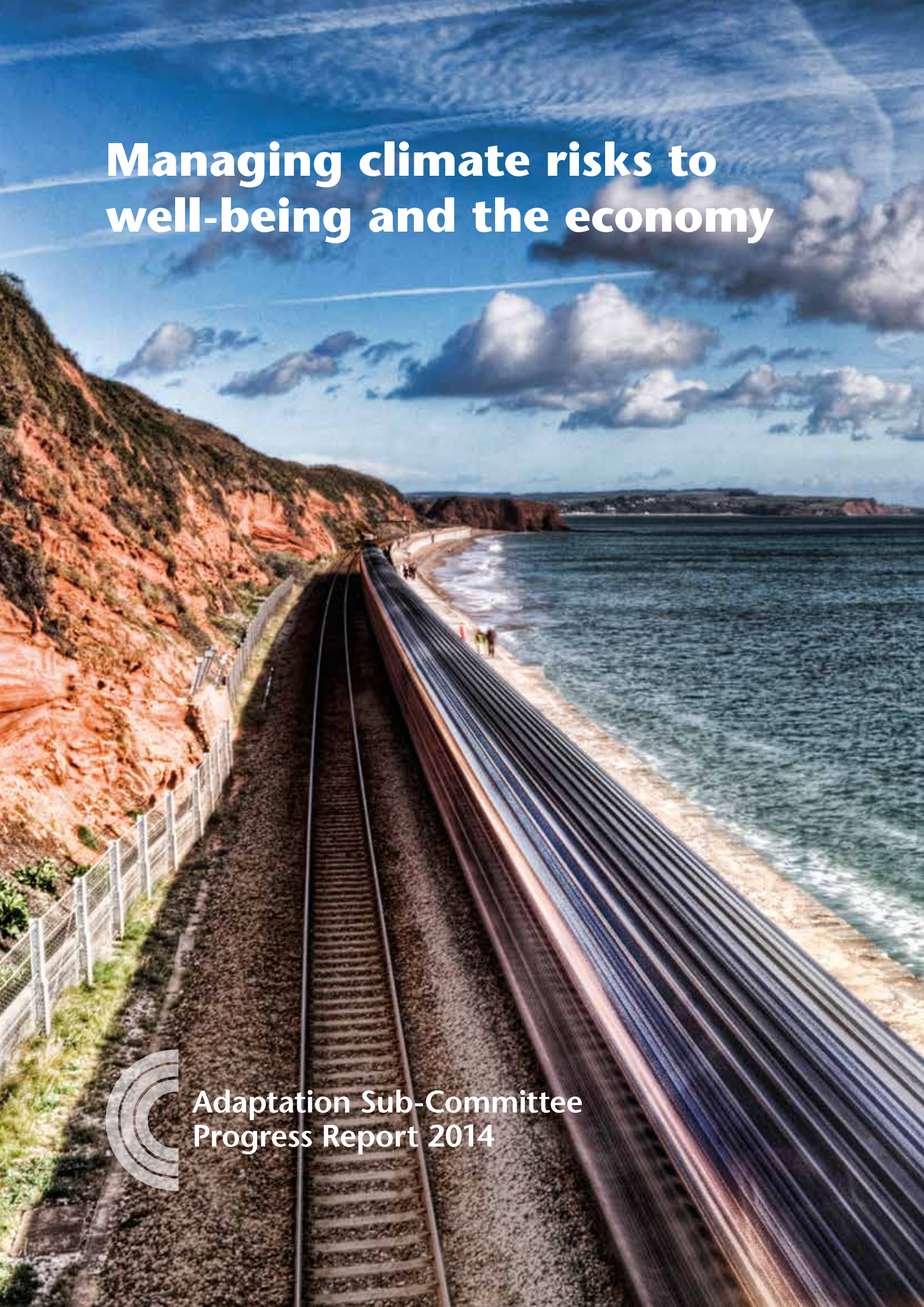
Managing climate risks to well-being and the economy



Adaptation Sub-Committee
Progress Report 2014

Committee on Climate Change
7 Holbein Place
London
SW1W 8NR

www.theccc.org.uk

@theCCCuk

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Foreword

Although there is a high degree of confidence that the world's climate is changing as a result of human activity, the precise impacts on the UK are still somewhat uncertain. Therefore the emphasis of adaptation to climate change has to be on increasing the nation's resilience to a range of possible futures. In addition to gradual changes in average temperature and patterns of rainfall, and rise in sea level, it is likely that there will be an increase in the frequency and severity of extreme weather events such as the floods and storms of last winter. The attribution of individual weather events is still an area in which the science is developing, but there is emerging evidence that man-made greenhouse gas emissions have already made heatwaves, and possibly flooding, more likely in the UK.

Events such as last winter's storms and floods illustrate the costs of a lack of resilience, with many thousands of people forced to leave their homes, businesses and transport disrupted, with the associated costs to the economy and to well-being. Building resilience for the future is an essential component of the nation's strategy for a healthy population and growing economy.

This year's report assesses the current state of resilience to weather and climate of our infrastructure, businesses, health care system and emergency services. We also update our work on flooding, which is the top risk from climate change identified within the 2012 UK Climate Change Risk Assessment.

As the latest IPCC assessment concludes, building resilience for the future through adaptation is not an alternative to mitigating climate change and reducing greenhouse gas emissions. Our report provides clear advice for Government on what is sensible and feasible to do now in terms of adaptation. The Committee on Climate Change will continue to advise Government in pursuing a pragmatic and cost-effective approach to mitigation.

This report, together with our previous two reports, also develops a set of indicators that will help the Government to track whether or not the actions it and others are taking will increase resilience to the future climate. Next year we will use these indicators to fulfill our statutory duty and report to Parliament for the first time on whether there has been sufficient progress in implementing the National Adaptation Programme.

Lord John Krebs Kt FRS

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The Adaptation Sub-Committee

Lord John Krebs, Chair

Professor Lord Krebs Kt FRS is currently 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 Samuel Fankhauser

Professor Samuel Fankhauser is Co-Director of the Grantham Research Institute on Climate Change and Deputy Director of the ESRC-funded Centre for Climate Change Economics and Policy, both at the London School of Economics, and a Director at Vivid Economics. He is a former Deputy Chief Economist of the European Bank for Reconstruction and Development.

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, Prof 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 and Chair of the Population and Lifelong Health Domain at University College London (UCL). She was a member of the UCL/Lancet Commission report on managing the health effects of climate change. She was previously Chair of the Medical Research Council Population Health Sciences Group. She is a Wellcome Trust governor.

Professor Martin Parry

Professor Martin Parry OBE is a visiting Professor at Imperial College and was Co-Chair of Working of Group II (Impacts, Adaptation and Vulnerability) of the Intergovernmental Panel on Climate Change's (IPCC) 2007 Assessment Report. He was chairman of the UK Climate Change Impacts Review Group, and a coordinating lead author in the IPCC first, second and third assessments. He has worked at the Universities of Oxford, University College London, Birmingham and University of East Anglia.

Sir Graham Wynne

Sir Graham Wynne is a former Chief Executive and Director of Conservation of the RSPB. He is currently a Special Adviser 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.

Executive summary

The global climate has already changed as a result of man-made greenhouse gas emissions. Here in the UK, land and sea temperatures have increased, sea levels have risen, and rain storms appear to be intensifying. Last winter's floods are consistent with the projected consequences of climate change, and the storms highlighted again the costs, damages and disruption that extreme weather can cause.

The Fifth Assessment by the IPCC sets out the latest science and the expected impacts of climate change. If global greenhouse gas emissions continue to increase at their current rate, average temperatures are expected to rise by more than two degrees above pre-industrial levels by around the middle of this century, and by four degrees by the end of this century. Increases of two degrees or more will bring major challenges for public well-being and the economy, and the risk of dangerous and irreversible impacts.

In the UK, the most significant early impacts of climate change are likely to be increases in the frequency and severity of extreme weather – heatwaves and flooding, and possibly storms and drought. Enhancing resilience to extreme weather will be an important aspect of future economic competitiveness. Adaptation of the built environment will be necessary to help safeguard the health and well-being of a growing and ageing population. Emergency response organisations will need to have effective plans and sufficient capacity to cope with the increasing likelihood of natural disasters. Businesses that fail to anticipate climate change risk their own failure.

This report explores what should be done in England to prepare for the consequences of climate change (Scotland, Wales and Northern Ireland have separate adaptation programmes). It completes a series of three ASC reports exploring the key threats and opportunities highlighted in the 2012 UK Climate Change Risk Assessment. Given the storms and flooding witnessed this winter, the report begins with an update on adapting to flood risk. The key messages of the report are:

- *Flood risk:* **Continuing development on the floodplain is increasing the reliance on flood defences. Under-investment in these defences is storing up costs and risks for the future. Hundreds of flood defence projects are currently on hold. Despite recent improvements in asset management, three-quarters of existing flood defences are not being sufficiently maintained.** New long-term investment scenarios to be published by the Government this autumn need to make clear the implications for future flood risk arising from current spending plans and ongoing development in flood risk areas. Key recommendations made by the 2008 Pitt Review, to strengthen accountability for local flood risk management and require sustainable drainage in new development, remain outstanding and need to be taken forward urgently.

- *Infrastructure resilience:* **Electricity transmission and distribution companies are implementing comprehensive strategies to safeguard the resilience of their networks to climate change. Network Rail is taking many of the necessary steps. However, there are shortcomings in the approaches being taken by water companies, and for strategic roads, ports and airports, and ICT services.** More systematic approaches are needed across regulated and non-regulated sectors to manage the risk of disruption to key services from a changing climate. Steps should include monitoring weather-related disruption, assessing future climate risks, investing in improving resilience, and regularly reporting on the progress being made.

- *Businesses:* **Some large companies are considering the risks from climate change to their facilities and to their supply chains. However, there is little evidence of action more generally, especially amongst smaller companies.** Further support and incentives are needed to make sure appropriate flood resilience measures are adopted by businesses. The Government should press ahead and reform the water abstraction regime to encourage water efficiency by industry and to protect the environment. Advice on risks to supply chains needs strengthening. UK companies selling adaptation goods and services have grown faster than the economy as a whole but are being outpaced by overseas competitors. The reasons for the UK falling behind in this growing market should be explored.

- *Well-being and public health:* **Heatwaves are likely to contribute to more deaths in the future, due to climate change combined with an ageing population. A Heatwave Plan has been introduced to reduce the public health impacts arising from periods of high temperatures. However there is a more fundamental need to adapt the existing building stock and design new buildings to be safe and comfortable in a hotter climate.** Many homes, hospitals and care homes are already at risk of overheating. By the 2040s, half of all summers are expected to be as hot, or hotter, than in 2003 when tens of thousands of people across Europe died prematurely. A standard or requirement is needed in order to ensure new homes are built to take account of the health risks of overheating now and in the future. Cost-effective passive cooling measures should be adopted rather than relying on air conditioning, which will be expensive and exacerbate the urban heat island effect.

- *Emergency planning:* **Because of a lack of information, we have been unable to assess the level of preparedness for weather-related emergencies amongst local responders.** The capacity in the emergency response system to manage severe weather events needs to be evaluated, particularly in the context of climate change. This evaluation should include the required national capability for flood rescue, how budget reductions across a number of agencies might have affected the collective ability to respond, and the coverage of climate hazards in community risk registers. Failure to address these issues in a coordinated way between national and local responders risks inefficiency, confusion, and resource shortages in the event of a crisis.

- *Next steps:* **The Adaptation Sub-Committee will continue to collect evidence and monitor the progress being made to prepare the country for climate change.** Our first statutory report on the National Adaptation Programme will be presented to Parliament in July 2015.

Adapting to flood risk

Past investment in flood defences, and recent improvements in forecasting, early warning and flood emergency planning, helped to limit the impacts of the December 2013 tidal surge. However, current under-investment in flood prevention, together with a reliance on defences to protect new development, will increase the potential for avoidable flood damage. Major new development in flood risk areas appears to proceeding, or is being refused, in line with Environment Agency advice. However, specific advice is not provided on thousands of minor planning applications in the floodplain each year. The cumulative impact of new development on future flood risk is unknown.

- Limited national and local funding means hundreds of flood defence schemes are on hold, and three-quarters of existing flood defences are not being maintained as they should each year. The new long-term investment scenarios being published in autumn 2014 by the Government should make clear the implications for future flood losses arising from current spending plans, and continuing development in flood risk areas, in the context of climate change. Evidence should be published on the cumulative impact of Environment Agency staff reductions on important flood risk management functions.
- The Government should evaluate whether local flood risk management arrangements are now in place across the country in line with the recommendations made by the Pitt Review. Some of the funding provided by Defra to Lead Local Flood Authorities for their new roles and duties under the 2010 Flood and Water Management Act is being diverted to other council services. Statutory local flood risk management strategies have yet to be published in many areas. Local scrutiny of plans and actions appears to be lacking.
- The Government and the insurance industry should take action to ensure the 'Flood Re' subsidised flood insurance scheme incentivises and supports additional flood mitigation by high risk households. This will help improve the scheme's poor value for money. Tackling flood risk will be the most cost-effective and sustainable approach to keeping flood insurance affordable in the long-term.
- There is increasing potential for surface water flooding in urban areas. We have found low uptake of sustainable drainage systems in new development. Rules to limit the loss of front gardens to impermeable surfacing introduced after the Pitt Review are not being enforced by local councils. The Government should introduce without further delay the Flood and Water Management Act provisions to require sustainable drainage in new development, also recommended by the Pitt Review.

Resilience of national infrastructure

The energy transmission and distribution sector, and to some extent Network Rail, are monitoring weather-related disruption, assessing future climate risks, investing in resilience, and reporting on progress. Similar approaches should be taken for the strategic road network, in the water sector, for ports and airports, and amongst ICT providers, where evidence of progress is less apparent.

- Infrastructure networks are a priority for adaptation action as assets are long-lived, sensitive to extreme weather, and failures in one network can cascade onto others. Loss of vital services can be detrimental to the economy, as well as to peoples' health and well-being. Acting now to improve the resilience of infrastructure makes economic sense, especially in the context of climate change.
- Natural hazards such as storms, flooding and drought already account for 10-35% of all delays or interruptions of service to electricity, road and rail customers.
- Climate change will lead to an increase in the number of infrastructure assets exposed to high temperatures, flooding, coastal erosion and subsidence in the coming decades. Infrastructure assets could also become more exposed to high winds and storms, but there remain large uncertainties in projecting these changes.
- Major new infrastructure projects, such as HS2 and nuclear power stations, are accounting for relevant climate hazards including increases in flood risk. However, planning policy statements are sector-based and there is limited strategic assessment at the national and sub-national levels to guide where new infrastructure should be located. The resulting potential for a systemic build-up of risk should be considered by the Government, for example in areas exposed to coastal flooding, and water scarcity.

Business opportunities and risks

Climate change is expected to increase the risk of interruption and financial loss to businesses but may also present opportunities for those able to take advantage of changing market conditions. Some larger companies are assessing climate risks, including those to their supply chains, and are responding accordingly. However, there is little evidence of action by small and medium-sized enterprises.

- The number of employees working in areas with a high likelihood of flooding could almost double by the 2050s as a result of climate change, from 275,000 now to around 500,000. After evaluating the 'repair and renew' grant scheme launched to help businesses recover after the 2013/14 winter floods, the Government should consider how best to encourage businesses to enhance their resilience to flooding.
- In England, nearly half (46%) of the water abstracted by the paper manufacturing industry and over one-third (36%) by the chemicals sector is from water-stressed catchments. The Government should press ahead with reform of the water abstraction regime. This should help manage demand and share the available water between businesses and other users more efficiently, while protecting the environment.

- Adverse weather is one of the most frequent causes of supply chain disruption. Risks to business supply chains appear to be greater further upstream, where goods are sourced from vulnerable countries, yet businesses often only consider risks to their immediate suppliers. The Environment Agency should evaluate the Business Resilience Health Check tool and consider extending their more detailed advice on supply chains to a wider range of sectors such as manufacturing and textiles.
- The UK appears to have comparative advantage in some adaptation products and services but recent sales growth by UK companies has been slower than that in other major producing countries. The Government should explore the reasons for this and consider if more could be done to promote exports.

Well-being and public health

Further action is needed to adapt the existing building stock and design new buildings to counter the impacts of high temperatures on health and well-being. The Government should consider how to raise awareness, and promote the use, of cost-effective passive cooling measures in existing homes. A requirement or standard is needed to ensure that new buildings can be kept cool without having to rely on air conditioning.

- Exposure to extreme heat is already a health issue. Currently, one-fifth of homes in England could experience overheating even in a cool summer. Flats, which are generally more at risk of overheating than houses, now make up 40% of new dwellings compared to 15% in 1996. Urban greenspace, which helps to mitigate the urban heat island effect, has declined by 7% since 2001. In the UK, excess deaths from high temperatures are projected to triple to 7,000 per year on average by the 2050s as a result of climate change and a growing and ageing population.
- There is low public awareness of the changing risk from heat, and the level of action to adapt homes appears to be low. New homes are adding to the potential problem, as Building Regulations do not account for the health risks from overheating now or in the future.
- Cold winters will remain the largest weather-related risk to health in England, and at least £800 million is being spent per year to improve insulation in homes. Adapting homes to handle both high and low temperatures – increased insulation alongside passive cooling measures and ventilation – is necessary and readily achievable if considered together.
- Unpublished data indicate that around 90% of hospital wards are of a type that is prone to overheating, and the ability to control temperatures is often limited. Awareness of the Government's Heatwave Plan amongst healthcare professionals and uptake of the actions advised within it should be independently reviewed. Health and Wellbeing Boards should consider how to ensure delivery of the plan in care homes. The Care Quality Commission should consider setting standards for maximum temperatures in hospitals and make sure staff can control internal temperatures.

- More information is needed to be able to assess preparedness for other health impacts including those related ground level ozone, UV radiation and pathogens, and the resilience of health sector buildings such as hospitals and care homes to flooding and subsidence.

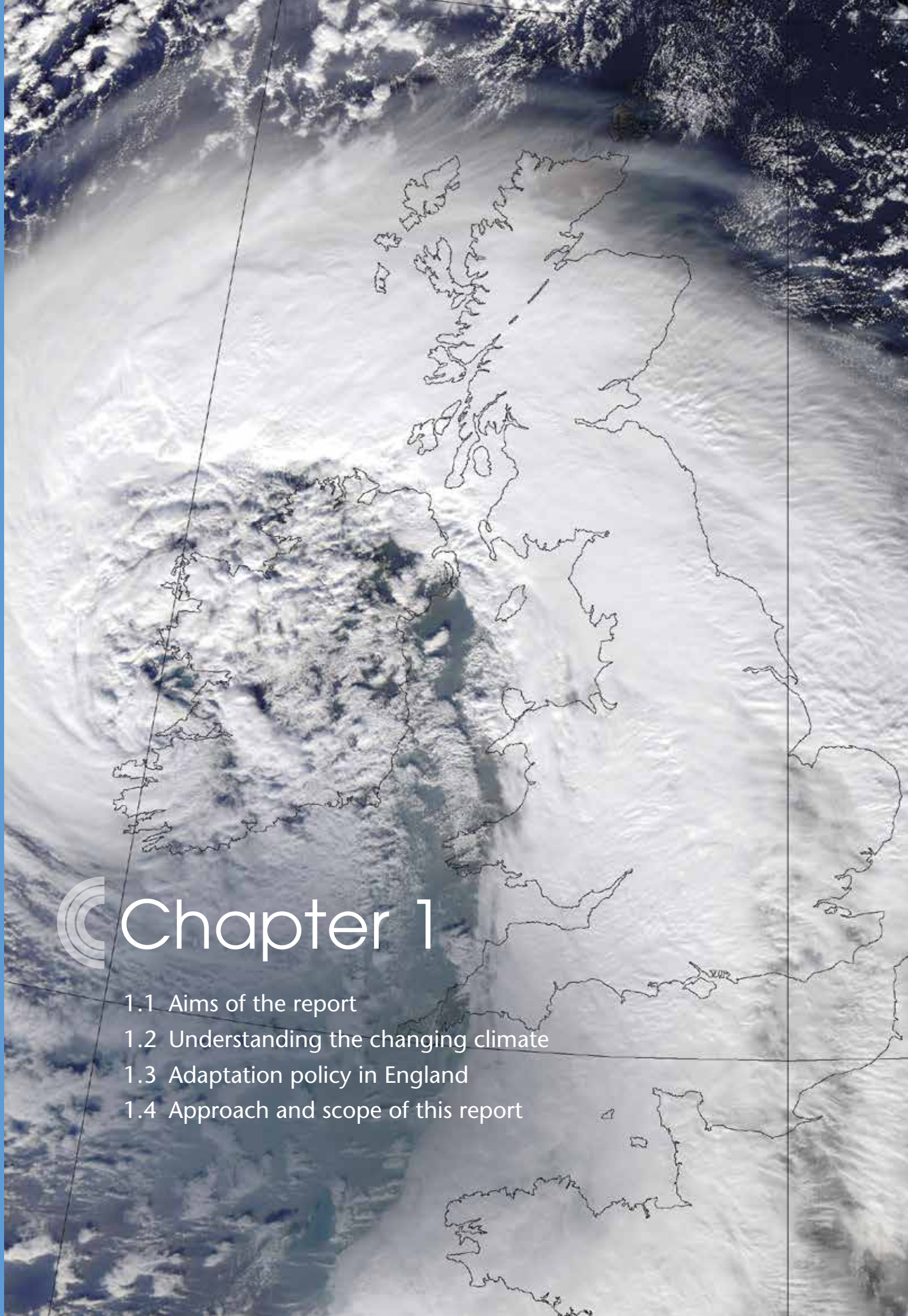
Emergency planning

The need for an effective emergency response capability will increase with climate change. The demands placed upon the emergency services will be exacerbated by continuing building in flood risk areas, a growing and ageing population, and a building stock not designed for extreme heat. There is a lack of information on the level of national capability in some areas. The 2004 Civil Contingencies Act provides a robust framework for emergency planning in the UK, and risks from severe weather feature in the National Risk Register. However, the Government should consider four areas where further action may be needed to ensure that the system is set up to cope with increasingly severe weather events.

- In order to fully assess preparedness, more comprehensive information is needed on the action being taken by emergency responders to plan for and in response to extreme weather. A single body, with cross-departmental representation, could be given responsibility for collecting and analysing data and advising the Government.
- In some cases, neither the current level of emergency capability nor the capacity required under potential future scenarios is known. For example, the current national capability for flood rescue is not clear, nor what may be required in future. Only some rescue assets are declared by emergency responders and the total need in the event of a large scale flood is unknown. The Government should review current capabilities, and future requirements, where this knowledge is lacking.
- There are fewer staff in the Fire and Rescue Service, the Environment Agency and the Police than in previous years. Further reductions in local authority budgets are planned. The cumulative impact of these staff and budget reductions needs to be assessed in light of the resources that may be required in a range of emergency scenarios.
- Community risk registers may not be giving sufficient weight to all climate risks outlined in the National Risk Assessment, such as drought. Community risk registers should be subject to independent scrutiny to assess whether they have appropriate coverage and are fit for purpose.

Next steps

In July 2015 the Adaptation Sub-Committee will present its first statutory report to Parliament on the progress being made to prepare for climate change. Our report will combine the evidence within this and our two previous reports to assess the National Adaptation Programme published by the Government last year. A call for evidence on the set of indicators we intend to use to measure progress is being launched. We will also deliver an independent evidence report in July 2016 to inform the Government's next UK Climate Change Risk Assessment due in January 2017.



Chapter 1

1.1 Aims of the report
1.2 Understanding the changing climate
1.3 Adaptation policy in England
1.4 Approach and scope of this report

Chapter 1:
Introduction and context

Key messages

This report is part of a series by the Adaptation Sub-Committee assessing preparations for the major risks and opportunities from climate change in England. The report follows on from those in previous years on the built and natural environments, to focus on the implications of climate change for the economy and public well-being. It also provides an update on flooding and flood risk management. It is the last annual report before the ASC's first statutory report to Parliament in July 2015 on the progress being made in preparing the country for climate change.

The IPCC Fifth Assessment confirms that the climate is changing, with human activity extremely likely to be the dominant cause. In a scenario where emissions continue to rise at their current rate, global average surface temperatures are expected to breach the two degrees threshold by around the middle of this century. Global average surface temperature has increased by around 0.8°C since the 1850 – 1900 baseline used by the IPCC, with UK average temperatures rising broadly in line with the global trend. The UK Government, together with others around the world, considers rises beyond two degrees to bring increasing risk of dangerous and irreversible impacts. By the end of the century, a 3.2°C to 5.4°C global rise above the baseline can be expected based on continuing emissions growth, with further warming into the next century.

The UK will be subject to climate change impacts. There is evidence that historical emissions and warming have already altered the patterns of UK weather, changing the range of temperature extremes we can expect. There is also some evidence of a shift in rainfall patterns. Some studies suggest that extreme weather events that the UK has experienced in recent years are at least partly attributable to human activity and climate change. The UK should prepare for more intense heatwaves, and longer and more intense wet and dry spells. Variability in the weather year to year will mean cold winters remain possible through the century but with decreasing frequency. There remains uncertainty in how factors such as the jet stream, important in influencing UK weather, might be affected by global warming.

A combination of reducing global emissions, whilst adapting to the impacts of inevitable warming, is the only effective response to climate change. It remains technically and economically feasible to reduce global greenhouse gas emissions to a level that is consistent with limiting warming to around two degrees, but this will be extremely challenging. Whilst reversing the historical trend in emissions growth will do little to prevent further climate change in the next few decades, it will help avoid the increasingly severe impacts that can otherwise be expected in the second half of this century and beyond. In addition to avoiding damages in the future, adaptation now will bring immediate benefits in building our resilience to current weather extremes. Early adaptation avoids unnecessary damage and will be cheaper and involve less risk than having to take more drastic action at a later date.

The Government published its first National Adaptation Programme in July 2013 to address the findings of the 2012 UK Climate Change Risk Assessment. The ASC is tracking the progress being made by the National Adaptation Programme and will present a first statutory report to Parliament in July 2015. Adaptation programmes have also been published by the Welsh and Scottish Governments, and the Northern Ireland Executive.

The process of compiling a second UK Climate Change Risk Assessment has begun. The ASC is taking a lead role and will compile an independent evidence report to be published in 2016. This will inform an updated risk assessment due to be laid by the Government before Parliament in January 2017.

1.1 Aims of the report

This report is one of a series of progress reports by the Adaptation Sub-Committee to assess how England is preparing for the risks and opportunities of climate change. Together, these reports will provide the evidence base for the ASC's first statutory report to Parliament in July 2015 on the progress being made by the UK Government and others in implementing the National Adaptation Programme (NAP).

Our previous reports have focused on a range of risks identified for England in the first UK Climate Change Risk Assessment (CCRA). This year's report extends our previous work to consider in detail the primary risks to the economy and well-being. In 2012 we considered flood risk to people and property, and the potential for water scarcity. Last summer's progress report explored the ability of the land to continue to produce food and timber, as well as provide essential services such as carbon storage and coastal protection in a changing climate. It also considered the resilience of semi-natural habitats.

1.2 Understanding the changing climate

Updates in the science since our last progress report

"Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased."

This is the conclusion of Working Group I's contribution to the Fifth Assessment by the United Nations Intergovernmental Panel on Climate Change (IPCC).[1] The IPCC brings together scientific and economic experts from around the world to seek a comprehensive and balanced view of climate science. Working Group I considered the physical science of climatic change, involving 259 experts from 39 countries.

Concentrations of carbon dioxide in the atmosphere have increased by around 40% since the pre-industrial era, primarily from fossil fuel emissions and secondarily from land use change. In May 2013 the concentration of carbon dioxide in the atmosphere exceeded 400 parts per million (ppm).[2] This is 100 ppm higher than at any time prior to the 20th century in at least the last 800,000 years.[3] Concentrations of other greenhouse gases such as methane and nitrogen dioxide, emitted from industrial processes and intensive agriculture, have similarly increased.

Half of the 2.2 trillion tonnes of carbon dioxide released to the atmosphere from human activity since the industrial revolution has taken place in the last four decades.[4,5] Global carbon dioxide emissions now stand at more than thirty-six billion metric tonnes per year, or the equivalent of fifty billion tonnes of carbon dioxide if other greenhouse gases are included.[6,7]

It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century. Human influence has been detected in warming of the atmosphere and the ocean, in changes in the global water cycle,

1 IPCC (2013a), pg 4.
2 Scripps Institution of Oceanography (2013). Note carbon dioxide levels fluctuate with the seasons through the year. The average atmospheric CO_2 concentration measured at Mauna Loa, Hawaii in 2013 was 396.48 ppm.
3 IPCC (2013), pg 11.
4 Carbon Dioxide Information Analysis Center (2013). Total cumulative emissions since the beginning of the Industrial Revolution, 1750 to 2012, are estimated to be 385±20 gigatonnes of carbon (GtC) from fossil fuels and cement, and 205±70 GtC from land use change. 1 tonne of carbon is equal to 3.667 tonnes of carbon dioxide.
5 Carbon Dioxide Information Analysis Center (2010).
6 Carbon Dioxide Information Analysis Center (2013).
7 CCC (2013a).

in reductions in snow and ice, in global mean sea level rise, and in changes in some climate extremes.[8]

The basic physical relationship between greenhouse gases in the atmosphere and global warming via the greenhouse effect is well demonstrated. The evidence for human influence being the dominant cause of the observed warming to date has grown since the IPCC's last report in 2007. There is now a larger number of studies to draw upon, using a wider range of methods. There is also a more complete assessment of all the relevant uncertainties. Studies demonstrate a much stronger human influence on the climate in recent decades than that from solar activity or other natural factors.

Without substantial mitigation efforts, an average global surface temperature increase exceeding two degrees celcius can be expected around the middle of this century, and exceeding four degrees by the end of the century. Past emissions mean some further increase in global temperature is inevitable.

Under a scenario of continually growing emissions (scenario RCP8.5) central estimates of global average surface temperatures are:

- 2.6°C above the 1850 – 1900 baseline by 2046-2065 (likely range 2.0°C – 3.2°C).
- 4.3°C above the 1850 – 1900 baseline by 2081-2100 (likely range 3.2°C – 5.4°C).
- With further warming beyond the end of the century.[9]

There is a time-lag in the response of the climate system to increasing atmospheric concentrations of carbon dioxide and other greenhouse gases. As a result, even if future emissions fall rapidly, the world is committed to additional warming until at least 2040. Future global temperatures will be related to cumulative carbon dioxide emissions to date. Other changes such as rising sea levels are also inevitable, with sea levels continuing to rise for many decades beyond the point of any peak in global emissions.

Nearly all nations including the UK accept that beyond a two degree rise in global average temperature brings increasing risk of harmful adverse effects. The goal of avoiding this, adopted by the United Nations, remains achievable if countries act now to reduce future emissions.

To avoid a warming of more than two degrees, greenhouse gas emissions need to peak by the early 2020s and then fall rapidly. Delaying mitigation increases the risk of surface temperatures rising beyond two degrees. The UK has committed to fulfil its contribution, with plans to halve greenhouse gas emissions by 2025 from 1990 levels and achieve at least an 80% reduction by 2050. This target is set in statute in the 2008 Climate Change Act.

Global greenhouse gas emissions need to halve by 2050 if there is to be a reasonable chance of avoiding a two degree rise. Even if this is achieved there would remain a 50% chance of a two degree rise or greater, and a small chance of a three to four degree rise.[10] Adaptation will therefore be needed, to limit the worst impacts of a two degree rise, and

8 IPCC (2013a), pg17.
9 Figures from Table SPM.2, IPCC (2013a). The observed warming of 0.6°C between the baseline period (1850-1900) and the reference period for the Representative Concentration Pathways (RCP) scenarios (1986-2005) is included.
10 CCC (2013a).

potentially of four degrees or more if other countries do not follow the example being set by the UK, and the European Union, among others.

Impacts globally and for the United Kingdom

"In recent decades, changes in climate have caused impacts on natural and human systems on all continents and across the oceans. Increasing magnitudes of warming increase the likelihood of severe, pervasive, and irreversible impacts."[11]

A comprehensive assessment of the most up-to-date evidence on global climate impacts was published by the IPCC in March 2014. Working Group II's contribution towards the IPCC Fifth Assessment extended and built upon the broad picture of risks already known. Since the Fourth Assessment Report in 2007, there is an improved understanding of how the possible impacts from climate change may compound other factors such as population growth.

Box 1.1 presents high level conclusions from the Working Group II report.

Box 1.1: Risks from warming – key impacts globally and more locally

Working Group II identified the following risks for the 21st century, especially later in the century:

- Risks of death, illness or loss of livelihood in low-lying coastal zones and small island developing states due to storm surges, coastal flooding and sea level rise. Without adaptation, hundreds of millions of people will be affected by coastal flooding and will be displaced due to land loss by 2100; the majority of those affected will be from East, Southeast and South Asia (WGII chapter 5).
- Risk to health and livelihoods in urban populations from inland flooding. Changes in extreme rainfall of between 10 – 60% could lead to changes in flood frequency of 0 – 400% in urban areas depending on system characteristics (WGII chapter 8).
- Breakdown of infrastructure networks and critical services such as electricity, water supply and health and emergency services due to extreme weather (WGII chapter 10).
- Risk of mortality and morbidity during periods of extreme heat, particularly for vulnerable urban populations and those working outdoors in urban or rural areas. In Australia, the number of "dangerously hot" days, when core body temperatures may increase by ≥ 2°C and outdoor activity is hazardous, is projected to rise from the current 4-6 days per year to 33-45 days per year by 2070 (WGII chapter 11).
- Risk of food insecurity and the breakdown of food systems linked to warming, drought, flooding, and precipitation variability and extremes. Negative impacts on global crop yields are projected to become likely from the 2030s (WGII chapter 7).
- Risk of loss of rural livelihoods and income due to insufficient access to drinking and irrigation water and reduced agricultural productivity, particularly for farmers and pastoralists with minimal capital in semi-arid regions. Across Africa, 90 million people live in rural areas where annual rainfall is between 200 and 500mm per year, and where decreases in annual rainfall, changes in intensity or seasonal variations may cause problems for groundwater supply (WGII chapter 9).
- Risk of loss of marine and coastal ecosystems, biodiversity, and the services these ecosystems provide for coastal livelihoods, especially for fishing communities in the tropics and the Arctic. For a warming of 2°C above pre-industrial average temperatures, fish yields in some high-latitude regions could increase by 30 – 70%, whereas in the tropics and Antarctica they may decline by 40 – 60% (WGII chapter 6).
- Risk of loss of terrestrial and inland water ecosystems, biodiversity, and the services these ecosystems provide. There is a high level of risk that for a global temperature increase of 2°C by 2080 – 2100 and without adaptation to reduce deforestation, moist Amazon forests could reach a tipping point and change abruptly to less carbon-dense drought and fire-adapted ecosystems (WGII chapter 4).

11 IPCC (2014a) pg 4, 14.

Box 1.1: Risks from warming – key impacts globally and more locally

The report included some information on potential changes for Europe, including a summary of potential changes for the UK corresponding to global warming of around 2°C and 4°C by the end of the century (WGII chapter 23):

Table B1.1: Projected changes for the UK at 2C/4C global warming in 2071-2100

Climate risk	Projected changes with 2°C of warming globally by 2070 – 2100 (RCP 4.5)[12]	Projected changes with 4°C of warming globally by 2070 – 2100 (RCP 8.5)[12]
Sea level rise	Global mean sea level rises of between 0.36 – 0.63 m.	Global mean sea level rises of between 0.48 – 0.82 m.
Annual precipitation	No change in annual average precipitation, though changes in seasonal precipitation are projected.	Up to a 15% increase in annual precipitation.
Heavy winter precipitation	Up to a 15% increase in heavy winter precipitation.[13]	Up to a 25% increase in heavy precipitation.[13]
Heavy summer precipitation	Up to a 15% increase in heavy summer precipitation everywhere except north-east England.[13]	Up to a 15% increase in heavy summer precipitation everywhere.[13]
Dry spells	No change in the number of dry spells.[13]	An increase of 2 – 4 days in the length of dry spells.[13]
Heat stress	Increase by up to 20 in the number of heatwaves for the period 2070 – 2091 compared to 1971 – 2000 for southern England.	Increase by up to 45 in the number of heatwaves for the period 2070 – 2091 compared to 1971 – 2000 for the south coast.[14]

Source: Working Group II's contribution to the IPCC Fifth Assessment Report. Projections for changes for the UK at 2 and 4°C are summarised in chapter 23 and are taken from Jacob et al. (2013).

12 RCP: Representative Concentration Pathways used in the IPCC's Fifth Assessment Report.
13 Defined as an event in the 95th percentile of the distribution observed in 1971-2000.
14 Heatwave is defined as a period of more than 3 consecutive days with daily maximum temperature exceeding the 99th percentile of the daily maximum temperature of the May – September season for 1971-2000.

The UK will experience the impacts of climate change. The warming already observed has altered some aspects of UK weather, changing the range of extremes expected particularly in terms of temperature but also rainfall.

Climate change attribution studies attempt to detect whether the chance of extreme weather has changed as a result of greenhouse gas emissions from human activity. Changes in extreme temperatures are easier to detect than changing rainfall patterns, flooding, storms and drought. Such studies are becoming more sophisticated, with results to date suggesting, for example, that:

- Climate change has at least doubled the risk of high summer temperatures matching or exceeding those experienced in the European heat wave of 2003.[15] That year saw the hottest temperatures across parts of Europe for at least 500 years. UK records were broken, with temperatures reaching 38.5°C in Kent. By the 2040s half of all summers in Europe are expected to be as hot, or hotter, than 2003. By 2100, under a business as usual emissions scenario, a summer like 2003 could be at the cold end of the spectrum for the period.
- The likelihood of warmer winter temperatures has increased. In November 2011 the average monthly temperature in central England was 9.6°C. Such warm weather in November is now estimated to be about 60 times more likely than in the 1960s (now a 1-in-20 year event, estimated previously as a 1-in-1,250 year event). The number of days of air frost in each year has fallen across the country, by up to 50 days in parts of Wales, Scotland and North West England. Severe cold seasons are currently expected to become less frequent but will continue to occur due to natural variations in the climate from year to year.
- It is very likely (90% confidence) that greenhouse gas emissions over the 20th century substantially increased the risk of flooding in England and Wales in autumn 2000.[16,17]
- The chance of extremely wet winters in southern England has increased by 25%. Preliminary results from simulating the UK winter storms of 2013/14 suggest what may have previously been a 1-in-100 year winter rainfall event may now have become a 1-in-80 year rainfall event.[18]

UK weather is largely dictated by dynamic atmospheric patterns such as the jet stream. Changes in the global climate system may affect their behaviour in ways not yet fully understood.

The polar jet stream is a river of fast flowing air in the upper atmosphere that encircles the northern hemisphere. It is created by a temperature differential between the arctic and the warmer air to the south in the temperate regions and tropics. Its position and strength varies from week to week. The jet stream has a large bearing on the weather experienced in the UK.

15 Met Office (2014b).
16 Pall et al (2011).
17 The precise magnitude of the anthropogenic contribution remains uncertain, but in nine out of ten simulations 20th century anthropogenic greenhouse gas emissions increased the risk of floods occurring in England and Wales in autumn 2000 by more than 20%, and in two out of three cases by more than 90%.
18 Environmental Change Institute, University of Oxford (2014). Results are in comparison with a simulated atmosphere without 20th century greenhouse gas emissions from human activity.

There is the potential for the jet stream's position, speed and amplitude (waviness) to all be affected by global warming.[19] Weather systems ordinarily move across the UK, leading to changeable weather. However some studies have linked the accelerated warming of the arctic region to an overall slowing of the jet stream's west to east motion. Together with higher amplitude waves in the jet stream, weather systems can become caught in its folds and be held in one area for a period of time. These 'blocking' patterns create persistent weather, leading to heatwaves or flooding depending on the type of weather system being held.

The jet stream has also been linked with periods of extreme cold weather as experienced in the UK in March 2013, and the United States 'polar vortex' event during the winter of 2013/14. High amplitude waves in the jet stream can pull cold air from the polar region further south than normal. How the behaviour of the jet stream is likely to change with global warming is not well understood. It is an area of active research.

The role of adaptation in the response to climate change

A climate strategy relying on adaptation alone brings clear, major risks. Reducing global greenhouse gas emissions is essential given limits in adaptive capacity. There are limits in the level of climate change to which human and natural systems will be able to adapt. At significantly higher global temperatures (beyond two degrees) the costs of adaptation are likely to rise sharply, residual damages are likely to remain large and there is greater potential for irreversible damage. Adaptation is not a substitute for mitigation, and both need to be integral to the UK's climate strategy.

Alongside mitigation, adaptation will be needed to prepare for the further inevitable changes in climate that are expected. Preparing for climate change today will reduce the costs and damages of a changing climate in the future. It will also allow UK businesses, communities and individuals to take advantage of any potential opportunities.

Well-designed adaptation helps build resilience to current weather extremes as well as to conditions that might arise in future. Adaptation can contribute towards the delivery of other important objectives: economic stability, improving well-being and public health, protecting and enhancing the natural environment.

The ASC previously identified two broad criteria to identify the priority areas where adaptation measures are required now to help prepare the UK for climate change.[20] In a well-adapting society, risks are identified and managed in sectors that are already highly sensitive to weather and climate change. Meanwhile, flexible and robust options are implemented in areas that can expect to be impacted in future.

- **Climate-sensitive decisions:** decision-makers should identify and manage risks in areas with a high sensitivity to the weather and climate in the short-term. Adaptation in these areas will provide immediate benefits, increase the resilience to current and future climate and reduce the risk of potentially long-lasting damage.

19 ClimateNexus (2013).
20 ASC (2010).

- **Decisions with long-lasting consequences:** decision-makers should not close off options that will make it harder to adapt in the future. This includes in situations where there are long-lived assets, potentially irreversible impacts, and scope for systemic consequences.

1.3 Adaptation policy in England

With the launch of the UK Government's National Adaptation Programme in July 2013 the statutory adaptation policy framework for England is now in place.

The 2008 Climate Change Act mandated a government-led approach to ensure progress in adaptation in England as well as committing the UK to reduce its greenhouse gas emissions. In terms of adaptation, the legislation provided for four main components:

- **A UK Climate Change Risk Assessment (CCRA)** to be prepared by the UK Government and updated every five years. The first CCRA was presented to the UK Parliament in January 2012.[21] The Department for Environment, Food and Rural Affairs (Defra) has asked the ASC to take the lead in preparing an evidence report in advance of a second CCRA due to be presented to Parliament in January 2017. Our evidence report will be published six months earlier, in July 2016. To begin the process, the ASC conducted a call for evidence between February and April 2014 and has appointed independent lead contributors for each of the evidence report's main chapters.
- **A National Adaptation Programme (NAP)** to be prepared by the UK Government, to set objectives and describe the actions that will be taken to prepare the country for climate change. The first NAP was published in July 2013.[22] The National Adaptation Programme primarily covers England only other than in areas where policy responsibility is reserved rather than devolved. Adaptation programmes have now also been published in Wales,[23] Northern Ireland,[24] and Scotland.[25]
- **An Adaptation Reporting Power,** giving Defra's Secretary of State the power to require organisations that provide critical public services ('reporting authorities') to report on their climate risks and associated adaptation actions. This power was exercised for a first round of reports that were published in 2012. For the second round taking place in 2015, the Secretary of State has made reporting voluntary.
- **The Adaptation Sub-Committee to the Committee on Climate Change**, with statutory roles in advising the UK and devolved governments on climate risks and reporting to the UK Parliament on the progress being made by the National Adaptation Programme.

The approach we will take to assessing progress against the National Adaptation Programme and providing advice on the Climate Change Risk Assessment is described further in Chapter 7.

21 Defra (2012a).
22 HM Government (2013).
23 Welsh Government (2011).
24 DOENI (2014).
25 Scottish Government (2014).

Since the ASC's last progress report in July 2013 the UK Government has issued a number of consultations and taken decisions that will have implications for the cost and speed of adaptation in this country:

- **In September 2013 the UK Government provided further details of their plan to subsidise flood insurance for high-risk households on a time-limited and transitional basis.**[26] The 2014 Water Act subsequently legislated to allow a subsidised flood reinsurance pool to be created for high risk households. 'Flood Re' will be funded by a new £180 million levy on household insurance policies. The costs, opportunities and potential risks of this policy are discussed further in Chapter 2. In November 2013 the ASC wrote to the Environment Secretary to suggest five ways to improve Flood Re's design from an adaptation perspective. This led to a number of changes to the scheme, described in Annex 2.1.
- **In December 2013 the Government announced proposals for implementing the next round of the Common Agricultural Policy (CAP).**[27] One of the key proposals from an adaptation perspective was the proportion of the £15 billion of EU subsidy available to England's farmers that will be allocated to environmental improvements. In the previous CAP round (2007-2013), including additional Government funding, £3.2 billion was used to pay farmers to improve the condition of degraded habitats including peatlands, which are particularly sensitive to changes in climate. The ASC published a policy note to state the case for allocating the maximum amount allowed under EU rules to environmental schemes. Doing so would help avoid falling behind the Government's stated targets for habitat restoration.[28] Following consultation the Government decided to allocate £3.1 billion to environmental schemes, with the possibility of this increasing to £3.2 billion at a review point half-way through the programme. Although this level of funding will help nearly maintain the scale of the current programme, it is unlikely to be sufficient to increase the rate of habitat restoration required to meet the Government's environmental targets.
- **Also in December 2013 the Government consulted on two options for reforming the water abstraction regime in England.** Reform of the abstraction regime is long-overdue as it does not protect the environment in times of water stress, is inflexible to future rainfall patterns, and does not incentivise water efficiency by abstractors. The ASC wrote to Defra ministers in March 2014 to make the case for the 'water shares' approach.[29] Of the two options presented, it appears better placed to address the current regime's weaknesses whilst minimising the long-term costs of reducing the potential for water scarcity.
- **In February 2014 a long-term action plan to address flooding on the Somerset Levels and Moors was presented to the Government.** The ASC wrote to the Environment Secretary to call for a sustainable, cost-effective approach to managing flood risk on the Levels. The letter called for the wider drivers of flood risk to be recognised, such as some agricultural practices, inappropriate development, and land use change.[30] The costs and risks of not taking this approach are discussed further in Chapter 2.

26 Defra (2013a).
27 Defra (2013b).
28 ASC (2013c).
29 ASC (2014c).
30 ASC (2014b).

1.4 Approach and scope of this report

This report explores the risks posed by climate change for the economy and well-being in England, and the steps being taken to address current and future vulnerabilities. This progress report covers the majority of the remaining priority risk areas of the UK Climate Change Risk Assessment not previously explored in depth by the ASC. In light of the December 2013 tidal surge and winter storms of 2013/14, we also provide an update on flood risk management.

- *Adapting to flood risk – an update (Chapter 2)* extends the analysis presented previously.[31] Five million properties (around 1 in 6) are in areas of flood risk in England, with more than 7,000 properties damaged this winter. The chapter looks at the impacts of the winter floods, areas where progress is being made, and whether current policy and recent decisions are helping to address the expected increase in future flood risk.
- *Resilience of national infrastructure (Chapter 3).* There are plans to invest £375 billion in infrastructure over the next decade. Each recent storm and flood has shown aspects of important national infrastructure to be at risk of damage or disruption. The chapter explores the data available to assess key vulnerabilities as well as the actions being taken by infrastructure providers to address them.
- *Risks and opportunities for business (Chapter 4).* Businesses continually adapt to changing circumstances, managing risks and investing in new products and technologies. Businesses are exposed to climate risk, both from direct impacts and indirectly through their supply chains here in the UK and overseas. Climate change also presents opportunities for businesses looking to grow and exploit new markets.
- *Well-being and public health (Chapter 5).* This chapter considers climate change impacts on health and well-being in the context of our growing and ageing population. Adaptation in the built environment will play a key role given that people on average spend 90% of their time indoors. The chapter looks at the plans in place to handle the impacts on people from cold weather and heatwaves in particular, and the exposure of the health and social care system to climate risks.
- *Emergency planning (Chapter 6).* The Cabinet Office has identified a number of weather-related impacts in the National Risk Register. The 2007 floods were the largest civil emergency since the Second World War.[32] The December 2013 tidal surge was the largest in at least 60 years, with 18,000 people evacuated from low lying areas. Around 5,000 military personnel were deployed this winter to help respond to flood emergencies. This chapter explores the capacity within the current system to manage possible increases in the frequency and severity of climate extremes.

31 ASC (2012).
32 Pitt Review (2008a).

The ASC has developed an analytical approach to assessing the preparedness of key sectors.[33] The approach we intend to take in assessing the National Adaptation Programme is described further in Chapter 7. Box 1.2 describes the extent to which we have been able to apply the approach in full for the chapters included in this year's report. The lack of quantifiable evidence in some areas limits the degree to which current vulnerabilities, future changes in risk, and progress in adaptation, can be assessed at this stage.

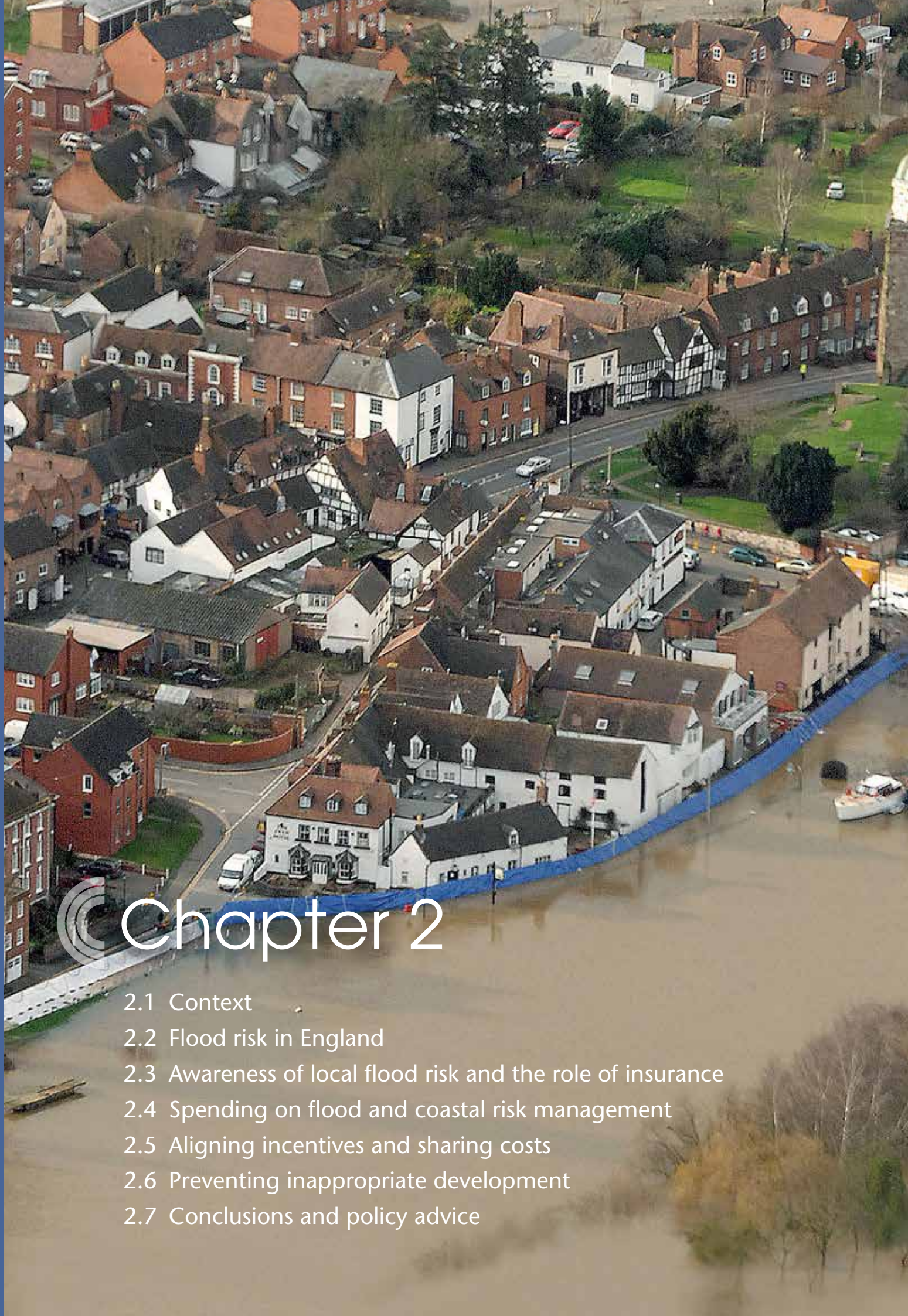
Box 1.2: 2014 Progress Report: application of the ASC toolkit to sectors of interest

	Chapter 2: Adapting to flood risk	Chapter 3: Resilience of national infrastructure	Chapter 4: Risks and opportunities for business	Chapter 5: Well-being and public health	Chapter 6: Emergency planning
Can we quantify current vulnerabilities?	Yes, maturing models of flood risk available	Risks not quantified in some sectors	Supply chain risks difficult to quantify at national level	Uncertainty remains for all risks particularly in terms of impacts on well-being	Yes, stated in Cabinet Office National Risk Register
Can we assess how climate change will affect risk?	Future surface water and groundwater flood risk less well understood than river and coastal flooding	Wind and snowfall projections less certain than for river and coastal flooding	International impacts including through supply chains and financial markets are less certain	Low confidence in impacts on health and well-being from flooding, pathogens, UV radiation, ground level ozone and aeroallergens	Changes in future climate extremes are very uncertain, so we have focussed our assessment on current vulnerability and action
Is there evidence of action to address risks?	National plans are published, statutory local strategies and plans patchy	For some sectors, not others	Evidence is scarce, partly due to commercial sensitivities	Yes, but difficult in many cases to quantify the impacts of the action taken	To some extent, though much information is classified
Can we identify where the policy framework is helping or hindering?	Yes	Yes	Current policy focuses on information provision, impact difficult to determine	Yes	Yes

Source: ASC.
Notes: Colour coding provides a qualitative assessment, based on:
Green: sufficient data available to make a reasonable assessment.
Amber: data allows a partial assessment to be made.
Red: data are not available or uncertainties are too large to make a reasonable assessment at this stage.

We will return to these sectors, along with those covered by our previous reports, in our first statutory report to Parliament in July 2015.

33 ASC (2013a).



Chapter 2

2.1 Context
2.2 Flood risk in England
2.3 Awareness of local flood risk and the role of insurance
2.4 Spending on flood and coastal risk management
2.5 Aligning incentives and sharing costs
2.6 Preventing inappropriate development
2.7 Conclusions and policy advice

Chapter 2:
Adapting to flood risk – an update

Key messages

Increased flood risk is the greatest threat to the UK from climate change. Historical emissions and global warming are likely to have already increased the potential for flooding in England. Models of the climate system suggest floods of the type experienced in England and Wales in autumn 2000, and between December 2013 and February 2014, have become more likely as a consequence of increased concentrations of greenhouse gases in the atmosphere.

Investment in flood defences, early warning and flood emergency planning, including since the Pitt Review was published in 2008, limited the impacts of the December 2013 tidal surge and helped ensure that there was no loss of life. However, current underinvestment in flood prevention increases the potential for avoidable flood damage, especially with climate change. Advances in asset management, effective prioritisation, and the Partnership Funding system are helping to maximise what can be achieved with limited resources but cost-effective activity is being postponed for lack of both national and local funding support.

- The extra £270 million announced since the 2013/14 winter flooding will be a temporary funding boost, primarily to repair defences that were damaged in the storms. Investment after 2015/16 will fall back to previously announced plans and then remain static in real terms until 2021. Previous assessments of need suggest sustained, real-terms growth in spending is required to avoid increasing flood risk. A new assessment is due to be published in autumn 2014.

- In 2014/15 almost three-quarters of the flood defence systems in England will not be maintained according to their identified needs. This is despite additional maintenance funding being provided by the Government after the 2013/14 winter storms. Numbers of flood risk management staff within the Environment Agency fell by 800 (20%) after the 2010 spending review, with a decrease of over 400 in the asset management teams responsible for the maintenance of defences and the response to flood incidents.

Some of the funding provided by Defra to Lead Local Flood Authorities for their new roles and duties under the 2010 Flood and Water Management Act is being diverted to other council services. Statutory local flood risk management strategies are only just being produced in many areas and there is little evidence that local oversight and scrutiny committees are holding public bodies and their partners to account for the actions being taken. This suggests the accountability gap for local flood risk management, highlighted by the Pitt Review, has yet to be addressed in many parts of the country.

The 'Flood Re' subsidised flood insurance scheme presents an opportunity, as a time-limited, transitional measure, to build awareness of risk and encourage additional cost-effective action. Its poor value for money could be improved by the administrator providing grants and financial incentives for high risk households and communities to address local risk. A history of subsidised flood insurance may explain why awareness of flood risk remains low amongst people living on the floodplain and why household-level action to avoid damage to date has been limited.

Environment Agency advice on development applications in flood risk areas, where it is provided, is followed by local planning authorities in almost all cases. These developments should therefore be safe, resilient and not increasing flood risk elsewhere. There is less clarity on the thousands of minor planning applications in flood risk areas where the Environment Agency does not provide specific advice. The cumulative impact of new development on future flood risk is assumed to be zero for the purposes of investment planning, but is in fact unknown.

- The Environment Agency has 40% fewer staff than in 2010 to advise local authorities and developers on planning applications in flood risk areas. The consequent need to prioritise its advice towards major planning applications of more than ten dwellings means an estimated 12,000 minor applications in the floodplain did not receive site-specific advice in 2013.

Key messages

- Developers are required to produce a Flood Risk Assessment under national planning policy. In many cases these are absent or inadequate in the initial planning application, accounting for the majority of objections to development on flood risk grounds lodged by the Environment Agency.

Uptake of sustainable drainage systems (SuDS) in new development appears to be low, as is use of permeable paving. Rules brought in following the Pitt Review to limit the number of additional gardens lost to impermeable surfacing are not being enforced. The automatic right to connect new development to public sewers remains, six years after the Pitt Review recommended this be withdrawn. Regulations requiring local authorities to approve and adopt SuDS in new development have been continually delayed. There remains low uptake of permeable paving options within both domestic and commercial projects.

Our analysis highlights a number of areas where further action appears justified to reduce the potential for increasing flood risk with climate change. As a first step, a synthesis of the lessons from the December 2013 tidal surge and the extensive flooding that followed should be published.

- **Funding and resources.** The new flood defence funding scenarios to be published in autumn 2014 should make clear the long-term implications of the Government's current spending plans. The Government should publish evidence to show the impact of recent and proposed rounds of Environment Agency job losses on important flood risk management functions. The balance in spending between investment in new and improved defences and maintaining existing systems should also be reviewed.
- **Managing local flood risk.** Six years on, the Government should evaluate whether the local flood risk management arrangements recommended by the Pitt Review are now in place and addressing the problems identified. The evaluation should assess the level of skills and resources available to local authorities and their partners, and whether they are being held to account for the action being taken.
- **Flood insurance and property resilience.** The Government and the insurance industry should agree a strategy for how the 'Flood Re' scheme will be used to incentivise and support additional action by high risk households. This would help insurance to remain affordable as the scheme is withdrawn.
- **New development.** The Government should assess the implications for future levels of flood risk arising from continuing development in the floodplain and in areas susceptible to surface water flooding. The reasons for missing or inadequate developer flood risk assessments should be investigated. The Environment Agency should be informed of the outcome of planning decisions when it objects and prospective purchasers should be told if a home has been built contrary to Environment Agency advice.
- **Sustainable drainage.** The SuDS provisions within Schedule 3 of the 2010 Flood and Water Management Act should be introduced without further delay. The uptake of permeable paving should be encouraged, including through more robust enforcement of existing regulations aimed at limiting the impact of paving-over front gardens.

2.1 Context

The winter of 2013/14 saw unprecedented levels of rainfall in southern England in 250 years of instrumental record. On 5 December 2013, the largest tidal surge in sixty years affected the north east, east and north west coasts of England. During January 2014 some parts of the country experienced rainfall three times the historic average. An estimated 7,000 properties flooded across the winter period.

A series of winter storms began on St Jude's day on 27 October 2013. Wind speeds of 99 miles per hour were registered at the Needles Old Battery on the Isle of Wight. The storm surge on 5 December led to 18,000 people being evacuated in coastal locations such as in Great Yarmouth in Suffolk and Jaywick in Essex. Further storms in the days before Christmas caused widespread flooding and disruption across southern England, stretching through Dorset, Hampshire, Surrey and Kent.

For the second consecutive winter, large tracts of the Somerset Levels and Moors were inundated by flood water for an extended period. As a result, a "major incident" was declared in late January by Somerset County Council and Sedgemoor District Council. 5,000 military staff were called in to provide support to the emergency services. In February 2014, the flooding extended along the Severn Valley to Worcester, and along the Thames to Windsor, Staines and Chertsey. The Thames reached record levels in Sunbury and Walton.

The increasing risk of flooding is the greatest threat to the UK from climate change. The UK storms were part of a global picture of unusual weather this winter. The storms triggered debates in Parliament and the media as to whether climate change may have played a role. Evidence is emerging that climate extremes here in the UK as well as overseas have become more likely as a result of historic emissions.

- The Met Office presented in February 2014 an analysis of teleconnections in the Earth's climate system, linking the winter storms in the UK, the polar vortex in the United States, and the drought in California, to persistent rainfall over Indonesia and the tropical West Pacific.[1] The rainfall in the West Pacific was associated with higher than normal ocean temperatures in that region.
- Preliminary results published since the 2013/14 winter storms suggest a statistically significant rise in the chance of extremely wet winters in southern England as a result of past greenhouse gas emissions.[2] The evidence suggests the chance of a very wet winter in southern England has increased by 25%.
- Previous research found that the conditions that led to flooding in England and Wales in autumn 2000 have been made more likely by past emissions (with 90% confidence).[3] A separate study also found a climate change influence on the likelihood of such an event, though not as clearly.[4]
- Global average sea levels rose by 16 centimetres over the 20th century, making tidal flooding as a result of a surge such as that seen in December 2013 more likely.[5] Sea level rise in southern England will be higher than in the north due to the UK landmass continuing to shift after the last ice age.

The winter storms demonstrated how much progress has been made in flood and coastal risk management in recent years. This includes improvements in engineered solutions such as flood defences, but also in important forecasting and flood warning services.

An estimated 1.4 million properties in England were protected by flood defences over the course of the winter storms. There was no loss of life directly as a result of the December 2013 surge, the largest in sixty years. The 1953 surge of a similar magnitude killed 307 people.

1 Met Office (2014a).
2 Environmental Change Institute, University of Oxford (2014).
3 Pall et al. (2011).
4 Kay et al. (2011).
5 IPCC (2013a). Between 1901 and 2010, global mean sea level rose by 19 centimetres, rising at a rate of 3.2 millimetres per year between 1993 and 2010.

The Flood Forecasting Centre was established in 2008 as a joint venture between the Environment Agency and the Met Office following recommendations made by the Pitt Review.[6] The centre identified a high risk of tidal flooding several days in advance of the December surge. This allowed sufficient time for national and local responders to implement emergency response plans. 160,000 flood warnings were issued to homes and businesses. At one stage during the surge, sixty-four areas had severe flood warnings in place. This is the highest level of warning, reflecting a danger to life.

The Thames Barrier was closed 50 times over the winter to protect 200,000 properties in and around London. This is far higher than in any previous winter and twelve times the annual average.[7] The Thames Estuary 2100 plan recommended that a breach of a 50 closures per year threshold be used as a trigger to review whether long-term defence options for London need to be reconsidered.

The Thames Estuary 2100 plan (TE2100) considered future scenarios and options for protecting London and the surrounding area from tidal flood risk across this century. The strategy found that the current barrier with modification and upgrade should be able to protect London and the surrounding estuary to a reasonable standard at least until the 2070s.[8] The strategy was designed to be adaptable should sea levels rise faster than expected.

The strategy recommended not operating the barrier more than 50 times per year. More than this could lead to the integrity of the structure being compromised due to insufficient time between closures to conduct essential maintenance. Recognising that a new barrier for London would take at least a decade to build the 50 closures per year threshold was recommended as a potential trigger point to review longer-term defence options.

In 2012, the Adaptation Sub-Committee's progress report made a number of recommendations to address the risk of flooding in England (Box 2.1**). Priority actions were then identified in the Government's National Adaptation Programme relating to flood risk in the built environment (**Box 2.2**). This chapter provides an update on the progress made since 2012, and discusses the implications of recent developments in flood risk management policy and its implementation, including:**

- New flood risk maps were published by the Environment Agency in December 2013. These show greater detail for river and tidal flood risks in the National Flood Risk Assessment dataset (NaFRA), and for the first time, provide the public with a surface water flood map.
- A new system of subsidised flood insurance for high risk households ('Flood Re') is being introduced by the insurance industry and the Government. This will blunt otherwise helpful signals for flood risk to be addressed. However, if appropriately designed the scheme has the potential to help build greater awareness of flood risk amongst high risk households and create stronger incentives over time for flood risk to be managed.

6 Pitt Review (2008a).
7 On average the Thames Barrier has been closed four times per year over the three decades it has been in operation (there were 124 closures prior to the December 2013 tidal surge and 2013/14 winter storms).
8 TE2100 assumes sea levels rise as expected under a high emissions scenario.

- A number of spending decisions have been taken by the Government since the 2010 General Election, most recently with an extra £270 million for the Environment Agency announced in the weeks after the 2013/14 winter storms.
- Flood and Coastal Resilience Partnership Funding ('Partnership Funding') was introduced in 2011. The results of this policy are now becoming clearer. The system encourages cost savings and local contributions to be found in cases where national funding will not meet the full costs of a flood defence.

Box 2.1: Advice on managing flood risk, presented in the ASC's 2012 Progress Report

Expenditure on flood defences
Support sustained and increased investment in flood defences from public and private sources, given that current spending plans will not keep pace with the increasing risk from climate change.

Land use planning
Ensure local authorities consistently and explicitly assess the potential for accommodating development elsewhere before deciding to allocate land in the flood risk areas (the 'sequential test').

Ensure local authorities transparently assess the long-term costs and benefits of allowing development in flood risk areas in their Sustainability Appraisals.

Improve the development management process to ensure that local authorities always inform the Environment Agency of the outcome of any objection on flood risk grounds.

Uptake of property-level measures and sustainable drainage systems
Less than 400 properties a year installed property level measures between 2008 and 2011. In our analysis, it would be cost-beneficial to increase this to 9,000-14,000 properties per year.

Encourage greater use of sustainable drainage systems to manage surface water.

Source: ASC (2012).

Box 2.2: Priority actions within the National Adaptation Programme: flood risk and the built environment

The Government's National Adaptation Programme (NAP) was published in July 2013. In the built environment chapter, the NAP sets out a vision for buildings and places to be resilient to a changing climate and extreme weather, with organisations in the built environment sector having an increased capacity to address the risks and take the opportunities from climate change.

The stated objective in the NAP in terms of flood and coastal erosion risk management (FCERM) is:

"To work with individuals, communities and organisations to reduce the threat of flooding and coastal erosion, including that resulting from climate change, by understanding the risks of flooding and coastal erosion, working together to put in place long-term plans to manage these risks and making sure that other plans take account of them."

To realise this vision and achieve the objective, the NAP lists a number of priority actions in several areas.

Focus area: Flood and coastal erosion risk management:

- Implement the National FCERM Strategy for England.
- Secure, with industry, new arrangements for flood insurance beyond 2013.
- Develop Local Flood Risk Management Strategies that set out the approach to managing local flood risk and consider the effect of future climate change and the increasing severity of weather events.

Focus area: Spatial planning:

- Implement the National Planning Policy Framework (NPPF).
- Update Planning Practice Guidance to support the implementation of the NPPF.

Focus area: Making homes and communities more resilient:

- Continue to encourage the uptake of Property Level Protection to reduce the impacts of floods on people and property.

Focus area: Longer-term implications:

- Ongoing National Coastal Erosion Risk Mapping Work.
- Review of the Long-Term Investment Strategy.

Source: HM Government (2013), The National Adaptation Programme.

2.2 Flood risk in England

Around five million properties in England, including four million households, are at some risk of flooding from rivers, the sea, or from surface water. New online maps were published by the Environment Agency in December 2013, in part to fulfil the requirements of the European Floods Directive. For the first time, a national map showing the risk of surface water flooding is available to the general public. Alongside households, around a million commercial, public sector and other non-residential buildings are located in areas at risk.

The new maps identify for the first time areas at a 'high' likelihood of flooding. This is where the annual chance of flooding in the area is 1-in-30 (3.33%) or greater. Previously the highest level of flood risk shown was where the annual chance was 1-in-75 (1.3%) or greater. Areas at a 'very high' risk of flooding, with a 1-in-10 annual chance (10%) or greater, have also been assessed. These are not shown on public maps but the dataset is available under licence from the Environment Agency.

Changes in risks classifications have been introduced to simplify their description to the public. Table 2.1 **compares the new and previous risk classifications.** The same categories are used to describe the likelihood of flooding from rivers and the sea, and surface water.

Table 2.1: Changes in flood risk likelihood thresholds and terminology in the National Flood Risk Assessment

	1-in-30 annual chance or greater	1-in-75 annual chance or greater	1-in-100 annual chance or greater	1-in-200 annual chance or greater	1-in-1000 annual chance or greater
Previous flood risk categories	SIGNIFICANT		MODERATE		LOW
New flood risk categories (from December 2013)	**HIGH**	**MEDIUM**		**LOW**	
Number of properties (of which households) *in areas at risk of flooding from rivers and the sea*	244,000 (153,000)	503,000 (350,000)		1,603,000 (1,274,000)	
Number of properties (of which households) *in areas at risk of surface water flooding*	282,000 (209,000)	490,000 (388,000)		2,232,000 (1,809,000)	

Source: Environment Agency, unpublished.
Notes: A 'Very High' category of flood risk (10% annual chance or greater) has also been modelled by the Environment Agency. This category is not shown on the public-facing maps and website but is available under licence. A 'Very Low' category is also available, where the annual chance of flooding is less than 1-in-1000 but the area is within the extreme flood outline. Approximately 600,000 properties are in areas at risk of flooding from rivers and the sea, and also in areas at risk from surface water.

Flooding is more likely than the language used to describe flood events may suggest. Flood events are typically described as "once in a lifetime" or a "1-in-200 year event". This terminology describes the annual chance of a flood of a particular magnitude happening in one specific location. The chance of a flood of a particular magnitude happening somewhere in England in any given year is much higher.

The chance of a catastrophic flood happening in England within the next two decades, causing in excess of £10 billion in damage is around 10%.[9] Such a flood would cause ten times more flood damage than the combined impact of the tidal surge and storms across the winter of 2013/14, and three to four times more damage than the widespread flooding of 2007. Insurance companies are required by financial regulations to hold sufficient capital to remain solvent in 99.5% of years. This means a greater than 1-in-200 loss scenario could lead to some insurance companies defaulting on claims.

For each household in the country, the chance of flooding can be summed across all households to estimate the number of homes that can be expected to flood per year as a long-term average. Such an Estimated Annual Households Flooded (EAHF) figure could then be used to track overall progress in flood risk management over time.

9 Based on a 1-in-200 year loss scenario, using figures published by Defra (Defra, 2013a and Diacon, 2013) assessing the costs and benefits of the 'Flood Re' insurance pool for high risk households. It is proposed that the Flood Re pool is reinsured in order to meet claims in any one year of up to £2.5 billion, to cover its exposure in a 1-in-200 loss scenario. Flood Re is expected to underwrite up to 55% of residential UK flood losses (£190 million out of £343 million average annual losses). Household damages account for around 40% of total economic losses from a flood, based on the 2007 flood event (Environment Agency, 2010). This means a 1-in-200 loss scenario for Flood Re, when scaled to the UK overall, would involve £4.5 billion in residential flood losses, and economic losses potentially in excess of £11 billion.

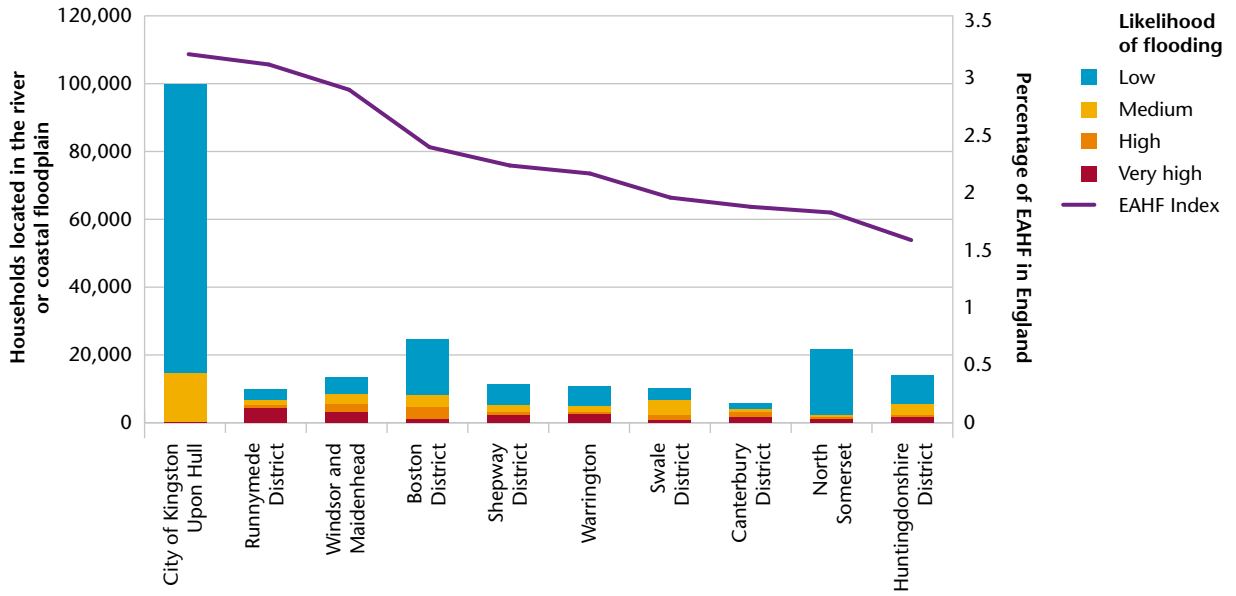
An EAHF figure could be expected to increase with climate change and as new homes are built in flood risk areas, and if flood defences are not sufficiently maintained. It should reduce if investment in new and improved flood defences more than keeps pace with the drivers of increasing risk.

Deriving an EAHF figure from Environment Agency data is difficult because their maps show the probability of the onset of flooding in an area, rather than the chance of the properties in the area suffering damage. The chance of property damage is likely to be considerably lower than suggested by the Environment Agency's flood risk maps. In the event of a flood, water levels may not exceed the thresholds of properties in the area, and where it does, local measures such as property-level protection may prevent damage from occurring.

A preliminary EAHF index has been created that can be used to identify those parts of the country where household flooding is most likely over time. Figure 2.1 **shows the ten local authorities with the highest EAHF index in England. Across the 323 district and unitary authorities in England, these ten account for around a quarter of all expected household flooding from rivers and the sea.**

The EAHF index takes account of the full range in flood likelihoods; localised, high probability frequent flooding as well as low probability severe events. The index takes account of the community flood defences in place to prevent flooding.

Figure 2.1: The ten unitary and district local authority areas in England with the highest Expected Annual Households Flooded index based on flooding from rivers and the sea



Source: HR Wallingford (2014) for the ASC, using the Environment Agency's 2013 National Flood Risk Assessment (NaFRA), and OS MasterMap address layer, 2013.
Notes: NaFRA data estimating the annual chance of flooding onset for each 50m² grid square in England was combined with OS MaasterMap data to estimate the number of English households in areas expected to flood per year. The presence of flood defences has been taken in to account and dwellings on upper floors of buildings have been removed. The exact individual probability of flood onset within each grid square was used (eg. 0.037%) rather than the flood risk category (high, medium, low etc). The results exclude NaFRA grid squares without a flood risk category.

Despite the defences in place, these data suggest Kingston-Upon-Hull can expect the most river and coastal flooding over time. As well as some households in the high and very high flood risk categories, Hull has 100,000 households in the medium and low flood risk categories. This risk profile means there might be little flooding year to year, interspersed by occasional very significant flood damage.

Runnymede District has the second highest EAHF index in England but a different risk profile. There are less than 10,000 households in the floodplain in Runnymede District but more than half of these are in high or very high flood risk areas. This means more regular but smaller scale flood losses can be expected.

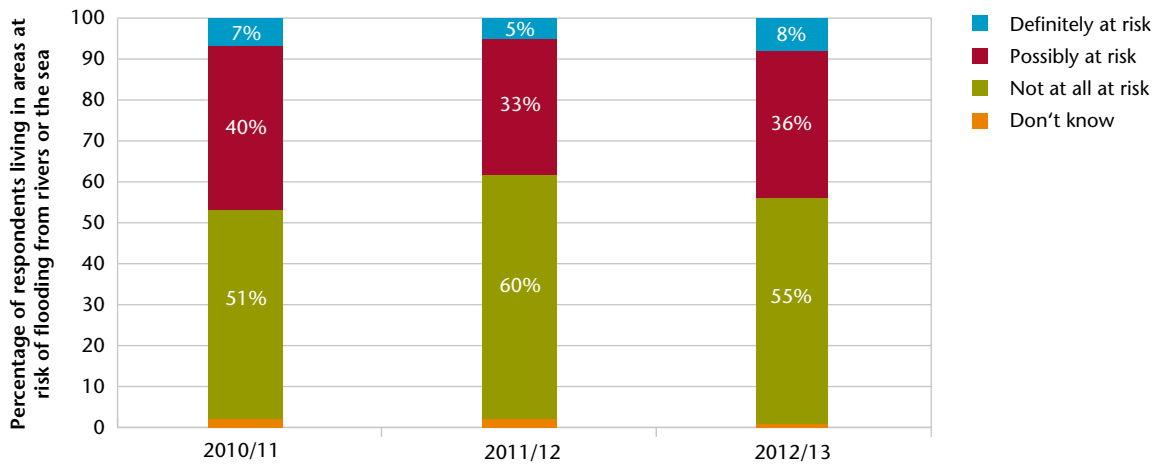
2.3 Awareness of local flood risk and the role of insurance

Awareness of local flood risk has remained low, and relatively stable, in recent years (Figure 2.2)**. This is despite resources being invested to increase awareness, by the Environment Agency, local authorities and others including the National Flood Forum.**

Overall, more than half of people living in flood risk areas do not know, or do not accept, that they are living at risk. In contrast, 8% of households surveyed in flood risk areas recognised they were definitely at risk. This is despite a higher proportion, 17%, saying their home had been affected by flooding at some point in the past and around half recognising they lived near to a water source prone to flooding.

This lack of recognition may in part be explained by households not currently bearing the true economic costs of living on the floodplain. Flood defences are built and maintained primarily at the national taxpayers' expense. The cost of home insurance in flood risk areas is subsidised by other policyholders – the prices currently paid by households for buildings and contents policies generally do not reflect the chance of

Figure 2.2: Awareness of flood risk amongst people living in the floodplain



Source: Harris Interactive (2013) for the Environment Agency.
Notes: All respondents were asked "Do you believe your property is at risk of flooding? Do you feel it is…?" Sample sizes were 1,005 (2010/11), 505 (2011/12), 803 (2012/13). The increase from 5% to 8% who responded 'definitely at risk' from 2011/12 to 2012/13 is statistically significant. This may be explained by the sustained flooding across 2012 that affected many parts of the country.

needing to make a claim. The degree to which current property and rental values take account of local flood risk will therefore be limited.

Changes in the provision of home insurance in flood risk areas should help build much greater awareness of flood risk and create stronger incentives for cost-effective action. In November 2013, the ASC wrote to the Environment Secretary to suggest five ways to improve the scheme from a long-term adaptation perspective.[10] Annex 2.1 **summarises the ASC's advice and the changes made to the scheme as a result.**

Proposals to establish a 'Flood Re' flood reinsurance pool were announced by the Government in June 2013. The system will continue to subsidise flood insurance for high risk households on a time-limited and transitional basis. It will be paid for by the existing estimated cross-subsidy in the market being captured by a new £180 million levy on household insurance policies. As the benefit of the pool is being met at the expense of other policyholders, and the same value of flood losses will still occur, the scheme delivers little economic benefit. The scheme is set to deliver economic benefits that are less than the costs involved, at around 70 pence of benefit for each £1 of cost.[11] As such the scheme falls below the minimum value for money criteria and fails the Accounting Officer tests for public expenditure. A ministerial direction from the Defra Secretary of State will compel the department to proceed.

The scheme is due to be introduced in 2015, from which point the price of flood insurance will be capped according to the council tax band of a property. These caps will increase each year to allow a free market for flood insurance to emerge gradually over the twenty-five year lifetime of the policy. Households in Council Tax Band H and new homes built since 1 January 2009 will be excluded from the scheme.

Over the lifetime of Flood Re, owners and occupiers are likely to find insurance increasingly more expensive in flood risk areas than elsewhere. This should in turn lead to local awareness of flood risk increasing. It will also create stronger incentives for households to alleviate flood risk where it is possible and cost-effective.

The current lack of awareness of local flood risk may be inhibiting local engagement, and willingness to contribute towards community-level flood risk management solutions.

Under the Partnership Funding system introduced in 2011, a share of the costs of flood defence projects can fall to local councils, businesses and communities in cases where value for taxpayers' money is less strong than for other schemes elsewhere in the country.[12] Where awareness or acceptance of flood risk is low, communities are less likely to value, and therefore be willing to contribute towards, improved flood alleviation.

Increasingly risk-reflective insurance terms should help promote flood awareness and additional action. It will also help improve flood models and the assessment of individual property risk.

10 ASC (2013b).
11 Defra (2013a), Impact Assessment.
12 Defra (2011a).

Risk-reflective insurance terms will create stronger financial incentives for households to call for, and to contribute towards, flood defence projects, and also to take steps to protect their own homes with property-level protection measures. Insurance pricing based increasingly on risk should create additional feedback, scrutiny and challenge of the underlying flood models being used by insurers and the Environment Agency. This should lead to their improvement, reducing the potential for the risk in some areas to be overstated. A database of flood claims, to be provided by the insurance industry as part of the new system, will help validate the Environment Agency's flood models. The Government will also have access to the data held by the Flood Re administrator, including the details of the highest risk individual property addresses in the UK. Following advice from the ASC, these households will now be provided with additional information, help and support in the transition to a free market for flood insurance.

2.4 Spending on flood and coastal risk management

National investment in reducing future flood losses

In January 2014 the ASC published a policy note that estimated that spending plans this Parliament are half a billion pounds behind the long-term need if increasing flood risk is to be avoided.[13]

The note considered the amount of funding being provided by Government and the expected levels of external contributions under the Partnership Funding system. Overall expenditure was compared with the scenarios in the Environment Agency's long-term investment strategy (LTIS).[14] The LTIS scenarios estimated how much would need to be spent over time to decrease, hold steady, or expect an increase in long-term flood risk. The LTIS estimated that an extra £20 million plus inflation needs to be spent on average each year to avoid the number of properties at significant flood risk increasing by 2035. A Foresight Study,[15] updated as part of the Pitt Review,[16] also pointed towards real-terms growth in spending levels being required to avoid flood risk increasing.

Within eighteen months of the LTIS being published, the Environment Agency's Flood and Coastal Erosion Risk Management Grant-in-Aid (GiA) budget was reduced by £138 million (21%).[17] Within this, the flood defence budget for capital works was reduced by £121 million (32%).[18] The 2012 Autumn Statement reinstated some funding, with an extra £120 million over two years for new and improved defences.

An extra £270 million for flood and coastal defence has been announced since the ASC's policy note was published. The funds provide a temporary boost to the investment profile, and will primarily fund the repair of defences damaged in the

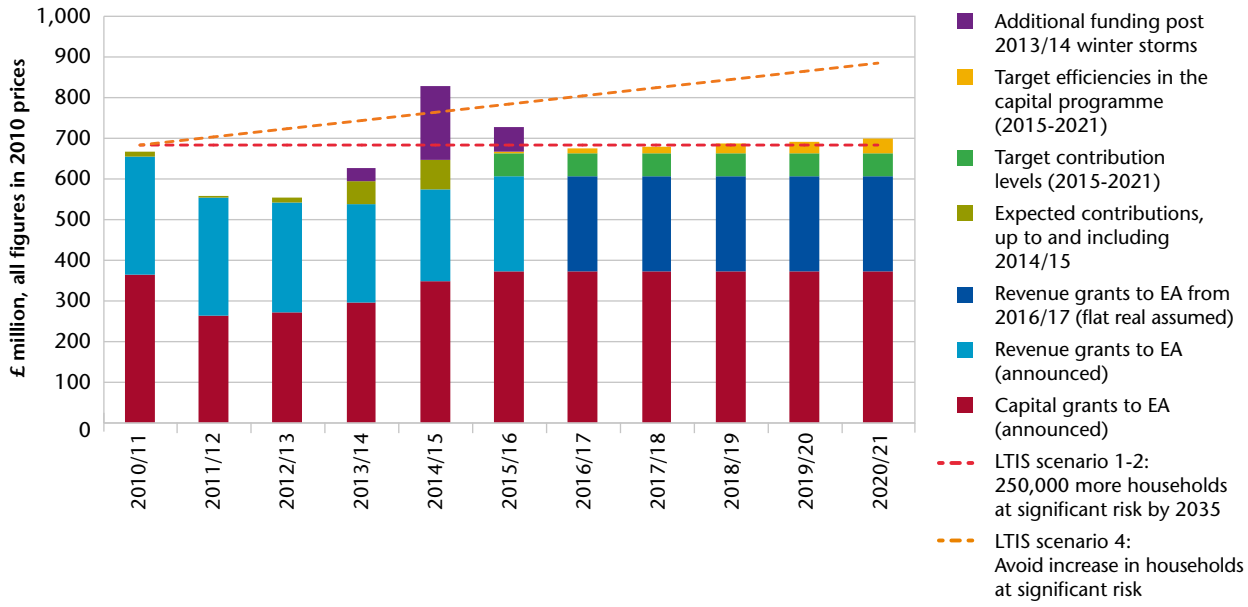
13 ASC (2014a).
14 Environment Agency (2009).
15 Office of Science and Technology (2004).
16 Pitt Review (2008b).
17 From £659 million, the Environment Agency's flood defence grant-in-aid budget for 2010/11 in May 2010, to £521 million, the budget for 2011/12 in October 2010. During 2010 the flood defence grant-in-aid budget was cut twice, by £30 million in July 2010, and further amounts as part of the Spending Review announced in October 2010.
18 From £380 million, the Environment Agency's planned flood and coastal defence capital budget for 2010/11 in May 2010, to £259 million, the post-2010 Spending Review capital budget for each year in the period 2011/12 – 2014/15.

winter storms. £130 million was announced in January 2014 during the winter flooding, with a further £140 million announced in the 2014 Budget. Of this, £70 million will be spent increasing maintenance levels, over two years, within and outside of the areas hit by the winter storms. Spending levels after 2015/16 are set to fall back to previously announced plans. Figure 2.3 shows the impact of the new funds, in the context of past and future spending levels.

Taking in to account other sources of funding, and planned efficiencies,[19] current spending plans for the next Parliament are in line with the second lowest investment scenario the Environment Agency considered in 2009. The Government has committed to publish a new assessment of long-term funding needs as part of the 2014 Autumn Statement.

A six-year capital settlement was announced as part of the Government's 2013 Spending Round, at £370 million in 2015/16 then rising with inflation to above £400 million by 2020/21. Multi-year settlements are important to provide greater certainty over future funding, to allow the Environment Agency and other risk management authorities to create efficiencies in delivery by packaging projects together, and to be able to secure better prices from suppliers under longer-term contracts.

Figure 2.3: Current and future spending on flood and coastal defence against the latest assessment of need published in the Environment Agency's long-term investment strategy



Source: ASC based on Defra (2014a) and Environment Agency (2009).
Notes: Figures are presented in real terms, in 2010 prices. The Environment Agency has committed over the current spending period (2011/12 – 2014/15) to deliver sufficient efficiency savings to offset inflation in the costs of new and improved defences (a subset of the capital budget). In addition, efficiency savings in administration (an element of the revenue budget) of around 33% are being delivered over the current four year spending period. Taken together it is assumed that inflationary pressures can be offset across both the revenue and capital budgets over the current four year spending period to 2015. To reflect this, inflation has been removed from the LTIS scenarios over the same period. From 2015 it is assumed that in general, continuing to counter inflation through improved efficiency will be difficult. However, the Environment Agency's commitment to achieve a further 10% in efficiency savings within the capital programme between 2015 and 2021 is shown as a separate line. 'LTIS Scenario 1-2' is a composite of Scenario 1 ('flat cash') up until 2014/15, then Scenario 2 ('flat real') from 2015/16 to 2020/21. External contributions totalling £148 million are shown for the period 2011/12 to 2014/15. Contribution levels for future years have yet to be announced but a commitment to add 15% to the capital programme from external funding sources has been agreed between Defra and HM Treasury.

19 As part of the long-term capital settlement to 2020/21 there is a commitment to supplement government funding by 15% from external contributions, and for efficiencies in the capital programme to allow, by 2020/21, 10% more per year to be achieved with the funding provided by HM Treasury.

However, even with additional efficiencies and the projected levels of external contributions for the period, overall expenditure between 2016/17 and 2020/21 is expected to be similar to the second lowest investment scenario considered by the Environment Agency in 2009 (Scenario 2, 'flat real'). This projected around 250,000 more households being at significant flood risk by 2035. This also assumes any further development of the floodplain will not add to the overall numbers of 'at risk' properties. In reality, 4,000 new properties are being built in areas of significant flood risk each year based on the pace observed over the decade to 2011.[20]

Capital investment in new and improved defences

There are always likely to be more flood and coastal defence schemes in the pipeline than can be afforded at any one point in time. However, projects with reserved funding in 2014/15 will dominate the pipeline for the next five years. As a result there will be limited funding to begin new projects in 2015/16, and beyond.

In February 2014, the Environment Agency published their investment plans for the 2014/15 financial year together with indicative funding allocations for later years through to 2018/19.[21] The plans list 779 projects with reserved funding in 2014/15, sharing between them £300 million in GiA.[22] These projects are set to cost £2.9 billion to deliver in total, an average of £3.7 million per project, or £7,100 per household protected.

Seventy percent of the available capital GiA over the next five years will be absorbed by projects already under construction or with reserved funding in 2014/15. Between them, projects with indicative funding over the four years from 2015/16 will share the remaining 30%.

There are almost 500 flood and coastal defence projects that won't be funded until 2019/20 at the earliest. These add up to a known funding requirement amounting to £3.6 billion for 2019/20 and the years beyond. This compares to the current GiA budget for capital schemes of around £320 million per year. Within the £3.6 billion, £1.33 billion will be needed to complete projects with committed or indicative funding in 2018/19.

Spending to maintain existing flood defence assets

Maintaining existing flood defence systems can be amongst the most cost-effective uses of resources in the long-term. Limited resources mean flood defence systems across England are being maintained at below optimal levels. This will have implications for the long-term requirement for capital investment to refurbish and rebuild defences, with renewals being needed earlier than may otherwise be necessary.

The Environment Agency has prepared a System Asset Management Plan (SAMP) for each of the 2,700 groups of flood defence assets in England that work together as a system

20 ASC (2012).
21 Environment Agency (2014a).
22 An additional £6 million is being made available to local authorities and internal drainage boards for studies, flood risk management strategies and other miscellaneous projects.

to protect an area. SAMPs are categorised according to whether there would be 'high', 'medium' or 'low' consequences if flood defences were to be over-topped or fail in flood conditions. Each SAMP identifies a minimum, and an optimal, maintenance regime for the asset system. The minimum need is the lowest unavoidable cost of maintaining statutory compliance and operational readiness for a system over a twelve month period, accepting that the standard of service may decline as a result. 'Optimal' in this instance means the amount of maintenance that minimises the whole-life cost of the system, balancing the need for ongoing attention (revenue expenditure) with longer-term repairs, refurbishment and renewal (capital expenditure).

The budget for the ongoing maintenance of flood defences was reduced by 20% in the 2010 Spending Review. Even before the winter storms of 2013/14 the condition of flood defence assets protecting high consequence areas was in decline. The proportion of Environment Agency flood defence assets at the required condition in high consequence areas fell to 96.5% in September 2013, from a peak of 98.7% in 2011/12.[23] The Environment Agency's target is to maintain at least 97% of assets in high consequence systems in target condition. The Environment Agency has since fallen further behind its target, to 94.0%, following the 2013/14 winter storms.

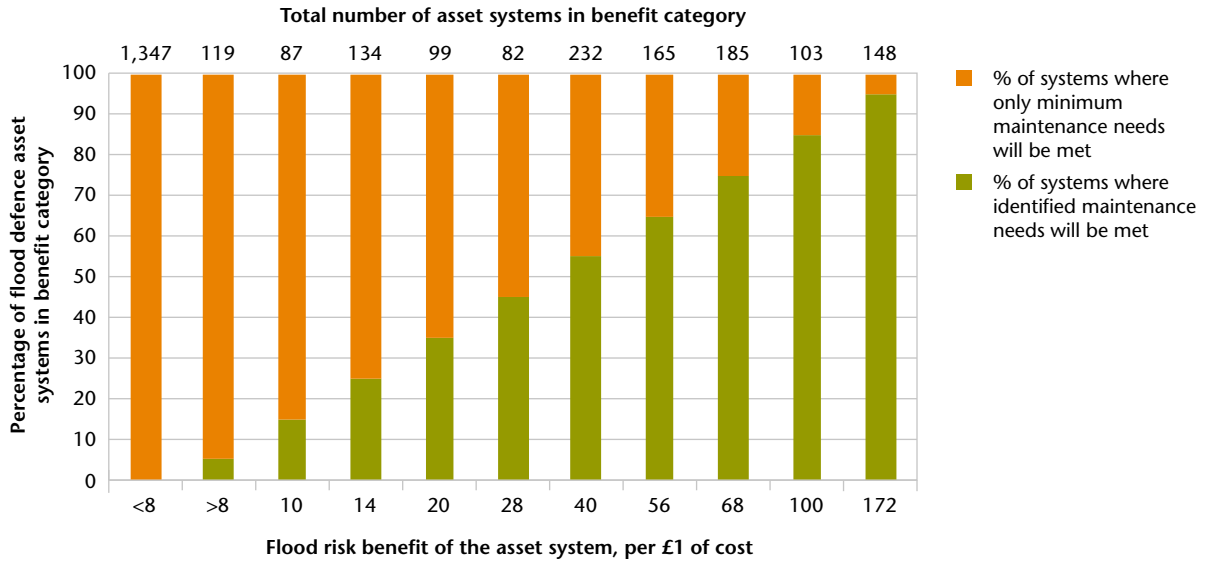
An extra £35 million per year has been allocated to revenue maintenance in 2014/15 and 2015/16 following the storms. This reinstates the annual maintenance budget, in cash terms, to around the level spent in 2010/11. This money together with the extra capital being spent repairing defences should bring the Environment Agency back on track against their target to maintain 97% of assets in high consequence systems in the required condition. There are no targets to maintain medium and lower consequence systems in reasonable condition. Decisions have yet to be taken on the annual maintenance budget for 2016/17 onwards.

Even with the increased maintenance budget, current resources mean almost three-quarters of flood defence asset systems will not be maintained in 2014/15 according to their identified needs (Figure 2.4**).** There are sufficient resources to meet each asset systems' minimum statutory and operational requirements. Once these needs have been met, the remaining funding is prioritised towards asset systems that deliver most flood risk benefit. As a consequence those asset systems in the lowest benefit categories will receive little or no maintenance above the bare minimum.

The benefit to cost ratios shown in Figure 2.4 **compare the benefit of maintenance against a counterfactual scenario of there being no defences in place.** SAMPs consider the need for both capital and revenue expenditure over the lifetime of the asset system. The marginal benefit of conducting minimum maintenance, or the identified maintenance regime, against a scenario of no maintenance at all would be useful in understanding the flood risk impact of the limited maintenance activity being performed. It would also be useful to understand how much in total needs to be spent to meet the unavoidable costs of existing asset systems, and how much then remains to fund systems' full identified needs.

23 Environment Agency (2014b).

Figure 2.4: Maintenance of Environment Agency flood defence asset systems (2014/15)



Source: Environment Agency, unpublished.
Notes: Data are from System Asset Management Plans (SAMPs) based on an overall revenue budget for maintenance in 2014/15 of £170 million. The available funds each year are first allocated so that the minimum needs can be met for every asset system. The remaining funds are then prioritised on a risk and benefit basis, so that systems delivering more flood risk benefit are maintained more often. 'Minimum needs' is the lowest unavoidable cost of maintaining statutory compliance and operational readiness for a system over a twelve month period, accepting that the standard of service may decline as a result. 'Identified needs' is the regime needed to minimise the whole-life costs of the asset system, balancing ongoing routine (revenue) maintenance with intermittent (capital) renewal and replacement costs.

The Environment Agency's capacity to manage flood risk and respond to flood emergencies

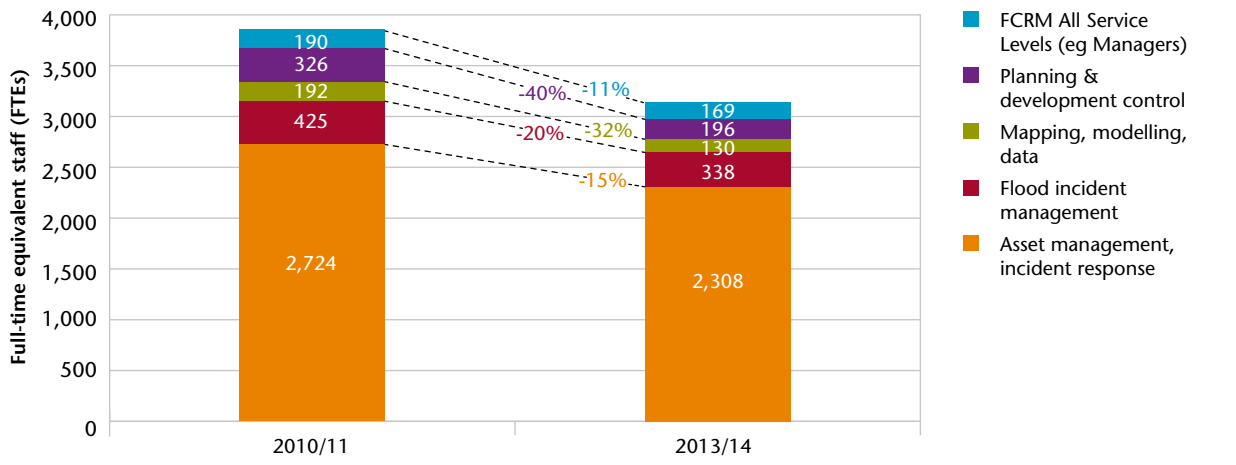
The cumulative impact of past and planned Environment Agency staff losses on important flood risk management functions is unclear. The Environment Agency had 800 fewer flood risk management staff in March 2014 than in September 2010, and a further 750 staff across the Environment Agency are due to be lost by October 2014.

The overall number of Environment Agency flood risk management staff working in non-corporate roles has reduced from 3,857 to 3,141 since 2010/11.[24] In 2011, in response to concerns in Parliament about the impact of the 2010 Spending Review, the Government stated that spending on flooding was a priority and that "*…the settlement managed to safeguard forecasting and warning services, and incident response, and the risk-based maintenance of existing defences.*"[25] Figure 2.5 shows that the numbers of staff involved in all these activities have fallen. It is not clear to what extent these reductions in staff have been offset by increased efficiencies including as a result of rationalising and reorganising the Environment Agency's local, regional and national teams. Such evidence, as well as regarding any efficiencies realised by other means, has not been published.

The Environment Agency states that the further reductions in overall staffing levels, from 11,000 at the beginning of the year to 10,250 by October 2014, will not result in the loss of any "front line" flood and coastal risk management posts.

24 The remaining 80 full-time equivalent posts relate to corporate roles (finance, human resources, for example), apportioned to flood risk management functions.
25 Defra (2011b).

Figure 2.5: Number of Environment Agency flood and coastal risk management staff (2010/11 and 2013/14)



Source: Environment Agency, unpublished.
Notes: In 2013/14, the Environment Agency had 800 fewer flood risk management staff than in 2010/11 (full-time equivalents, FTEs). Staff working in cross-cutting corporate roles apportioned to flood risk management functions are not included in the chart. The further reductions in staff by October 2014 are not included in these figures. Reductions by October involve an estimated 750 staff across the Environment Agency.

Local authority expenditure on flood risk management

Local authority spending is under pressure and at least some of the funding provided for managing local flood risk is being diverted to other council services (Figure 2.6)**. This is leaving flood risk management teams with less than they feel they need, including to fulfil their statutory duties. Taking steps to reduce local flood risk is not a statutory duty for local authorities.**

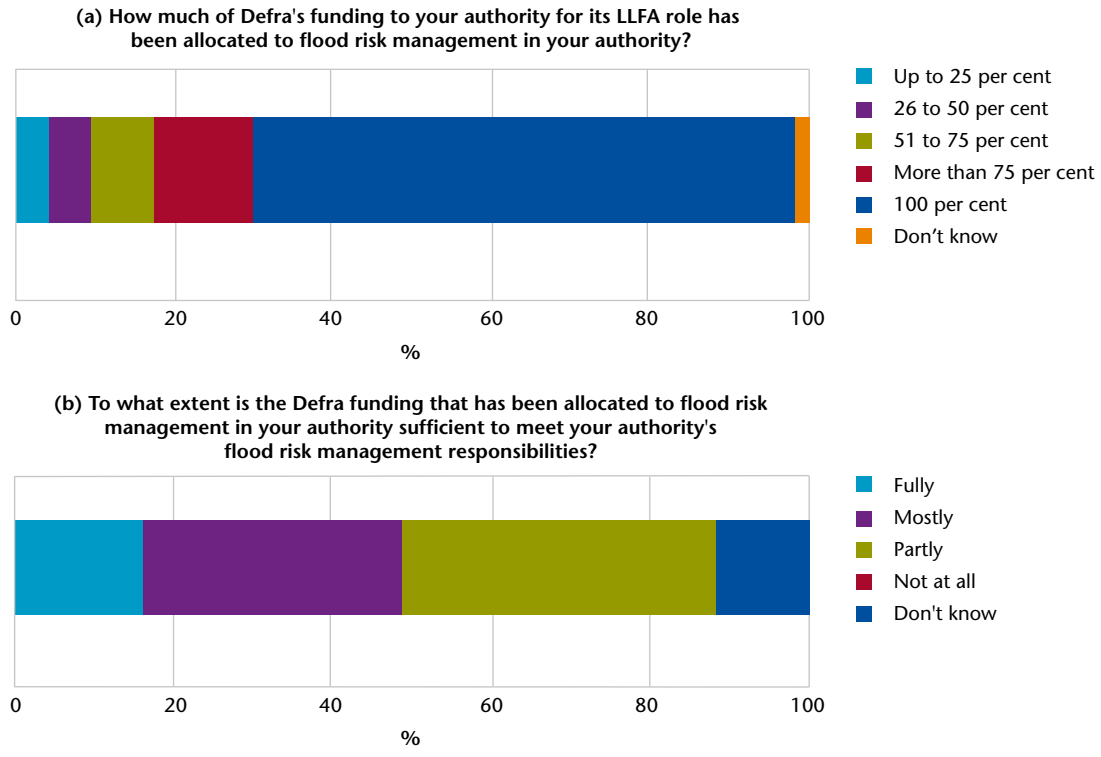
Lead Local Flood Authorities (LLFAs) were created under the 2010 Flood and Water Management Act, following recommendations by the Pitt Review. Their role is to bring together the national and local partners involved in managing local sources of flood risk in the area, and to together develop a local flood risk management strategy. LLFAs also have statutory roles to identify key flood management assets, and investigate flood incidents. LLFAs have been provided with £36 million per year by Defra to fund these new roles.

Whilst some of the new roles are statutory, the core task of managing and reducing flood risk is not. Even where statutory roles are specified, there is scope for LLFAs to determine the level of activity required to meet them. There is no deadline by which the statutory summary of the local flood risk management strategy needs to be published. Only five out of the 152 LLFAs in England had finalised a strategy and published a summary by April 2013.[26] Of the remainder, four lead local flood authorities reported that they had not yet begun work on their local flood risk management strategy.

A third of local authorities responding to a Local Government Association survey in 2012[27] said at least some of the funding provided by Defra had not been allocated to flood risk management within the local authority. In the same survey, less than a fifth of authorities

26 Environment Agency (2013d).
27 Local Government Association (2012).

Figure 2.6: Funding for Lead Local Flood Authority roles under the Flood and Water Management Act



Source: LGA Flood Risk Management Survey (2012).
Notes: The survey was conducted by the LGA's in-house local authority survey team. Questionnaires were sent to all 152 lead local flood authorities in England and 99 responses were received. The number of lead local authorities responding to these questions were (a) 95, and (b) 96.

said they felt they have the funds needed to fully meet their new responsibilities. A third of LLFAs did not respond to the survey. This self-selecting sample may be biased towards those authorities with more resources in place.

Holding local authorities and their partners to account for tackling flood risk will be difficult without an agreed local flood risk management strategy and accompanying action plan in place. This together with an apparent lack of oversight and scrutiny suggests the accountability gap for managing local flood risk remains in many parts of the country. The Pitt Review recommended that local oversight and scrutiny committees be established to review plans and call to account those bodies involved in managing local flood risk (recommendations 90 and 91, below). Powers for scrutiny committees to perform this role were included in the 2010 Flood and Water Management Act. There is limited evidence of new flood risk management scrutiny committees being established, or existing scrutiny committees being tasked with this role.

- *Pitt Review, recommendation 90:* All upper tier local authorities should establish Oversight and Scrutiny Committees to review work by public sector bodies and essential service providers in order to manage flood risk, underpinned by a legal requirement to cooperate and share information.

- *Pitt review, recommendation 91:* Each Oversight and Scrutiny Committee should prepare an annual summary of actions taken locally to manage flood risk and implement this Review, and these reports should be public and reviewed by Government Offices and the Environment Agency.

2.5 Aligning incentives and sharing costs

Partnership Funding was introduced in 2011. Since then, funding from local partners and sources has increased significantly.[28] External contributions during the three years prior to Partnership Funding being introduced totalled £13 million. £148 million in contributions are expected during the current four year period. Over forty per cent of the flood defence projects with reserved funding in 2014/15 have at least some element of external funding (332 out of 779). Contributions for these schemes total £421 million, with five schemes accounting for £235 million. Contributions are set to meet 15% of the total costs of schemes with reserved funding in 2014/15, in line with commitments made by Defra to HM Treasury for the period.

Partnership Funding creates helpful incentives for project costs to be reduced as well as responsibility for flood alleviation to be shared. Under the previous system, project costs were typically funded in their entirety, or not at all.[29] This diminished the incentive for project partners to reduce project costs if they were always likely to be met in full by the Government. There are several notable schemes whose costs have fallen significantly since Partnership Funding was introduced.

- The Leeds City Flood Alleviation Scheme was prepared for government approval under the previous funding system, with costs set to total £190 million.[30] Since Partnership Funding was introduced, requiring costs to be shared with local interests, the scheme has been redesigned. Costs have been reduced to £50 million, with £18 million in confirmed local contributions.
- This means the GiA required by the scheme has fallen by £158 million. As a result, there is the potential for forty other projects to proceed alongside the Leeds scheme going ahead.[31] The revised scheme entered the construction phase in April 2014.

Government funding should focus on where it can achieve the most in preventing future flood losses, and not be diverted to where it flooded last. A reactive approach will offer relatively poor value and increase future flood losses as the funds could have been better spent elsewhere. Allocating national funding to projects outside of the normal prioritisation approach would also undermine local responsibility for avoiding flooding, and contributions under the Partnership Funding approach.

There is a well-established approach to the national prioritisation of flood defence projects based on the delivery of outcomes, benefits and value for taxpayers' money. This would be

28 Defra (2014b).
29 Defra (2010).
30 Leeds City Council. http://www.leeds.gov.uk/docs/Leeds%20Flood%20Alleviation%20Scheme%20Leaflet.pdf
31 Based on the average scheme costing £3.7 million per project. To note this sum includes future maintenance costs, so the average construction cost per scheme will be less. Under the previous allocation system the full £190 million Leeds scheme may have been able to proceed as long as overall targets for the Environment Agency's capital programme were met. See Defra (2008).

undermined if national funding were allocated to projects outside of the normal allocation process, in response to flood events.

In March 2014, the ASC wrote to the Environment Secretary to advise that the long-term plan for managing flood risk on the Somerset Levels and Moors needs to be sustainable and cost-effective.[32] There is the potential for the recent episodes of flooding on the Levels to divert scarce national funding from more economically worthwhile projects elsewhere in the country. Annex 2.2 summarises the full advice provided by the ASC regarding the Somerset Levels and Moors Action Plan.

The Government has committed £20.5 million towards the Somerset Levels and Moors action plan. The action plan includes no assessment of the benefits of this money being spent, either in the Levels or in terms of the opportunity cost of not spending it elsewhere. The dredging activity that forms a core part of the action plan is estimated to cost £5.7 million,[33] and deliver flood risk benefits of £1.90 per £1 spent.[34] This compares with the national average benefit to cost ratio for flood defence capital works of £8 per £1.

2.6 Preventing inappropriate development

Environment Agency advice on development in flood risk areas

Preventing inappropriate development helps to reduce the long-term build-up in vulnerability to flooding. New floodplain developments will be increasingly costly to protect, and insure, in a changing climate. As highlighted in the previous section, the number of Environment Agency flood risk management staff engaged in planning and development control has been reduced by 40% since 2010. This is the largest reduction amongst all the Environment Agency's flood risk management teams as a result of the 2010 Spending Review.

The Environment Agency is a statutory consultee for planning applications over one hectare in size that are within the floodplain.[35] Planning policy does not set specific standards or tolerable levels of risk against which the Environment Agency should assess an application.[36] Instead, the Agency takes a 'risk-based' approach, using its expert judgement to determine whether to respond directly to an application, or rely on the developer using the Agency's Flood Risk Standing Advice.

Where the Agency directly responds, it will assess whether an application has adequately assessed flood risk and put in place measures to ensure the development will be safe, resilient and not increase flood risk elsewhere. Where it has concerns, the Agency may either suggest conditions that the planning authority should set if permission is to be granted, or it can formally object. If these concerns are not addressed, the Agency will

32 ASC (2014b).
33 Somerset Levels and Moors Action Plan (2014).
34 Environment, Food and Rural Affairs Committee (2014).
35 Defined as Flood Zones 2 and 3. The Agency is also a consultee on applications in areas with critical drainage problems. The Agency is not a consultee for development applications within an existing dwelling, such as extensions or alterations.
36 This is not the case in Wales, where planning policy requires floodplain development to be designed so that it will remain dry in a 1-in-100 year river flood event and 1–in-200 year coastal flood event.

decide whether to sustain its objection until a final decision is made by the planning authority or the application is withdrawn by the developer.

The Environment Agency is responding on flood risk grounds to fewer minor planning applications and increasingly prioritising its advice towards major developments.[37] The reduction in Environment Agency responses to minor development is despite the number of minor planning applications in England remaining broadly stable over that time.

- The number of minor planning applications in England since 2009 has averaged around 120,000 a year. The number of major applications has averaged at around 13,000 a year since 2009, although it increased to nearly 15,000 in 2013.
- In 2009 nearly 60% of Agency responses were to minor applications.[38] By 2013 this had fallen to nearer 40%.[39] The remaining responses were to major developments.

We estimate that the Environment Agency did not provide specific advice to around 12,000 minor applications in the floodplain in 2013. Where the Agency is not consulted or does not respond to a minor planning application, the developer and local authority can refer to the Environment Agency's Flood Risk Standing Advice. Developers and planning authorities are not being given specific, tailored advice by the Agency on individual developments in the floodplain in these instances.[40]

- The number of planning applications in the floodplain to which the Environment Agency do not respond is not recorded by planning authorities, the Agency, nor central government. This makes it difficult to robustly assess the cumulative impact of development on flood risk.
- Our previous analysis found that on average 13% of all development in England per year is in the floodplain.[41] Applying this assumption to the 118,000 minor applications made in England in 2013 would mean that around 15,000 applications were in the floodplain. The Environment Agency responded to around 3,000 of these applications, which suggests that the remaining 12,000 did not receive specific tailored advice from the Agency and would have been reliant on Flood Risk Standing Advice.
- At the same time, the Environment Agency responded on flood risk grounds to nearly one-third (28%) of all major planning applications made in England in 2013. This suggests that there may be proportionally more major development taking place in the floodplain than previously estimated, or that the Environment Agency is responding to major development in areas of surface water risk as well as in the river and coastal floodplain.

37 DCLG publish quarterly National Statistics on the number of planning applications made and decisions granted in England. These distinguish between Major and Minor planning applications. Minor applications are defined as those where the number of dwellings to be constructed is between 1 and 9 inclusive and/or the site area is less than 0.5 hectares. As the Environment Agency is not a statutory consultee for applications of less than 1 hectare, it will not always be informed of minor applications by the planning authority. However, the Agency has the discretion to advise or object to minor applications if it sees fit.

38 The definition of minor development is the one used by DCLG's National Statistics on planning applications.

39 In 2009 there were 5,300 responses to minor applications and 3,700 responses to major applications. In 2013, the number of responses to minor applications had fallen to 3,200 with 4,000 responses to major development proposals.

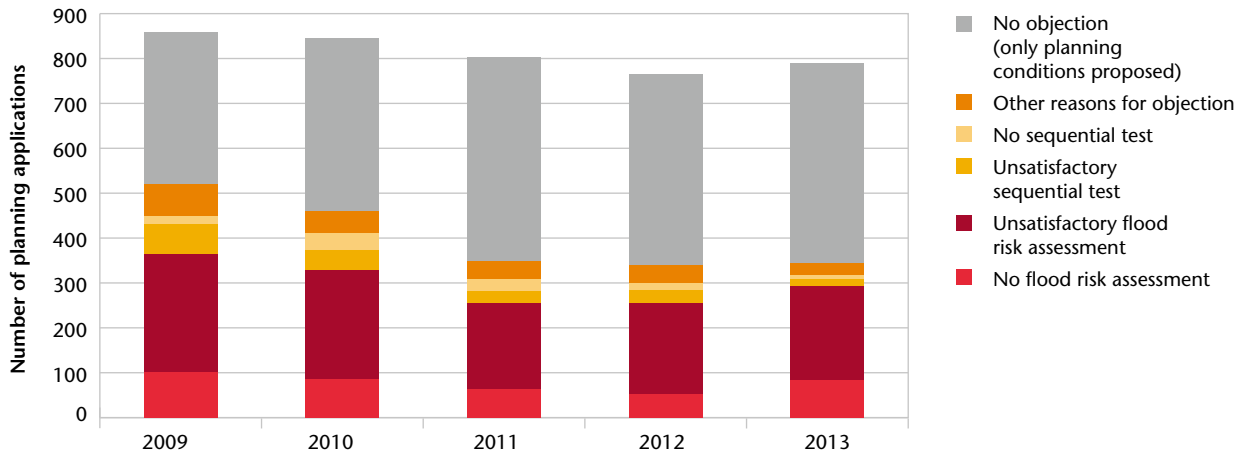
40 Note that the Environment Agency is likely to have advised on the Strategic Flood Risk Assessment that informs the planning authority's Local Development Plan. The SFRA should identify broad areas prone to flooding and enable the plan to set development policies, including for minor development, which avoids and manages flood risk.

41 ASC (2012).

The Environment Agency has been objecting to fewer applications since 2009. This may reflect improvements in the quality of applications by developers. However, the number of missing or inadequate flood risk assessments remains a cause for concern.

- The Environment Agency initially objected to 4,500 applications in 2009 and just over 3,000 in 2013. In most cases, the Agency will lodge an initial objection if it has concerns with the approach taken by the applicant to assess whether there are suitable alternative locations in areas of lower risk,[42] or if it has concerns with the site-specific Flood Risk Assessment (FRA) undertaken by the developer. In most cases the objection will be dropped if the concerns are dealt with through subsequent correspondence between the Agency and the developer.
- In our review of a sample of Environment Agency responses made between 2009 and 2013,[43] the majority of reasons given for initial objections was either the lack of or concerns with the quality, of the FRA (Figure 2.7). The Agency appeared to have fewer concerns with the application of the sequential test, although there were still cases where seemingly this test had not been applied.
  - In 2009, there were over 100 Environment Agency initial objections in our sample due to the lack of an FRA. This declined to 50 in 2012, but increased again to over 80 in 2013.
  - The number of initial objections due to inadequate FRAs declined from around 260 in 2009, but has remained at around 200 a year since.

Figure 2.7: Environment Agency responses to a sample of planning applications in the floodplain, including reasons for raising initial objections (2009-2013)



Source: Amec (2014) for the ASC.
Notes: Based on a representative sample of 4,060 Environment Agency responses on flood risk grounds to planning applications made between 2009 and 2013 across 42 local authorities. The sample represents around 10% of the total number of flood-related responses made by the Environment Agency to planning applications over the five year period in England. The Agency objected to 1,697 of the 4,060 applications sampled. In some cases, the Environment Agency included more than one reason for an objection, meaning that there were over 2,000 separate causes of an objection overall in the five year period.

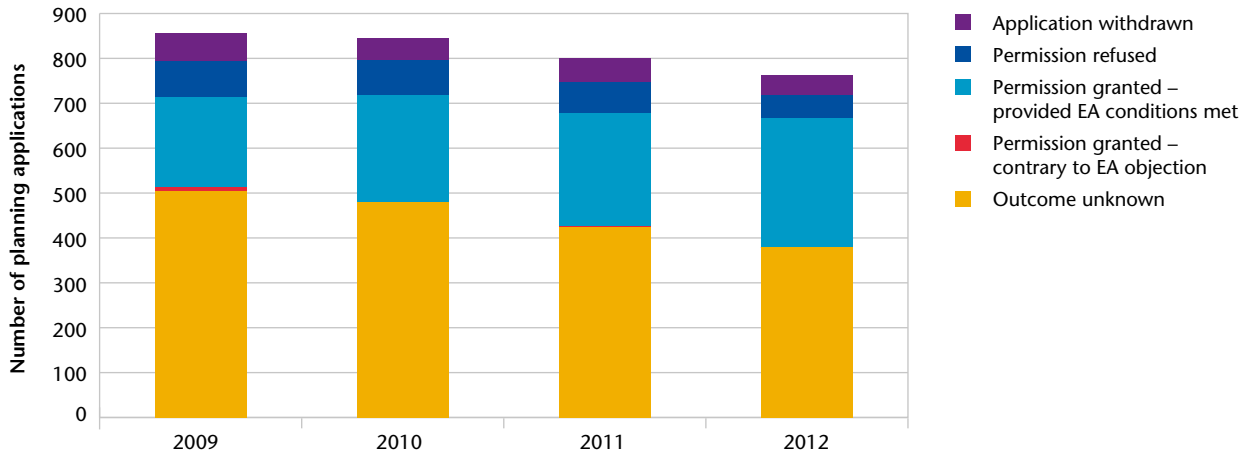
42 Known in planning policy as the 'sequential test'.
43 We reviewed at a high-level the Environment Agency's responses to a representative sample of just over 4,000 planning applications made between 2009 and 2013. See Amec (2014) for the ASC.

- Over 40% of the planning applications we assessed in more detail[44] did not initially factor in the implications for flood risk from projected sea level rise and increases in river flow. These were mostly minor development applications. We also found few examples of detailed assessments of how surface water flood risk may change in the future. The lack of evidence provided by applicants on how they had accounted for climate change was a common reason cited by the Environment Agency in their initial objections to an application.

Where the Agency does object to an application, they continue to be unaware of the final planning decision in a high proportion of cases. In our sample, the Environment Agency was not informed of the outcome in 41% of cases where it had objected to a development in 2012 (Figure 2.8). Whilst this was an improvement on 2009, when they were not informed in 50% of cases in our sample, it remains high given that planning policy guidance encourages local authorities to ensure that decision notices are sent to the Environment Agency whenever it has objected.

Where the Environment Agency is informed of the outcome, their advice is adhered to by local planning authorities in almost all cases. There were only 11 applications out of the 3,000 we reviewed between 2009 and 2012 where a sustained Environment Agency objection was over-ruled by the planning authority. Almost all these instances were in 2009. In most other cases developments were approved on the condition that the Environment Agency's advice was followed by the developer, with a small proportion either refused by the planning authority or withdrawn by the developer.

Figure 2.8: The outcome of Environment Agency responses to a sample of planning applications on flood risk grounds (2009-2012)



Source: Amec (2014) for the ASC.
Notes: Based on a representative sample of 4,060 Environment Agency responses on flood risk grounds to planning applications made between 2009 and 2013 across 42 local authorities. The sample represents around 10% of the total number of flood-related responses made by the Environment Agency to planning applications over the five year period in England. Data for 2013 (789 applications) is not included as it included a higher proportion of applications that have not yet been determined and/or where planning authorities have yet to notify the Environment Agency of the outcome. The sample size for this chart is therefore 3,267.

44 We further assessed the publicly-available supporting documentation (including Flood Risk Assessments, Environment Agency responses and Final Decision Notices) for 111 of the 4,000 planning applications. See Amec (2014) for the ASC.

It is also highly likely that the Environment Agency's advice is followed in the majority of cases where the local authority does not inform them of the outcome. The Agency's advice was accurately transposed by planning authorities into conditions set out in the final decision notices in almost all of the 111 applications we assessed in more detail. This included those applications where the planning authority did not inform the Environment Agency of the outcome.

However, there is a lack of consistent data available on whether developers are implementing the conditions set by planning authorities. Planning authorities are responsible for enforcing planning conditions, but there is no systematic approach to recording checks and enforcement where it takes place.

The standard conveyancing searches conducted as part of a house purchase would not ordinarily establish whether a home in a flood risk area was built against the Environment Agency's advice. Searches would also not normally discover whether conditions set by the planning authority were implemented by the developer.

Encouraging sustainable drainage including permeable paving

Traditional piped sewer systems cannot readily be adapted to deal with increased rainfall. Sustainable drainage systems reduce the quantity or speed of runoff from urban areas flowing into the sewer system. Regulations requiring the use of sustainable drainage systems in new development have yet to be fully introduced by the Government. It is six years since the Pitt Review promoted sustainable drainage systems (SuDS) in urban design following the widespread surface water flooding in 2007. It is four years since the Flood and Water Management Act legislated to encourage SuDS to be the default option in new development and redevelopments.[45]

The Government has ensured that national planning policy requires local planning authorities to actively consider SuDS when scrutinising development applications.[46] Building Regulations also make clear that sustainable drainage should be the preferred option for dealing with rainwater from the roof of the buildings and paved areas around the building.[47] However, the provisions in the Act to prepare national SuDS standards, establish SuDS Approval Bodies (SABs) and remove the right of new development to automatically connect to public sewers have been repeatedly delayed.

The Government intended to implement these measures in October 2014, but recently announced that this deadline will not be met due to fears about slowing the pace of house building.[48]

45 Schedule 3 of the Act requires the Secretary of State to publish national standards about how SuDS should be designed, constructed, maintained and operated and provides for the establishment of SuDS Approval Bodies (SABs) to approve, adopt and maintain SuDS. SABs will generally be county or unitary authorities. The Schedule also amends section 106 of the Water Industry Act 1991 to make the right to connect surface water run-off to public sewers conditional on the approval of the SAB.

46 DCLG (2012).

47 Part H of the Building Regulations that cover drainage and waste disposal.

48 Defra consulted on draft national SuDS standards in 2011. In May 2014 a letter from Defra notified that the proposed implementation in October 2014 will no longer take place. No new date has been proposed.

Less than half of the planning applications we reviewed considered sustainable drainage. This raises questions as to whether a large proportion of local planning authorities are following national planning policy on SuDS.

In our review of 111 planning applications made since 2009, the Environment Agency were content that more than half (73) had adequately assessed surface water management issues. However, less than half (50 out of 111) specifically referred to the use of SuDS in the proposed design and an even lower number proposed actual SuDS measures.[49] These were mostly for major developments, with very few minor applications referring to SuDS at all.

Our review found evidence of a range of constraints that limited SuDS proposals, including soil type, site topography and the lack of available space in urban sites. As such, the inclusion of SuDS was more common in relatively unconstrained greenfield sites. However, even when accounting for such constraints, our review suggests that many planning authorities are not actively considering and promoting SuDS.

Installation of permeable paving has increased in recent years, but from a very low starting point. Impermeable surfacing remains the norm. Concrete block permeable paving (CBPP) is a proven SuDS measure that allows rainwater to permeate between the blocks and into pre-designed water capture or attenuation systems below ground.[50] CBPP accounted for 6% of total block paving sales in England in 2009, rising to 10% in 2013.[51] This amounts to around 100 hectares of permeable paving installed across the whole of England in 2013.[52] Ten times more impermeable block paving was installed in the same year.

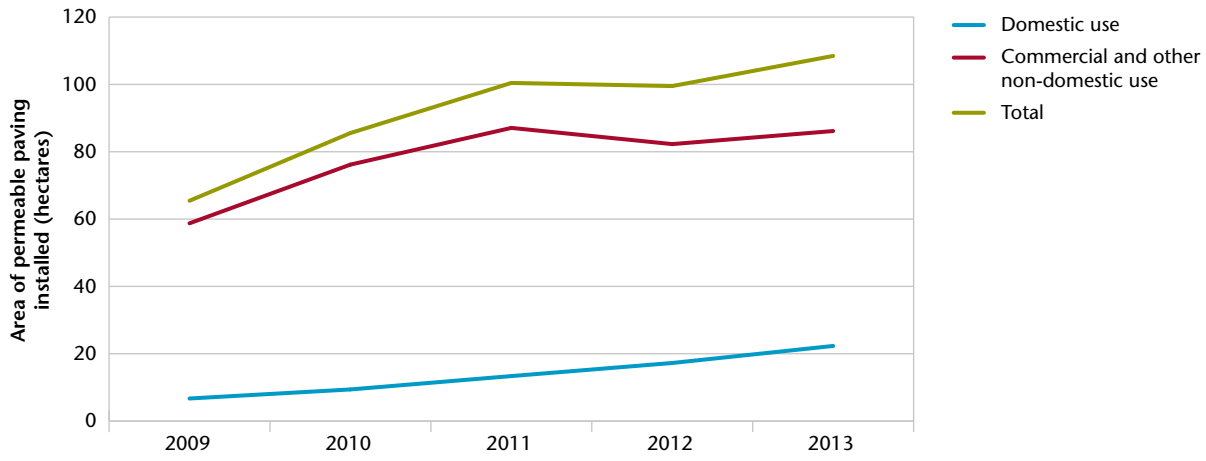
Despite increases since 2009, the uptake of permeable paving in front gardens remains very low, accounting for only 4% of domestic block paving sales in 2013. Sales of permeable paving have been higher in commercial and other non-domestic projects, such as car parks and pavements, but still make a low proportion of total commercial block paving (Figure 2.9).

- Around 7 hectares of front gardens was paved with permeable block paving in 2009. This had risen to 22 hectares by 2013, out of total domestic block paving sales of nearly 500 hectares in that year.
- Nearly 90 hectares of permeable paving was installed in commercial projects in 2013, which would include new development and some refurbishment of pavements and street paving by highway authorities. This represented 14% of all commercial block paving sales in that year.

The low uptake of permeable paving in front gardens suggests that planning regulations for households that have been in place since 2008 are not being enforced by local councils.[53] Householders must apply for planning permission if they intend to pave their front gardens with non-permeable materials. However, continuing

49 12 out of the 111 planning applications reviewed specified the inclusion of attenuation ponds or swales, and 15 proposed to install permeable paving.
50 CBPP has distinct 'spacing' elements that is filled with suitable natural grit to allow water to pass downwards into below-ground water storage systems.
51 Jenco and Climate Resilience Ltd (2014) for the ASC.
52 We were unable to identify regional variations in sales of permeable paving due to limitations with the data. However, it was suggested by the paving manufactures we spoke to that CBPP made up a higher proportion of sales in the north and east of England than in the south and west.
53 The 2008 Planning Act included changes to Permitted Development Rights requiring householders to seek planning permission if they propose to cover more than 5m^2 of their front gardens/driveways with impermeable paving and the water is unable to drain to a permeable area.

Figure 2.9: Area of permeable block paving installed in England categorised into domestic and commercial projects, based on data from manufacturers and suppliers (2009-2013)



Source: Jenco and Climate Resilience Ltd (2014) for the ASC.
Notes: Block paving manufacture and sales in the UK is dominated by six national companies, all of which are members of the trade association Interpave. In addition, there are some regional manufacturers and suppliers, at least one of which is an importer from Eire. A confidential data request was made to these companies seeking data on sales of concrete block paving and concrete block permeable paving between 2004-2013, with a particular focus on identifying trends in the domestic and commercial markets. Responses were received from all the companies contacted, although data covering a ten year period was only available from two companies. The 2009-2013 totals are based on data received from over 90% of England's manufacturers and suppliers.

dominance of non-permeable paving suggests that this regulation is not being enforced by planning authorities.

The majority of local highway authorities appear to be unwilling to adopt permeable paving when refurbishing pavements and carriageways. A small number of local councils have pioneered permeable options in recent years, but the paving manufacturers we interviewed noted that in their experience highway authorities are generally wary of switching to new construction and paving materials.

A key barrier to wider uptake of permeable paving is the perception that the costs are higher than traditional paving options. Our analysis of paving sales highlighted that many customers (both domestic and commercial) perceive higher costs associated with permeable paving. The paving manufacturers provided evidence that they argue demonstrates permeable options are easier to design and offer similar value for money to traditional paving.[54] Once installed, permeable paving systems require routine sweeping twice a year with major refurbishment necessary after around 35 years. Despite this, there is a perception amongst customers that permeable paving options have high maintenance requirements and a short life-span.

54 For example, the paving trade association (Interpave) commissioned research into the whole life costs of three types of permeable paving and five types of traditional paving systems. This concluded that each permeable option was competitive in all applications where ground conditions allowed. See Jenco and Climate Resilience Ltd (2014) for the ASC.

2.7 Conclusions and policy advice

Our analysis has highlighted areas where progress has been made but also where strengthened policy and increased funding and resources could help cost-effectively avoid unnecessary flood damage. Constrained national and local capital investment means hundreds of flood defence projects will not be funded until 2019/20 at the earliest. Limited Environment Agency resources mean the majority of flood defence systems are not being maintained each year according to their identified needs. Climate change will put increasing pressure on both the need to invest in new and improved defences and to maintain in appropriate condition those already in place.

A new assessment of long-term spending requirements is due to be published by the Government in autumn 2014. This needs to make clear the implications of current spending plans for future levels of flood risk, for all sources of flooding. The updated long-term investment scenarios should assess the level of funding that may be required in the 2020s and beyond, to hold constant, or to reduce over time, the potential for flood losses. The Environment Agency's previous assessment assumed that new development will not lead to any increase in future flood risk. Scenarios with and without new development factored in would provide a more realistic assessment to inform decision making.

In the next spending round, the Government should review the current levels of resources available to the Environment Agency and lead local flood authorities to manage flood risk and respond to flood incidents.

- The December 2013 tidal surge affected far fewer properties than the number damaged in 1953 and caused no loss of life. However a review to collate lessons would be useful to assess the overall effectiveness of the response to the tidal surge and the extensive flooding in the months that followed.
- The Environment Agency's revenue budget is yet to be decided beyond 2015/16. The next Government spending round, based on advice from the Environment Agency, should achieve a balance between investment in new and improved defences and the maintenance of existing asset systems in order to maximise value for taxpayers' money.
- The Government should publish evidence to show how the recent and proposed Environment Agency job losses have been and will be possible without impacting the delivery of important flood risk management functions. The Environment Agency has 800 fewer flood risk management staff than in 2010, and a further 750 staff across the Environment Agency are due to be lost by October 2014. Flood mapping and modelling, planning and development control, and flood incident management, all help to avoid flood damage. These areas saw the largest proportional staff reductions following the 2010 Spending Review.
- Defra should review with the Local Government Association the level of resources being allocated by lead local flood authorities to local flood risk management. Implications for skills and capacity should be identified; together with the extent to which important roles and functions under the Flood and Water Management Act are being delivered.

It is four years since the Flood and Water Management Act received Royal Assent, legislating for many of the recommendations made by the Pitt Review. The Government should evaluate whether Sir Michael Pitt's vision for flood risk management arrangements in this country following the 2007 flooding has been realised.

- The publication of a summary of the local flood risk management strategy in each area is a key part of the Government's flood risk management policy framework, and is a statutory requirement. The National Flood and Coastal Erosion Risk Management Strategy was published by the Government in 2011. In many cases local flood risk management strategies have yet to follow. This should be addressed as a matter of priority in each area. Local strategies need to be developed in close consultation with and cooperation between neighbouring authorities given catchments and coastlines span local authority boundaries.
- The Pitt Review recommended that local oversight and scrutiny committees be established to review local strategies and plans, and hold partners to account for their delivery. There is little evidence that such committees are fulfilling this role. This means there remains a key accountability gap at the local level for tackling flood risk.

The creation of the Flood Re insurance pool represents an opportunity to better understand the nature of flood risk in this country; to build awareness of risk, and to address over time the causes of flood damage. Progress has been made in the current proposals following ASC advice, but further reform would help the scheme fulfil its potential and reduce its costs.

- Tackling flood risk will be the most cost-effective and sustainable approach to keeping insurance bills affordable in the long-term. The Government and the insurance industry need to agree and publish a comprehensive strategy for encouraging and supporting flood risk mitigation amongst the households to be subsidised by the Flood Re scheme. This would help address the scheme's currently poor value for money.
- Scope remains for the incentives under the scheme for insurers, and for high risk households, to be improved in order to reduce costs and improve value for money. At the outset, Flood Re is set to reimburse insurers in full for each flood claim on ceded policies less a small excess. If insurers were only allowed to recover a proportion of each claim (near but not quite 100%) it would retain stronger incentives within the system for flood risk to be managed and for insurers to maintain an interest in keeping claim costs low. Otherwise there is a risk that claim costs will spiral, requiring the levy on all household insurance bills to be increased.

Flood Re should also help guard against inappropriate new development, as new homes built since 2009 will be excluded from the scheme. Recently updated Government guidance also makes it clear that where tests to protect people and property are not met, development in flood risk areas should be refused. As the Environment Agency's advice on flood risk grounds is followed by the local planning authority in almost all cases where it responds, it is likely that major development in

the floodplain is being designed in ways that minimise flood risk. However there are several aspects of the current planning regime that could be improved.

- The Environment Agency is not scrutinising all planning applications in the floodplain. There is evidence to suggest that flood risk is not being assessed as robustly in minor applications as it is in major development. There is, therefore, the possibility that thousands of individual minor developments may be adding to future flood risk. In order to address this uncertainty DCLG should:
  - Undertake an assessment of the net cumulative impact on flood risk of all development that has been allowed in the floodplain in England since 2009. This could be delivered by identifying a representative sample of approved major and minor developments to ascertain the extent to which flood risk mitigation measures were required and then implemented.
  - Consider setting a clearer standard of tolerable risk against which the Environment Agency can assess planning applications. This would provide more certainty that where development in the floodplain is approved, it will not be increasing flood risk.
  - Consider monitoring the number of properties damaged by flooding per year that were constructed after 2009.
- Local planning authorities and the Environment Agency should work with developers and relevant professional bodies in the flood risk management sector to improve the standard of flood risk assessments produced by developers for both major and minor planning applications, including how they account for climate change. This could include ensuring wider dissemination of existing guidance on undertaking flood risk assessments.
- Current guidance to planning authorities should be reinforced so that the Environment Agency is advised of the outcome in every case where they object. DCLG should also satisfy itself that planning conditions imposed on developments as a result of Environment Agency advice are being adhered to by developers, and work with local planning authorities to improve public access to this information.

The lack of progress on sustainable drainage is concerning given the impacts of surface water flooding, a risk which is likely to increase with climate change. The legal framework for enabling greater use of SuDS that Parliament intended when it passed the 2010 Flood and Water Management Act has still not been implemented and existing regulations are not being enforced. Local authorities can play a lead role in promoting the wider uptake of sustainable drainage measures particularly permeable paving options, in order to reduce the costs incurred from surface water flooding.

- Provisions on sustainable drainage in Schedule 3 of the Flood and Water Management Act need to be introduced without further delay. Once there is greater clarity on the national standards for SuDS and on the roles and responsibilities of SuDS Approval Bodies, it is likely that there will be an increase in the number of planning applications that propose SuDS measures.
- Local planning authorities and Local Lead Flood Authorities should consider how to better enforce existing regulations on the resurfacing of front gardens. The recently updated Environment Agency surface water flood risk maps could identify areas where the continued use of impermeable paving in front gardens is likely to increase flood risk for other households and critical buildings, such as hospitals, schools or care homes. Enforcement of planning regulations could then be focussed on those areas. LLFAs should also monitor the costs to local authority budgets of cleaning up and repairing damages caused by surface water flood events, to strengthen the case for action on reducing the loss of natural surfaces.
- Local highway authorities and Local Lead Flood Authorities should assess why there is a low uptake of permeable paving in pavement and carriageway renewals. The block paving industry can play a role in providing evidence and case study examples to help local highway authorities adopt permeable paving.

Annex 2.1: ASC advice on improving the Flood Re subsidised reinsurance pool for high risk households

ASC Advice	Why?	Result
Require Flood Re to build awareness of flood risk.	Flood Re will have data on the highest risk households in the UK. Provides an opportunity to build awareness and encourage action by households.	The Water Bill was amended by the Government to require the Flood Re administrator to provide insurance companies with information and guidance on flood risk, to pass on to their highest risk customers.
Place flood risk reduction at the core of Flood Re's purpose.	In order to address the underlying cause of unaffordable flood insurance and improve Flood Re's value for money.	The Flood Re administrator will be required to publish a strategy for how Flood Re will encourage and support flood risk mitigation amongst the households being subsidised.
Publish a framework for how the transition to a free market will take place.	So that households know in advance that their insurance costs will increase, allowing long term choices to be made.	The Flood Re administrator will be required to publish a plan for how the transition to a free market for flood insurance will be achieved.
Target the benefits of Flood Re more keenly.	To preserve incentives for flood risk to be managed, allow the annual levy on insurance bills to be reduced, and to improve Flood Re's value for money.	Not addressed. By subsidising flood insurance in high risk areas there remains the potential for Flood Re to undermine otherwise helpful incentives for flood risk to be managed.
Require households and insurers to retain some risk.	To retain incentives for flood risk to be addressed and for claim costs to be kept to a minimum.	Not addressed. There remains a risk that the costs of flood claims will rise under Flood Re as insurance companies will not directly bear the costs of claims themselves. May also mean households are out of their homes for longer as insurers will no longer have an incentive to return people home as quickly as possible in order to minimise the costs of claims.

Source: ASC (2013b).

Annex 2.2: Summary of ASC advice on the Somerset Levels and Moors Action Plan

ASC Advice	Why?
Recognise the rising sea levels and flood risk with climate change.	Average sea levels rose in the English Channel by 12cm over the 20th century and are expected to rise by a similar amount again by 2030. This will make draining the Levels ever more difficult. There is evidence that high river flows in the winter in the UK have already increased and that rainfall events are becoming more intense.
Consider the range of drivers of flood risk on the Somerset Levels and Moors.	The Levels is a largely artificial, engineered wetland landscape. Development – property, farming and other economic activity – becomes vulnerable to flooding when it encroaches on to the floodplain. To address this, the full range of land management as well as engineering options should be considered.
The Action Plan should be sustainable, and cost-effective.	Funding from central Government for flood risk management is limited, and as a result many worthwhile projects have to be held back each year. It would be unfair in the long-term for the Levels to attract more taxpayer support than similar areas elsewhere. It shouldn't require taxpayer funding to be diverted from other projects that would deliver greater flood risk benefit.
Whilst being long-term in its outlook, the plan should be adaptive in its approach.	The benefits of the plan may be uncertain at this stage, including the contributions that land management and dredging will deliver. An adaptive approach will keep options open whilst monitoring the drivers of vulnerability and assessing whether the plan is having the desired impact.
Responsibility should be shared for funding and delivering the plan.	Decisions that can help, or hinder, flood risk are taken locally by individuals, councils and local partners as well as by national bodies. To make sure incentives are aligned, the long-term costs should be shared amongst those who have a role and an interest in avoiding future flood damage.

Source: ASC (2014b).

Chapter 3

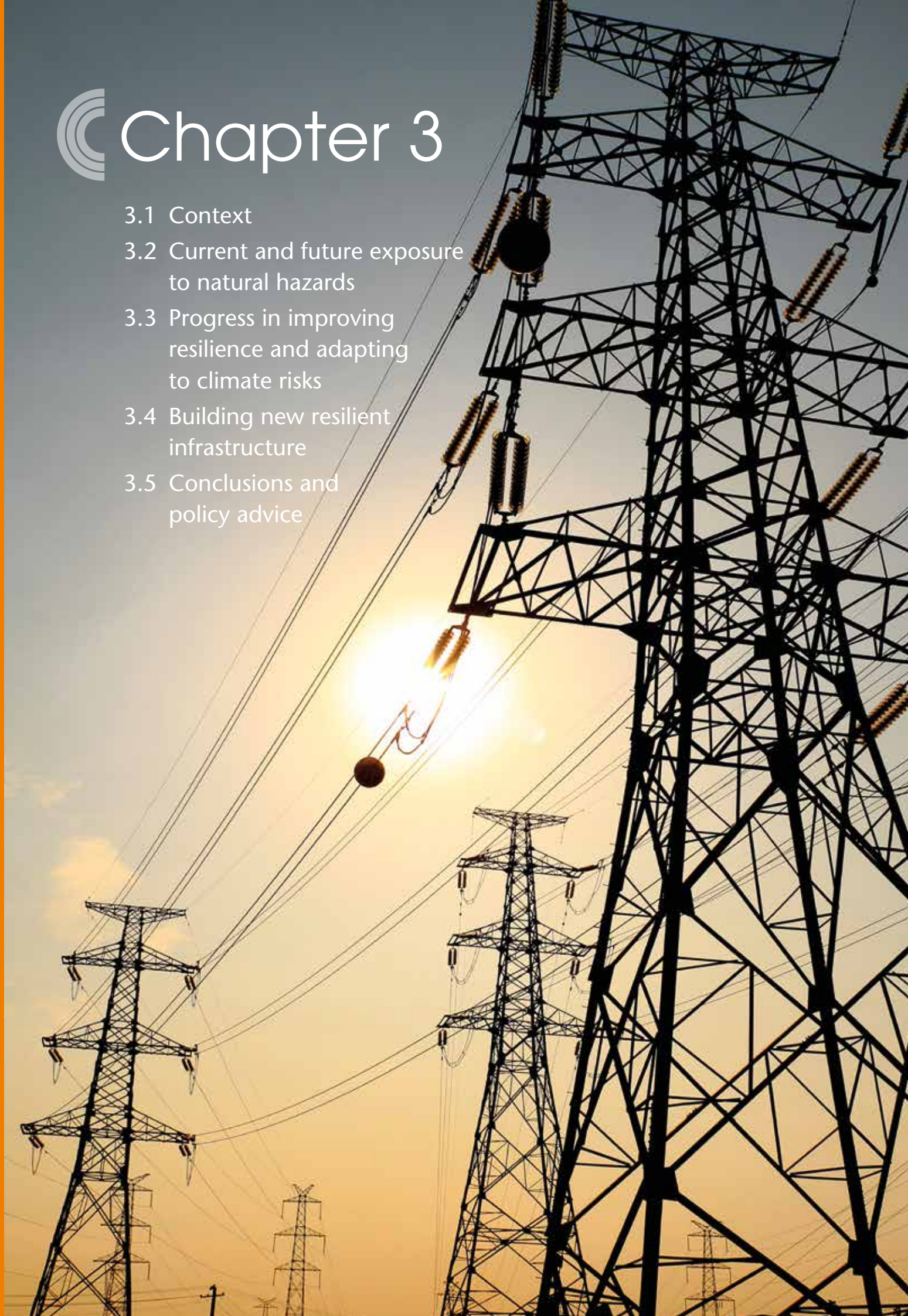
3.1 Context

3.2 Current and future exposure to natural hazards

3.3 Progress in improving resilience and adapting to climate risks

3.4 Building new resilient infrastructure

3.5 Conclusions and policy advice



Chapter 3:
Resilience of national infrastructure

Key messages

The nation's physical infrastructure, composed of the facilities and systems necessary for the functioning of the country, is a priority for adaptation. Infrastructure systems are long-lived, sensitive to severe weather, and their failure can have knock-on impacts on other networks. Resilient national infrastructure is a key attribute of economic competitiveness. Acting now to improve resilience makes economic sense, especially in the context of climate change.

- The resilience of infrastructure is routinely tested by extreme weather. Natural hazards such as storms, flooding, heavy snow and droughts already account for between 10-35% of all delays or service interruptions to electricity, road and rail customers every year. Flooding in particular can have long-lasting impacts on infrastructure networks and cause widespread disruption. Although there is uncertainty in the exact changes that can be expected, more severe and frequent extreme weather and flooding is projected with climate change.
- Most infrastructure assets are long-lived and costly to retrofit once they are built. Infrastructure planning and design should therefore account for the projected changes in climate over the rest of the century and beyond for the longest-lived assets.

Climate change is expected to increase the number of assets exposed to high temperatures, flooding, coastal erosion and subsidence in the coming decades.

- The majority of infrastructure assets that are potentially susceptible to flooding from rivers or the sea are located in lower risk parts of the floodplain where the likelihood of flooding is less than 1-in-100 annually. However, climate projections suggest that the number of assets in areas with a high likelihood of flooding (1-in-30 annual chance or greater) will increase by at least 50% by the 2050s.
- The short lengths of rail and major road networks that are currently directly exposed to coastal erosion are protected by sea walls. However, coastal defences can fail as was seen at Dawlish during the 2013/14 winter storms. Projections of future erosion suggest that an increasing length of the rail network will be exposed over the rest of the century.
- Whilst water scarcity is not currently a major risk for the 20% of electricity generation capacity that uses freshwater for cooling, increased water scarcity may become a more significant issue in some areas if water-intensive technologies such as carbon capture and storage are extensively deployed.
- Infrastructure assets could also become more exposed to high winds and storms, but there are large uncertainties in projecting future changes.

Electricity transmission and distribution companies are i) assessing risks from climate change, ii) taking action to build resilience and iii) reporting on the delivery of resilience measures in a transparent manner. Based on the evidence available, it appears that Network Rail, water companies, the Highways Agency, operators of ports and airports, and ICT providers are implementing some, but not all, of these steps.

- Electricity transmission and distribution assets were severely disrupted during the 2007 floods. Since then, coordinated steps have been taken with the economic regulator Ofgem to assess current and future flood risk, establish standards of protection and deliver a programme of resilience measures. Once implemented, nearly 90% of customers currently reliant on substations at high risk will have been protected by the 2020s, even after accounting for projected increases in the likelihood of flooding with climate change.
- Electricity generation is concentrated at a relatively small number of locations which are protected to a degree against extreme weather events. Customers can continue to be supplied through the transmission grid if individual power stations are disrupted.
- The rail sector has a legacy of ageing assets, some of which were severely damaged by the winter 2013/14 storms. Network Rail is increasingly taking a whole-life approach to managing its assets and assessing the resilience of its major routes to climate change, although it could go further to embed adaptation into its design specifications. Expenditure on the renewal of the most vulnerable structures, such as earthworks and sea walls, is set to increase in the coming years, and Network Rail reports annually on the progress being made.

Key messages

- Water companies have complex networks of assets including treatment works, pumping stations, pipes and sewers. These networks are exposed to flood risk and ground subsidence in particular. National-level data on the current impacts of these hazards is not collected. There is no consistent assessment of risks across the sector, and any steps taken by companies to reduce risks are not routinely reported.
- The strategic road network (motorways and trunk roads) has been built relatively recently and designed to modern engineering standards, which are periodically updated. When design standards are exceeded by extreme weather events, impacts are managed through traffic management systems and business continuity arrangements. Disruptions are recorded in detail but the steps being taken to increase resilience to extreme weather are not transparently reported.
- Ports and airports are privately operated so motivated by competition to ensure reasonable continuity of service. However, operators do not bear the full costs of impacts to the economy from service disruptions, which can be substantial at the largest airports and most specialised ports. The first round of the Adaptation Reporting Power ensured some reporting of the steps being taken to manage climate risks.
- The ICT sector has extensive built-in redundancy and private operators compete on the basis of service reliability. However, weather-related risks to ICT networks are not systematically covered by resilience policies. It is unclear whether the sector considers projected climate change in its risk assessments.
- The reports prepared under the second round of the Adaptation Reporting Power (due in 2015) will provide an opportunity for infrastructure operators to provide an update on their climate risks and adaptation actions. However, as participation is voluntary, coverage across all infrastructure sectors is likely to be partial and the least prepared sectors may choose not to report.

At the site level, new infrastructure appears to be designed to account for climate change. However, it is less clear how the planning framework for nationally significant infrastructure assesses the cumulative impacts of separate developments at the national or sub-national scale.

- Major new infrastructure projects like HS2 and the Hinkley Point C nuclear power station are being planned and designed to account for a range of climate risks. It is less clear how climate change is being accounted for in a number of smaller new infrastructure developments that have been recently approved.
- The sector-based National Policy Statements do not provide a strategic national overview to guide the location of new infrastructure, nor does there appear to be an effective mechanism for assessing the cumulative impacts of separate developments at the sub-national scale. Decisions being taken now could build up systemic risk in some areas, for example as a result of regional water shortages or increased coastal flooding.

The provision of national infrastructure should be strengthened in three areas to improve resilience to future climate impacts.

- **Improve monitoring and resilience planning.** As part of infrastructure Sector Resilience Plans, the Cabinet Office Civil Contingencies Secretariat should work with all major infrastructure sectors and lead government departments to ensure consistent monitoring of weather impacts, and advise upon appropriate resilience standards that are in the national interest. Local Resilience Forums should also consider how to encourage more transparent reporting and information sharing amongst infrastructure providers.
- **Strengthen regulatory frameworks**. As part of its review of cross-sector network resilience, the UK Regulators Network should ensure that proportionate and cost-effective approaches to improving resilience and reducing climate risk are in place for economically-regulated sectors. Regulatory arrangements should be used to ensure consistent reporting of risks and adaptation actions.
- **Avoid systemic build-up of risk.** As part of the ongoing development of the infrastructure planning regime, the Department for Communities and Local Government (DCLG) should consider introducing effective mechanisms for the assessment of cumulative risks arising from new infrastructure development at sub-national and national scales, as appropriate. DCLG should also provide guidance on the use of climate projections when interpreting the National Policy Statements to ensure that new infrastructure accounts for the full range of future climate risks.

3.1 Context

Introduction and scope

The Government defines the UK's national infrastructure (NI) as "facilities, systems, sites and networks necessary for the functioning of the country and the delivery of the essential services upon which daily life in the UK depends".[1] It identifies nine sectors as NI: energy, transport, water, information and communication technologies (ICT),[2] food, health care, emergency services, financial services and government itself. This chapter focuses on the first four sectors which provide the core infrastructure on which the remaining five depend, in line with the scope of the Government's vision on climate-resilient infrastructure.[3] The exposure of health, social care, and emergency services infrastructure to climate impacts is discussed in Chapter 4.

We have focussed on assessing the extent to which steps are being taken to protect national infrastructure from the physical impacts from natural hazards such as flooding and storms. Assessing current resilience to extreme weather is important because there are large uncertainties over future changes in the severity and frequency of weather events (Chapter 6). Our analysis has assessed the extent to which infrastructure providers are planning and delivering measures to protect exposed assets and plan for climate change when designing and renewing infrastructure systems.

For some infrastructure networks, built-in spare or back-up capacity is more important to resilience than the physical resistance of assets to natural hazards. This aspect of a resilience strategy is known as redundancy.[4] Telecommunications, for example, have sufficient back-up installations and spare capacity to allow re-routing of communications traffic in the event of failures or loss of components. In contrast, ports operate within a very competitive sector and many of them are highly specialised. The largest ports often handle twice as much cargo (if not more) in their respective area of specialisation than the next largest port. As such, in the case of failure in one of the UK's dominant ports it is unlikely that sufficient spare capacity would be found to avoid disruption.[5] Redundancy characteristics can vary over time: spare capacity in the electricity generation sector, known as capacity margins, is expected to decrease to potentially historically low levels by 2015.[6]

Importance of adapting national infrastructure

The protection of infrastructure is a priority in preparing for climate change. Infrastructure assets and networks are complex, long-lived systems (Annex 3.1) that are exposed to natural hazards (Annex 3.2). Decisions on the renewal of existing infrastructure and on the design and location of new infrastructure should account for projected changes

1 Cabinet Office (2010).
2 In this report, the ICT sector is defined as distributed communications (both fixed line and mobile) and their underlying core network, as well as data centres providing the core digital infrastructure.
3 HM Government (2011).
4 The Cabinet Office (2011) defines four components of infrastructure resilience: resistance, reliability, redundancy, recovery.
5 Grainger and Achutan (2014).
6 Ofgem (2013a).

in climate over the lifetime of the asset, as this is likely to be cheaper than retrofitting or bearing the costs of damages in the future. For some assets, lifetimes can be up to one hundred years or more.

Infrastructure systems are interdependent; many are connected physically or depend on one another to function. Disruptions to individual infrastructure assets can have systemic consequences for other infrastructure sectors and the wider economy.[7]

Assessing vulnerability to the current weather is the starting point to preparing for climate change. Infrastructure operators need to consider both 'resilience' to current weather and 'adaptation' to longer-term climate trends. Government policy for infrastructure resilience is led by Cabinet Office, whilst adaptation policy is led by Defra.

Recent events have shown that infrastructure in England has the potential to be severely damaged by extreme weather.

- During the storms and flooding in winter 2013/14:
  - over 2 million customers suffered power cuts, of which 16,000 were without power for more than 48 hours;
  - an 80 metre section of sea wall collapsed at Dawlish, Devon. This severed the main rail connection between the south-west of England and the rest of the country for around two months;[8]
  - flooding of a privately owned substation at Gatwick airport caused power loss in the North terminal and severe disruption over the busy Christmas period; and
  - the tidal-surge in December 2013[9] resulted in the flooding of a number of privately owned substations that severely affected three major ports, disrupting trade for several days.
- The 2007 floods resulted in the loss of water supplies for 350,000 customers in Gloucestershire for 17 days and the loss of power to 42,000 households.[10] Flooding of motorways left 10,000 people stranded for several hours.[11]

The resilience of national infrastructure is regarded as crucial for economic competitiveness.

- Infrastructure quality and cost is a significant consideration for 98% of companies when making investment decisions. Businesses attach the greatest weight to the quality and reliability of transport (85%) and, increasingly, digital networks (80%).[12]

7 ASC (2010).
8 The rail line took eight weeks to rebuild.
9 The recorded return period for the surge varied by location, but is in the order of 1-in-200 to 1-in-400 according to the National Tide and Sea Level Facility (NTSLF) tide gauges.
10 Cabinet Office (2011).
11 Highways Agency (2011).
12 KPMG (2013) for CBI. Based on 526 respondents from businesses of all sizes and sectors across the UK, including investors in, providers and users of infrastructure.

- Disruptions to infrastructure services have important cost implications for the economy as a whole. The Environment Agency estimates the 2007 floods cost £325 million in disruption to the provision of goods and services in England and Wales. This represents 60% of the total estimated economic costs of the flooding associated with impacts on important national infrastructure, the remainder being the direct physical damages to infrastructure assets.[13]

Future demand and planned investment

In the coming decades, infrastructure will have to meet an increasing demand while supporting the transition to a low carbon economy (Annex 3.3).

- Demand will increase as England's population is expected to rise from 53 million in 2010 to 62 million in 2035.[14] Failure to meet this demand could constrain economic growth. For instance, the Eddington Review[15] estimated that increased congestion could cost the economy £22 billion per year if the transport network does not keep up with demand.
- Reducing greenhouse gas emissions by at least 80% by 2050 from 1990 levels will require significant investment in infrastructure.[16] Research commissioned by the Committee on Climate Change shows that between now and 2030, low-carbon infrastructure could cost up to £8 billion for carbon capture and storage (CCS), and £17-21 billion for electricity transmission and distribution (compared to a 'no climate action' scenario).[17]

There are plans for more than £375 billion to be invested in infrastructure over the next decade.[18] This provides an opportunity to improve infrastructure resilience to the future climate.

- The Government has pledged to increase capital spending on infrastructure by £3 billion per year by 2015-16, and committed £18 billion in total to be spent over the five years of the next Parliament. On transport, annual road investment should triple by 2021 and £16 billion is planned until 2019 towards the construction of HS2.[19]
- A third of infrastructure in the 2013 National Infrastructure Plan is publicly procured and funded,[20] and elsewhere the Government plays a key role to incentivise and facilitate action in regulated markets and in non-regulated sectors (Box 3.1).

13 Adapted from Table 2.2 in Environment Agency (2010).
14 ONS (2014b).
15 Eddington, R. (2006).
16 ICE (2009).
17 Element Energy and Imperial College London (2013).
18 HM Treasury (2013a).
19 *Ibid.*
20 HM Treasury (2014).

Box 3.1: Government policy on infrastructure delivery

The National infrastructure Plan

The 2010 National Infrastructure Plan describes the overall approach to delivering national infrastructure. It recognises climate change mitigation and adaptation as one of the five major drivers that will have a long-term impact on the country's infrastructure. The Plan is updated annually with a specific section on infrastructure delivery, known as the 'pipeline'. The pipeline is a forward-looking, bottom-up assessment of potential public and private investment in infrastructure to 2020 and beyond, focusing on large infrastructure projects with a capital value of £50 million or more. The 2013 Plan identified a pipeline of 650 planned infrastructure projects and programmes worth £375 billion over the next decade, of which 45% is already in construction. The majority of investment is planned in the energy (£218 billion) and transport (£121 billion) sectors.

Infrastructure UK

This Treasury-based unit leads on the Government's cross-sectoral work on infrastructure and prepares the National Infrastructure Plan. Its role is to provide a stronger focus to the UK's long-term infrastructure priorities, encourage cost efficiency, and facilitate private sector investment.

National Policy Statements

Produced by the relevant lead government department, each National Policy Statement (NPS) states the Government's objectives for the development of nationally significant infrastructure in the sector, including how actual and projected capacity and demand have been taken into account. They include an explanation of how mitigation of, and adaptation to, climate change should be accounted for. There are twelve designated or proposed NPSs (Section 3.4).

Source: HM Treasury (2010), HM Treasury (2013a).

Policy framework for infrastructure resilience and adaptation

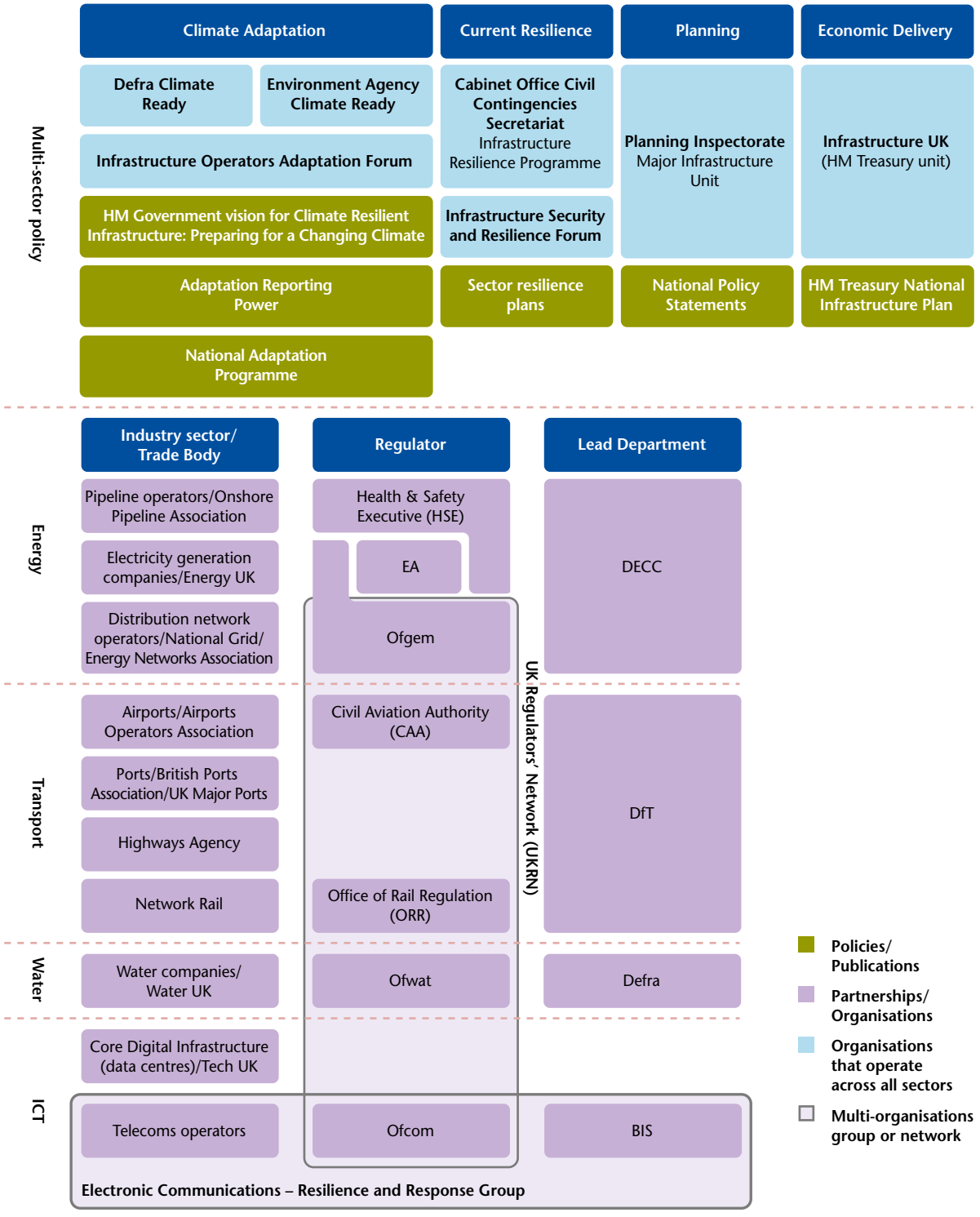
A wide range of stakeholders including the Government, industry and regulators are involved in assessing and planning for the resilience of infrastructure assets (Figure 3.1).

Government policy on infrastructure adaptation is coordinated by Defra with the relevant lead government departments. Following a two-year research programme,[21] the Government published its policy on infrastructure adaptation in 2011.[22] Following this, the National Adaptation Programme contains policy objectives and specific actions on infrastructure resilience (Box 3.2).

The Pitt Review into the 2007 flooding prompted the establishment of the Critical Infrastructure Resilience Programme within the Cabinet Office Civil Contingencies Secretariat. Lead government departments are required to produce Sector Resilience Plans every year, assessing the resilience of the UK's most important infrastructure to disruption from civil emergencies. The individual plans are classified, but are summarised in a high-level public document. In the National Security Strategy, the Cabinet Office identified natural hazards as one of the top risks to the UK's national infrastructure. The Cabinet Office produced a strategic framework and a practical guide to support building resilience to natural hazards.[23]

21 Defra (2011c).
22 HM Government (2011).
23 Cabinet Office (2010), Cabinet Office (2011).

Figure 3.1: Governance structure of infrastructure resilience and adaptation in England



Source: ASC.
Notes: The Health and Safety Executive (HSE) regulates the major hazards for pipeline operators and for electricity generation companies. Electricity generation companies are also regulated by Ofgem and the Environment Agency (noted 'EA' in the above chart) with regards to water abstraction licenses and the temperature and quality of the water they discharge to the environment. Water companies are also regulated by the Drinking Water Inspectorate (DWI) for water quality, and the Environment Agency for sustainable abstraction, but the resilience duty lies with their economic regulator, Ofwat.

The 2013/14 winter storms have prompted further reviews into infrastructure resilience. The new Cabinet Committee on Flooding has commissioned an annual resilience review to consider the local, regional and national response to extreme weather. The Department of Transport also commissioned a transport-focused resilience review.[24]

Box 3.2: Government policy on infrastructure adaptation to climate change

The Adaptation Reporting Power (2009)

The 2008 Climate Change Act grants the Secretary of State a power to request organisations 'with functions of a public nature' to undertake an assessment of the risks they face from climate change and how they plan to address those risks. For the first round in 2009, 91 key infrastructure providers and regulators in the water, energy and transport sectors as well as public bodies, such as the Environment Agency were requested to report. Defra launched a second round of reporting in 2013, but organisations will decide whether to report or not on a voluntary basis.

Government Vision and Action Plan for a Climate-Resilient Infrastructure (2011)

The report sets out the Government's policy on securing an energy, transport, water and ICT sectors 'resilient to today's natural hazards and prepared for the future changing climate', and how government can facilitate progress through 32 actions including:

- access to climate information, disclosure of risk and evidence;
- monitoring progress made on infrastructure adaptation;
- regulatory models; and
- the planning system for nationally significant infrastructure.

An implementation update was published alongside the National Adaptation Programme.

National Adaptation Programme (2013)

Infrastructure is one of six thematic chapters in the National Adaptation Programme (NAP). The objectives broadly aim to:

- strengthen the adaptive capacity of the energy, transport and water sectors through improving their asset management and the regulatory framework; and
- better understand local infrastructure vulnerability and infrastructure interdependencies, to determine actions to address risks.

The chapter lists a number of specific actions for the Government, industry bodies and regulators that can be categorised as:

- operators to implement the actions set out in their reports under the Adaptation Reporting Power;
- lead departments to factor in the changing climate when developing or implementing policy, for instance DECC on the design of the capacity market, as part of the Electricity Market Reform;
- encouraging joint working (e.g. DfT, UK Roads Liaison Group, ADEPT and Climate UK on local transport), pursuing existing initiatives (e.g. Operators Adaptation Forum) or existing research (e.g. Infrastructure Transitions Research Consortium); and
- announcing new research, such as area drainage plans and surface water flood maps by water companies and lead local flood authorities.

Source: HM Government (2011), HM Government (2013).

24 Reviews respectively led by Rt Hon. Oliver Letwin MP and Richard Brown CBE.

There has also been a significant amount of academic research into infrastructure resilience and adaptation in recent years, focussing particularly on interdependencies.

- The Infrastructure Transitions Research Consortium (ITRC) has developed a national risk model to assess the impacts of climate-related network failures on the economy and identify vulnerabilities under different scenarios.
- The International Centre for Infrastructure Futures (ICIF)[25] is developing an interdependencies planning and management framework for Infrastructure UK. Infrastructure UK is updating its 'Infrastructure Policy Timelines' document to identify interdependencies between sectors. Infrastructure UK has also launched a study on interdependencies valuations, to inform the HM Treasury Green Book guidance on policy appraisal in central Government.
- The dependency of the energy sector on water resources is being studied by the Environment Agency and Energy UK. Separate research by the Energy Research Partnership and UK Energy Research Centre is considering governance implications for water-energy interdependencies.

3.2 Current and future exposure to natural hazards

Current impacts

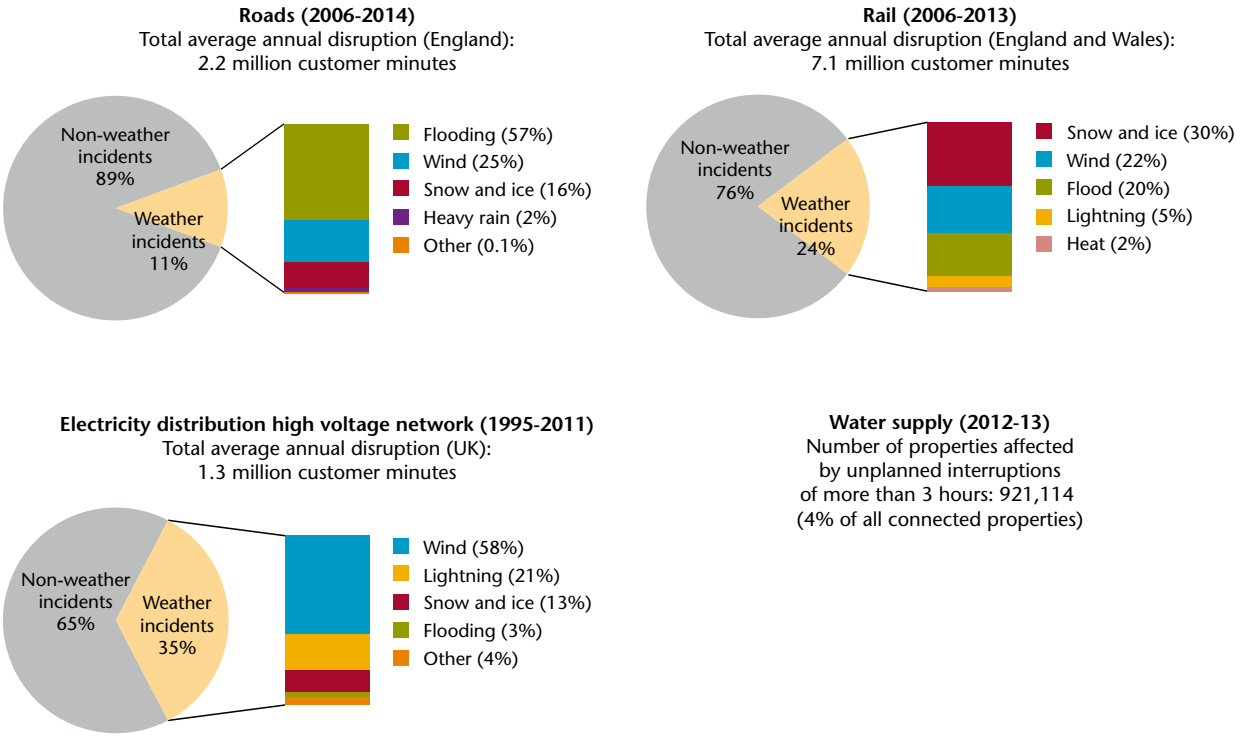
The electricity transmission and distribution, road and rail sectors all monitor disruption caused by natural hazards. In these sectors between 10% and 35% of all disruption is weather-related (Figure 3.2).

- *Electricity transmission and distribution:* The National Fault and Interruption Reporting Scheme (NaFIRS) mandates that distribution network operators (DNOs) report disruptions using common classifications, including weather and environment-related events. Between 1995 and 2012, 35% of all customer minutes lost from high-voltage substations were due to natural hazards. High winds and storm damage were the major causes of weather-related disruption. Although less frequent, flooding caused the longest average length of disruption per incident. Disruptions to the transmission network are rarer and at near-zero levels.[26]
- *Rail:* Network Rail monitors performance disruption, including incidents due to weather.[27] Over one-fifth of rail passenger delay minutes are caused by weather, mainly due to snow and flooding. Industry data shows that about 25% of all delays are caused by problems with network infrastructure such as earthworks, bridges and sea walls.[28] These disruptions can often last for long time periods as was the case with the Dawlish sea wall collapse.

25 ICIF, ITRC and other relevant infrastructure projects form part of the Adaptation and Resilience in the Context of Change (ARCC) Network managed by the UK Climate Impacts Programme (UKCIP).
26 Ofgem (2013a).
27 The current methodology used to attribute delay was been in place since 2006.
28 ORR (2013a).

- *Strategic roads:* The Highways Agency has been recording disruptions due to weather-related causes since 2004.[29] Over 10% of delays on the strategic road network (i.e. motorways and trunk roads) are attributable to the weather, mainly flooding.
- *Electricity generation:* Unplanned disruptions to power stations are reported to the National Electricity Transmission System Operator (GB NETSO). These have not caused power outages as the transmission network is able to supply customers from other sites or sources in case of disruption.

Figure 3.2: Disruption to key national infrastructure sectors and proportion of disruption attributed to weather-related incidents



Source: Network Rail, Highways Agency, National Fault and Interruption Reporting Scheme (NaFIRS), Ofwat (2013).
Notes: Disaggregated data on weather-related disruptions is not available for water companies, ports and airports, ICT and electricity generation. Unplanned disruptions in the water sector are recorded by Ofwat as DG3 key performance indicator. Customers for roads and rail relate to both passenger and freight traffic. Disruptions to the rail sector only refer to those due to the network infrastructure, and not caused by Transport Operating Companies (TOCs).

Evidence of weather-related disruption to water infrastructure, ICT, ports and airports is not consistently collected or transparently reported.

- *Water:* Disruptions to supply are reported to the regulator (Ofwat) to inform a key performance indicator, but there are no industry-wide classifications that allow the cause of disruption to be determined.[30]

29 A report commissioned by the Highways Agency noted limited evidence of the impact of hotter, drier summers on highway assets and recommended improving the monitoring of these impacts. Atkins (2013).
30 The DG3 indicator records disruptions longer than 3 hours but companies' targets relate to disruptions longer than 12 hours.

- *ICT:* Under the 2010 Digital Communications Act, telecommunications companies report incidents that exceed a certain threshold[31] but do not identify the subset that are weather-related.[32] Faults to data centres are recorded, but these reports are confidential.
- *Ports:* Information on impacts from extreme weather events or on general 'downtime' is not centrally collected. Data collected by individual ports tend to be commercially confidential.
- *Airports:* The Civil Aviation Authority (CAA) records quarterly punctuality data broken down by airport and scheduled versus charter flights, but does not identify the cause of delays.

Current and future exposure to river and coastal flooding

Between 5% and 42% of the infrastructure assets we assessed are located in areas susceptible to flooding from rivers or the sea (Figure 3.3).[33] Some sectors, such as water and waste water treatment, and electricity generation infrastructure, have more assets in areas at risk than other sectors as their facilities need to be situated near rivers or estuaries.

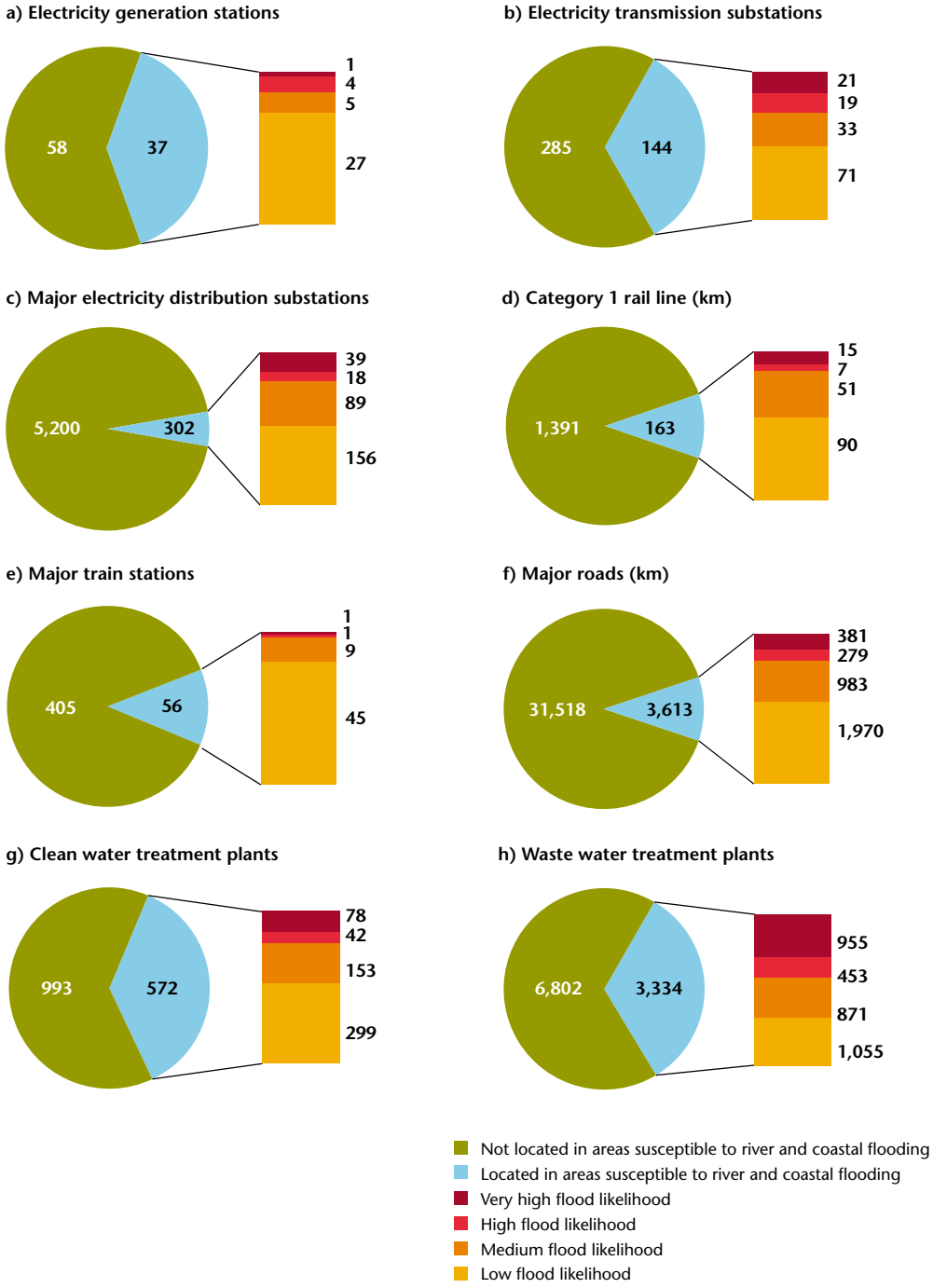
Even where assets are susceptible, the majority are in areas at relatively low likelihood of flooding as a result of community-scale defences being in place. Low proportions of assets are located in areas with a high likelihood of flooding.[34] The exception is waste water treatment plants where nearly 10% of assets are in high likelihood areas. However, the consequences of flooding for waste water plants are less severe than for other infrastructure assets. The focus for such plants is on making sure they can be brought back in to operation quickly once the flood waters have receded.[35]

Although there are relatively few assets located in areas with a high likelihood of flooding, the impacts when these assets are flooded can be far-reaching. Data from electricity distribution companies shows that over 700,000 homes and businesses, three water treatment works and one hospital are directly reliant on the 57 major substations located in areas with a very high or high likelihood of flooding (Figure 3.4).

The proportion of infrastructure exposed to flooding from rivers and the sea is projected to increase for all sectors by the 2050s. For some sectors there could potentially be a near doubling of the number of assets exposed from current levels (Figure 3.5).

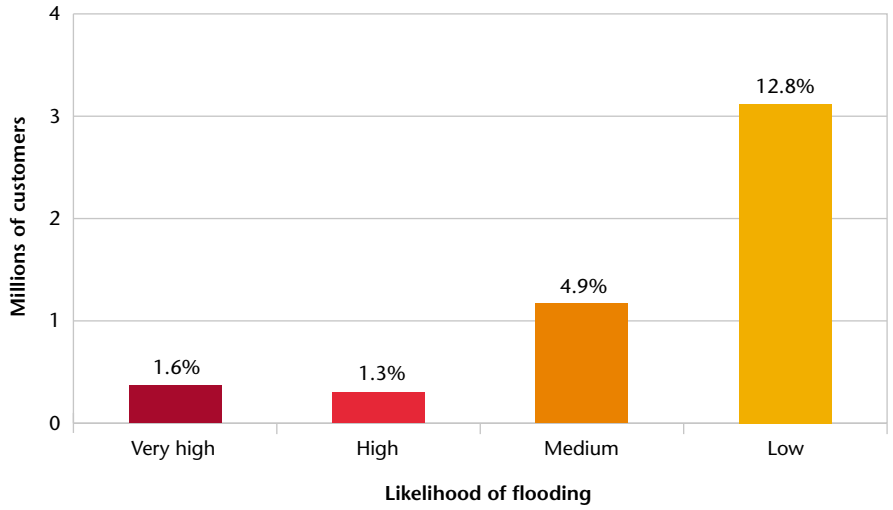
31 Disruptions affecting more than 1,000 customers for more than an hour. European regulations also require large scale disruptions to be reported to the European Network and Information Security Agency (ENISA).
32 The current system is being reviewed by the regulator Ofcom as it is thought that disruption is under-reported and the system disadvantages fixed services compared to mobile operators.
33 It is important to note that our analysis is at a national scale and so does not account for site-level factors. Assets may be located in apparently hazardous areas but in reality be at a very low risk of being affected. For example, a railway line or road located in the floodplain may be elevated on an embankment.
34 Defined as greater than a 1-in-30 annual chance after accounting for the presence of community-scale flood defences.
35 WrC (2014).

Figure 3.3: Infrastructure assets located in areas susceptible to river and coastal flooding and at differing likelihoods of being flooded, after accounting for the presence of community-scale flood defences



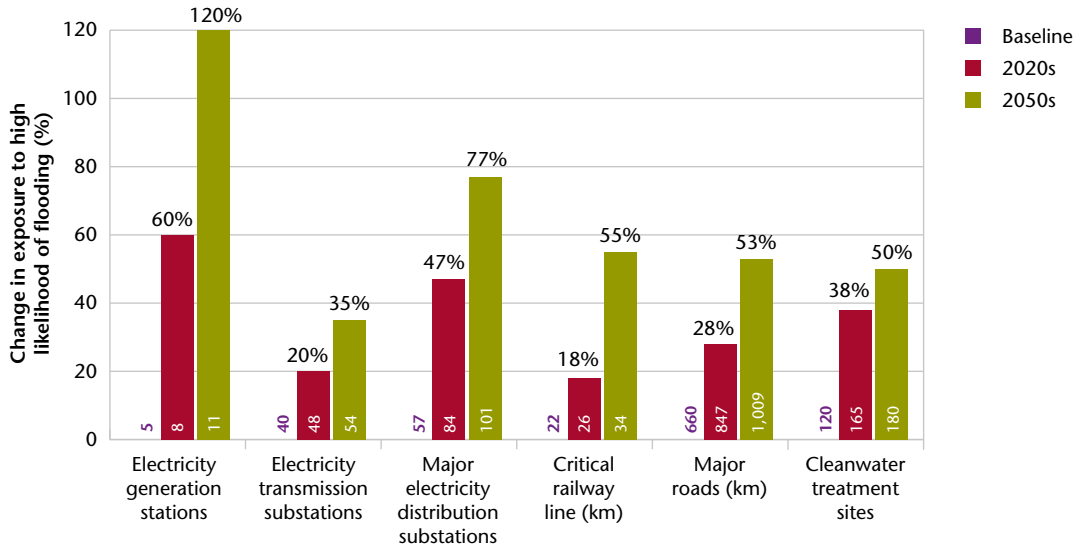
Source: HR Wallingford (2014c) for the ASC.
Notes: A method for undertaking a national scale assessment of potential exposure was developed using a Geographical Information System (GIS). Multiple layers of data on hazards (e.g. flooding) and location of infrastructure assets were built into a high-resolution spatial database. For river and coastal flooding, the Environment Agency's 2013 National Flood Risk Assessment (NaFRA) dataset was used. It defines the likelihood of the onset of flooding from rivers or the sea and enables a comparison of the relative risks and their distribution. NaFRA does not take any account of site level resilience, such as any site-specific flood proofing. It is therefore not possible to provide an indication of the specific vulnerability of individual assets. NaFRA does, however, take into account the presence and condition of community-scale flood defences. The different likelihood categories are as follows:
– Low: Less than 1-in-100 (1%) chance of flooding in any given year.
– Medium: Less than 1-in-30 (3.3%) but greater than or equal to 1-in-100 (1%) chance in any given year.
– High: Greater than or equal to 1-in-30 (3.3%) chance in any given year.
– Very high: Greater than or equal to 1-in-10 (10%) chance in any given year.
Major distribution substations are defined as those with a voltage between 6.6 to 132 kV. Category 1 railine is the mainline and commuter routes in and out of London and other major cities. Major train stations are those with at least 1 million passenger entrances and exits per year. Major roads include all A-roads, and are larger than the strategic road network operated by the Highways Agency, which only includes motorways and trunk roads.

Figure 3.4: Number and proportion of customers reliant on major electricity distribution substations located in areas at differing likelihoods of river and coastal flooding, after accounting for the presence of community-scale flood defences.



Source: HR Wallingford (2014c) for the ASC with data provided by Energy Networks Association.
Notes: The Distribution Network Operators have identified the number of substations located within the floodplain or that are at risk of surface water flooding through the ETR138 process and provide annual returns to Ofgem on the progress being made with flood mitigation. We used this data to identify those substations which are located within areas of very high, high, medium and low likelihood of flooding using the Environment Agency's NaFRA model. The DNO returns to Ofgem also include data on the number of customers directly reliant on those substations at flood risk. Note that one customer equates to one household or business. The total number of customers was derived from Ofgem (2012). The DNO returns to Ofgem also record the number of 'critical' customers reliant on substations located in the floodplain. These include waterworks, hospitals, railway infrastructure and large industrial sites. A total of 77 individual critical customers are directly reliant on major substations located in the floodplain, of which 8 are reliant on substations located in areas with a high or very high likelihood of flooding including 3 waterworks and 1 hospital.

Figure 3.5: Projections of the number of infrastructure assets located in areas with a high or very high likelihood of river and coastal flooding, after accounting for the presence of community-scale defences.



Source: HR Wallingford (2014c) for the ASC.
Notes: The red and green bars show the percentage increase in the number of assets in high (or very high) flood risk areas (1-in-30 annual chance or greater) in the 2020s, and 2050s, compared to a baseline. The 2020s relates to the 30-year epoch from 2010 to 2039, and the 2050s from 2040 to 2069. The figures at the base of the bars show the absolute number of assets located in these areas for each epoch.
The current annual likelihood of flooding provided by the Environment Agency's 2013 NaFRA dataset has been uplifted based upon the expected increases in peak flows estimated in the 2012 UK Climate Change Risk Assessment (CCRA). These increases are based on UKCP09 precipitation projections. The underlying river flow data on which NaFRA is based has a variety of start and end dates. The increases in river flows have a baseline period of 1961-90; there is little evidence to suggest that peak river flows have changed significantly since then as a result of climate change (see chapter 6 of the CCRA for more information). The analysis assumes no increase in the extent of flooding, only changes in annual likelihood. Assets are assumed to remain located in the same areas as the present day, which may not be the case for all assets. Current community-scale defences are assumed to remain in place and to be maintained, but not enhanced.
Large electricity generation stations are defined as those with a capacity greater than 1,000 MW. Major distribution substations are defined as those with a voltage between 6.6 to 132 kV. Category 1 rail line is the mainline and commuter routes in and out of London and other major cities. Major train stations are those with at least 1 million passenger entrances and exits per year. Major roads include all A-roads, so is a more extensive category than the strategic road network operated by the Highways Agency, which only includes motorways and trunk roads.

Current and future exposure to surface water and groundwater flooding, subsidence, landslides and coastal erosion

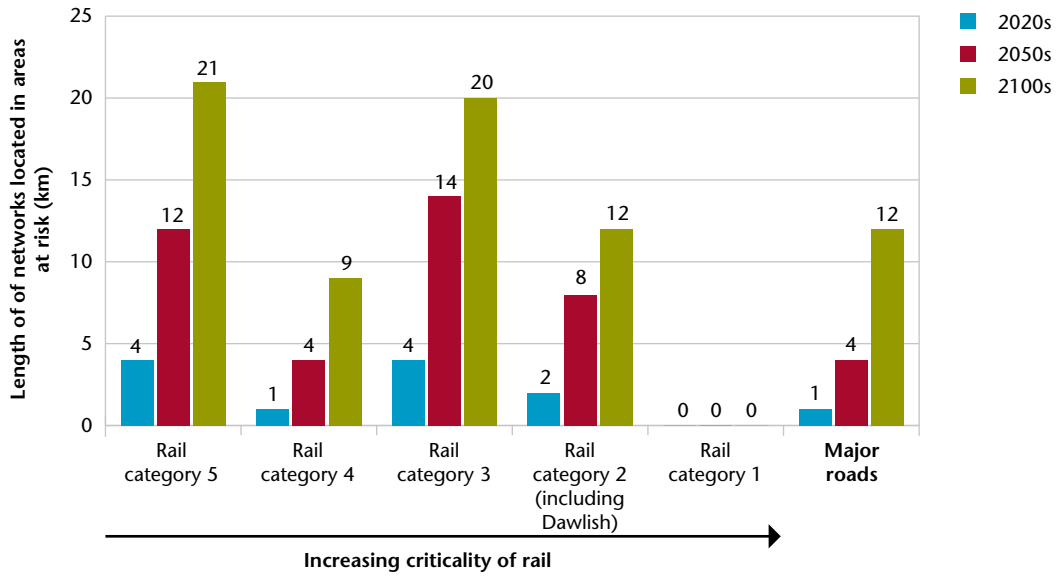
Infrastructure assets are currently exposed to a range of other natural hazards (Annex 3.4):

- *Surface water flooding:* Heavy rainfall can cause localised flash flooding, depending on local topography and drainage capacity. In our assessment, relatively low proportions of infrastructure assets are located in areas currently susceptible to this hazard.
- *Groundwater flooding:* Long periods of sustained rainfall can result in groundwater emerging above the surface in some areas, depending on a range of localised factors including soil type, geology, drainage and the presence of aquifers. We found that up to one-quarter of power stations, transmission substations and waste water treatment plants are located in areas with a high susceptibility to groundwater flooding.
- *Subsidence:* The deformation of the ground has the potential to damage the foundations of buildings and other infrastructure. One of the most widespread forms of subsidence is the shrinking and swelling of clay soils due to excessive rainfall, drought or land use changes.[36] Susceptibility of underground infrastructure assets, such as gas pipelines and electricity cables, as well as some above ground assets like electricity pylons and telecommunication towers is high in areas with where clay soils dominate, such as around London and the east of England.
- *Landslides:* The movement of a mass of rock, earth or debris down a slope, can damage infrastructure and block transport networks. Landslides can be triggered by excessive rainfall, as well as other natural processes such as erosion.[37] Susceptibility to landslides will depend on landform and underlying geology with the highest risk in parts of the south west and north west of England.[38] However, in our analysis a very low proportion of infrastructure is located in areas that are highly susceptible to natural landslides.
- *Coastal erosion:* Stretches of the English coastline are actively eroding, a natural process that can be exacerbated by heavy or prolonged rainfall and coastal storms. In our analysis, 11km of the 2,000km of the entire railway network in England is located in areas that are potentially at risk within the next 20 years, in the absence of coastal protection. This includes 1.5km at Dawlish in Devon, as well as small sections of track in other parts of the southern and eastern coast and in the north-west.[39] None of the Category 1 parts of the rail network and typically less than 1% of other infrastructure assets, including major roads, are in high risk areas. However, a relatively high proportion (10%) of underground gas pipelines is located in areas at risk of erosion within the next 20 years.

The length of railway and major roads exposed to coastal erosion is expected to increase over the rest of the century. Sea level rise is expected to increase the rate of erosion in some parts of the coast, resulting in higher numbers of properties and infrastructure assets becoming exposed.[40] Without adaptation, this could have significant implications for the rail network as well as, to a lesser extent, major roads (Figure 3.6).

36 According to the British Geological Survey, shrink–swell is the most damaging geo-hazard in Britain today, costing the economy an estimated £3 billion over the past 10 years (BGS, 2014).
37 Human activity can also contribute to the likelihood of a landslide, particularly the alteration of drainage, loading of the slope or the removal of material from the toe of the slope.
38 See HR Wallingford (2014c) for the ASC for a map depicting areas with a high susceptibility to natural landslides.
39 Of the 11km at risk, 16% is in Category 2 (including Dawlish), 40% is in Category 3 (mostly in the south east in areas like Hastings), 8% in Category 4 (mostly in the south west) and 36% in Category 5 (in the north west and south west). These categories are based on the average cost of a delay (related to the volume of traffic) and as such the most critical parts of the network are mostly inland.
40 Around 60,000 properties are located within areas that are predicted to be at risk of erosion within the next 100 years.

Figure 3.6: Projections of the length of railway and major road networks located in areas at risk of coastal erosion



Source: HR Wallingford (2014c) for the ASC.
Notes: National Coastal Erosion Risk Mapping (NCERM) data from the Environment Agency provides nationally consistent information for the purpose of regional management planning activities. The data describe the upper and lower estimates of erosion risk at a particular location, within which the actual location of the coastline is expected to lie. It is intended as an up-to-date and reliable benchmark dataset showing erosion extents and rates for three periods and across different Shoreline Management Plan (SMP) policy scenarios:
– Short Term (0 – 20yr).
– Medium Term (20 – 50yr).
– Long Term (50 – 100yr).
In addition to the time periods, the data for erodible coastlines provides recession rates for the fifth percentile (five per cent chance of the recession being greater than the given amount within the assessment term), fiftieth percentile (50% chance of the recession being greater than the given amount) and ninety-fifth percentile (95% chance of the recession being greater than the given amount), giving a measure of uncertainty. For the purpose of the indicators related to this hazard, assets are counted if they are within the estimated erosion zone for each time period and at the 5 percentile predicted erosion rate to provide a cautious assessment for the indicator. Rates of erosion take account of the preferred policy identified within SMPs for each stretch of coast.

Current and future exposure to high temperatures, high winds, snow, fog and lightning

Exposure of assets to high temperatures is projected to increase, although the impacts on infrastructure are not expected to be substantial. Much of the mechanical and electrical equipment used in the UK is designed to international standards, which means they can operate in a hotter climate than the UK and can be expected to cope as temperatures increase.[41]

Snow and ice, high winds, fog, and lightning strikes are by their nature widespread, and the influence of location on the severity of hazards is less relevant than other climate hazards. Nonetheless, it is feasible to monitor these hazards over time and assess the impact they have on infrastructure. The climate projections for these hazards are highly uncertain, and currently show minimal changes.

41 The EP2 project by the Met Office (2012) found that with a few exceptions, such as the thermal ratings of equipment and apparatus, there is currently no evidence to support adjusting network design standards.

Current and future exposure of electricity generation to water scarcity and drought

Almost one quarter (16 GW) of electricity capacity from thermoelectric power plants relies on freshwater for cooling. Around 60% of all power plants in England are cooled with sea and tidal water, including all nuclear generation.[42] 12% of power plants rely on freshwater for cooling, together accounting for 16GW capacity, or nearly one-quarter of total capacity. 200 million m³ of freshwater was used for cooling power plants in 2012,[43] of which around half was returned to the environment.

Almost all electricity generation that relies on freshwater abstraction is situated in catchments that currently have sufficient water available. Only two power stations that rely on freshwater for cooling are located in areas where there is not enough water available for abstraction and the environment during an average summer. These power stations have a combined capacity of 0.5 GW. The remaining power stations reliant on freshwater are located in catchments that have sufficient water available year round. This is because freshwater abstraction for electricity generation generally takes place in the lower reaches of large rivers like the Trent and the Humber that are at a minimal risk of being affected by low flows.

Any increase in water scarcity or temperature in the future may reduce the capacity and effectiveness of freshwater cooling water systems. Freshwater used for cooling is returned to the environment at a higher temperature. Any increases in average water temperature due to climate change may therefore increase the likelihood of cooling water causing environmental damage when it is returned. This could in turn result in some power stations being unable to abstract during periods when water temperature is high because of potential environmental damage, or when there is insufficient water available in a catchment. Energy companies have, however, identified this as a 'low-to-medium' risk.[44]

Changes to energy generation in the future may increase demand for freshwater in some locations. Some scenarios of the future energy mix suggest a wider deployment of technologies that are relatively water-intensive, such as carbon capture and storage (CCS). Plants fitted with carbon capture consume from 44% to 84% more water per unit of power than traditional fossil fuel fired power stations, due to an increase in cooling and process uses.[45] The fitting of CCS to gas and coal power plants currently located in Yorkshire, and potentially in Teeside[46] could add pressure to three catchments, two of which may become at risk of water stress by the 2050s with climate change.[47] The overall impact of CCS on water resources is uncertain, as the technology can use tidal water for cooling.

42 Accounting for operational and approved thermal capacity, and not including the capacity scheduled to close by 2023 under the Large Plant Combustion Directive.
43 This equates to around 2% of all freshwater abstraction in England, according to Defra (2013f).
44 AEP (2011).
45 Parsons Brinckerhoff (2012).
46 In 2014, the White Rose CCS project in North Yorkshire was awarded multi-million pound contracts to undertake Front End Engineering and Design (FEED) studies from the Department for Energy and Climate Change. Tees Valley Unlimited has been awarded £1million for pre-FEED studies on industrial CCS.
47 Tees, Aire and Calder, Louth Grimsby and Ancholme, from standard flow scenarios C, J and G in Environment Agency (2013a).

3.3 Progress in improving resilience and adapting to climate risks

We have found evidence that the electricity transmission and distribution sector, and to a lesser degree the rail sector, are assessing climate risks, taking action in response, and reporting on progress against plans. There is less evidence available within the other sectors we have explored (Table 3.1).

Table 3.1: Summary of the ASC's assessment of progress in improving resilience and adapting to climate risks

Sector	Risk assessment	Resilience measures	Progress reporting
Electricity transmission and distribution			
Rail			
Strategic Road Network			
Ports			
Airports			
Water			
ICT			

Source: ASC.
Notes: These colours refer to whether we have complete (Green), partial (Amber), or no evidence (Red) for the following:
– Risk assessment: Evidence of detailed assessments to understand how current weather and projected changes in climate are likely to affect operations.
– Resilience measures: Identification of resilience measures to reduce risks based on cost-benefit assessments (sector/companies may not be on track to achieve all their targets).
– Progress reporting: Regular reporting on progress in implementing resilience measures in a clear and publicly available format (this information may not be in a specific publication focusing solely on resilience).
Note that an Amber may mean that some, but not all, companies within a sector provide evidence.

Electricity transmission and distribution

Risk assessment

The electricity transmission and distribution sector has developed technical standards for managing current and future risks from flooding and storms. These provide a consistent approach across the industry to identifying the most critical assets at the highest level of risk in order to prioritise action (Box 3.3). Application of these standards is used to make a business case to the regulator for funding resilience measures that provide value for money to the consumer through the price control process. The process includes an assessment of the risks from climate change.

Box 3.3: Energy Network Association Technical Reports: A transparent and accountable approach to improving the resilience of the electricity distribution network in a changing climate

ETR132: Overhead line vegetation management

Tree-related faults on the UK network significantly increased between 1990 and 2006. The observed increase in the duration of the growing season, which has gained ten days in Northern Europe since the 1960s and is projected to continue, is likely to be contributing to this trend.

Network operators have a statutory requirement to keep overhead power lines clear of vegetation for public safety reasons, but since 2006 operators have also been required to undertake a risk assessed programme of "resilience vegetation management".

The Energy Networks Association (ENA) produced an Engineering Technical Report (ETR132) in 2006 to guide implementation against this requirement. The standard requires operators to deliver proactive tree cutting and felling programmes targeted towards critical overhead lines, to improve performance in storm conditions.

ETR138: Resilience to flooding

The 2007 floods highlighted the potential vulnerability of major electricity substations to large flooding events as well as the lack of industry-wide standards to assess acceptable levels of flood risk. As a result, a Task Group was established consisting of industry, government, Environment Agency and Met Office representatives, together with members of the Pitt Review team, and the regulator Ofgem. The Task Group developed a common approach to the assessment of flood risk and risk mitigation measures to deploy subject to a cost-benefit assessment.

The resulting standard published in 2009 sets out a six step approach:

- Identify all substations located within the river and coastal floodplain.
- Undertake detailed flood risk assessments for each individual substation to model how projected flood depths could affect vulnerable components. The flood risk assessment should add 20% to predicted flood depths to allow for projected increases in peak river flows. Sites in the coastal floodplain should apply standard allowances for sea level rise for the lifetime of the assets (nominally 60 years).
- Identify the consequences of each 'at risk' substation being flooded, in terms of number of customers that would be directly or indirectly affected and impacts on the wider network.
- Establish the current level of protection from existing flood defence schemes operated by public bodies such as the Environment Agency or local authorities.
- Establish the most appropriate options for further protecting the site, and the associated costs.
- Propose an appropriate solution based on a cost-benefit assessment.

Source: ENA (2006), ENA (2009), ENA (2011).

The electricity generation companies adopted a coordinated approach to assessing their risks from climate change under the ARP process. The Association of Electricity Producers[48] agreed a common template for categorizing and reporting risks, which were then used by the individual energy company ARP reports in 2011.

Resilience measures

Around £330 million will be spent by the electricity transmission and distribution sector on measures to enhance resilience to flooding and storms between 2011 and 2023.[49] This expenditure has been agreed with the regulator based on an assessment

48 The AEP has now become Energy UK.

49 Information obtained from Ofgem on annual expenditure by Distribution Network Operators in England. Note that the Licence Boundary of one network operator (Scottish Power Manweb) spans both North Wales and parts of mid Cheshire, Wirral and Merseyside. Their expenditure cannot be separated into a Welsh/English territory and consequently has been omitted – thus the expenditure figures stated below are a slight understatement of the overall English level.

of costs and benefits and the willingness to pay for the investment amongst electricity customers and breaks down into:

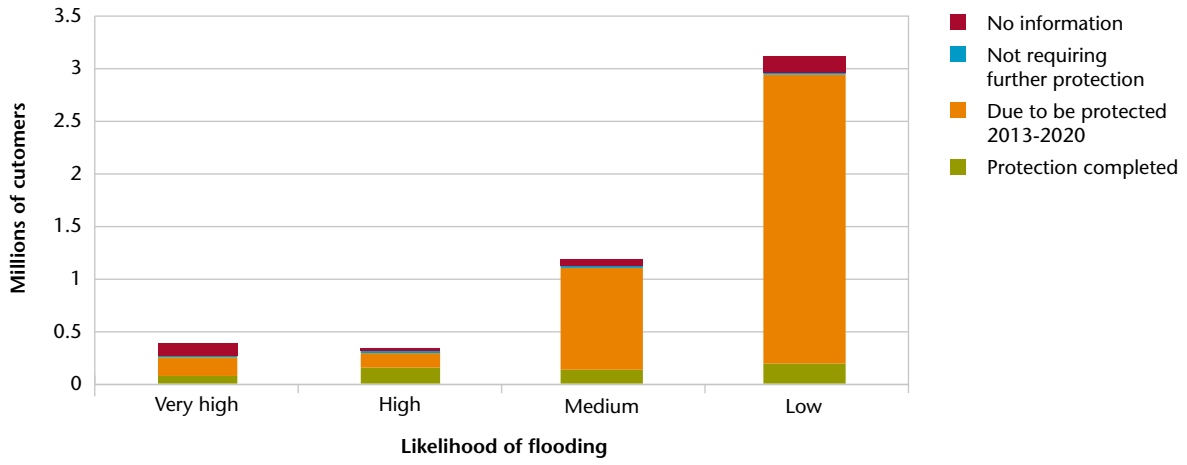
- *Flood resilience measures*: £12 million annual spend between 2011 and 2014 and £21 million forecast spend in 2015. Projected annual spend from 2016 to 2023 is £13 million, meaning total expenditure of £172 million over the period 2011 to 2023. If implemented, this investment will deliver additional protection to all those substations identified as being at risk by the ETR 138 process.
- *Resilience vegetation management*: £8 million annual spend between 2011 and 2014 and £11 million forecast spend in 2015. Projected annual spend of £15 million from 2016 to 2023, resulting in total expenditure of £158 million over the period 2011 to 2023.[50]

Progress reporting

The electricity network operators report annually to Ofgem on the progress made in delivering flood resilience measures agreed through the ETR 138 process.

- By 2013, flood risk assessments had been completed for nearly 80% of the major distribution substations identified as being at flood risk. The remaining substations are due to have flood risk assessments completed by 2015.[51]
- Progress with the implementation of flood protection measures generally appears to be on track (Figure 3.7), with nearly 20% of the 300 major substations located in areas susceptible to river and coastal flooding having already benefitted from protection and most of the remainder on course to have measures implemented by 2020.[52]

Figure 3.7: Number of customers reliant on major electricity distribution substations located in areas susceptible to river and coastal flooding at differing flood likelihoods that have protection measures completed or due to be completed

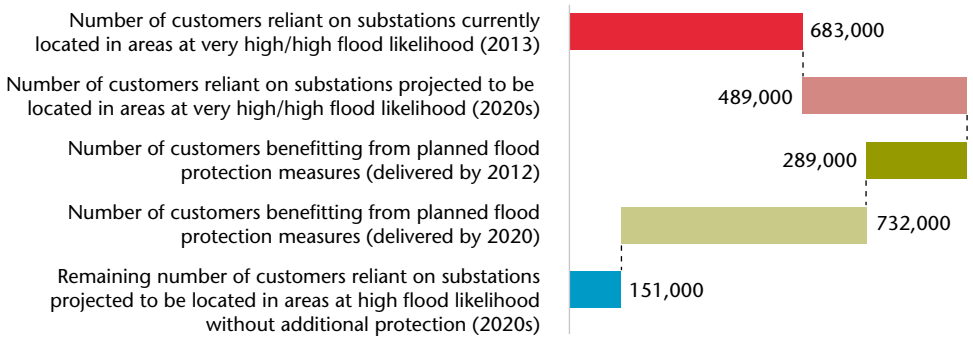


Source: HR Wallingford (2014c) for the ASC, using data from the Distribution Network Operators submissions to Ofgem.
Notes: The Distribution Network Operators provide annual returns to Ofgem on the progress being made with flood mitigation (known as the V11 returns). We used the data in the V11 returns to assess the number of major substations located within areas of very high, high, moderate and low likelihood of river and coastal flooding that have had protection works completed, or due to be completed.

50 Note that a further £1 million will have been spent on cyclic tree cutting for safety clearance between 2011 and 2013, which is distinguished from the risk-based proactive resilience vegetation management set out in ETR132 (as described in Box 3.3).
51 Note that information on whether an FRA had been completed or is due to be completed was not available for 31 of the 300 substations.
52 In theory, substations located in areas at the highest likelihood of flooding should be protected first, but in practice the phasing of work can be tied to asset replacement or public flood defence programmes, so this is not always the case.

As progress is being reported for electricity transmission and distribution, it is possible to assess whether additional effort is needed when accounting for climate change. In our analysis, the number of major electricity substations located in areas with a high or very high likelihood of flooding is likely to increase from 57 currently to 84 in the 2020s (see Figure 3.5). If this were to be the case, then the number of customers directly reliant on those substations would also increase, from 683,000 to almost 1.2 million. The electricity distribution companies had, by 2012, implemented flood resilience measures to 19 major substations in areas of high flood likelihood, reducing the number of customers potentially at risk by nearly 289,000. The delivery of planned flood resilience measures between 2012 and 2020 will help to reduce the number of customers at risk by a further 732,000. However, without additional action, there will still be around 151,000 customers (or 13% of the total number at risk) reliant on substations in areas of high likelihood that will not have benefitted from flood resilience measures (Figure 3.8).

Figure 3.8: Number of customers reliant on major electricity substations currently located in areas at a high or very high likelihood of river and coastal flooding and that are projected to be in areas of high or very high likelihood in the 2020s with climate change



Source: HR Wallingford (2014c) for the ASC, using data from the Distribution Network Operators submissions to Ofgem.
Notes: The number of customers benefitting from planned flood mitigation measures delivered by 2020 includes measures taken for those substations currently located in areas of medium likelihood, but that are projected to be in areas of high likelihood by the 2020s.

Rail

Risk assessment

The rail industry has proactively undertaken a climate change risk assessment and Network Rail is starting to account for projected changes in climate in its route management.

- The Railway Safety and Standards Board (RSSB) industry-wide study *Tomorrow's Railway and Climate Change Adaptation* (TRaCCA), involving the Met Office, used a methodology that combines assessment of climate hazards and the vulnerability of railway assets and operations. This informed Network Rail's Adaptation Reporting Power report in 2011.

- Network Rail will be publishing more detailed and locally specific weather resilience and climate change adaptation plans for each of the eight routes in September 2014.[53] These plans will include detailed vulnerability assessments, applying UKCP09 projections and data on historic weather-related delays, to identify priorities for resilience measures in the short-term, as well as longer-term adaptation solutions that may be required.

Network Rail is increasingly taking a long-term approach to managing its assets, but has not yet fully embedded climate change into its specifications and standards. Network Rail's management of its assets is moving from an approach based on 'find and fix' to one of 'predict and prevent'. Models have been developed to forecast the amount of investment and volume of renewals required to manage the rail network over the next 40-50 years. These models do not, however, account for projected changes in climate but instead assume that the weather experienced in the future will be similar to what is has been in recent years. In the regulator's assessment (the Office for Rail Regulation, ORR), Network Rail has not sufficiently embedded climate resilience into specifications for the design of its assets, or in the standards the company sets for asset maintenance and renewals.[54]

Resilience measures

Over £2,300 million will be spent on renewing the rail network's ageing structures, such as bridges, earthworks, tunnels and coastal defences over the next five years. Both the industry and regulator recognise that historic investment in civil engineering structures (termed 'civils') has been insufficient to deliver acceptable levels of risk in the long-term, particularly given their vulnerability to extreme weather. The £2.3 billion capital expenditure agreed for renewing civils over the next five years is 22% higher than over the previous price control period,[55] but is still around £450 million below the amount Network Rail originally estimated would be needed in this period.[56]

- *Earthwork renewals and expenditure:* Network Rail aims to reduce the annual number of earthwork failures in England and Wales from over 87 at the end of the previous price control period to 72 by the end of the current period. Around £100 million a year will be spent in the current price control period, a slight increase from the annual average of around £90 million in the previous period.
- *Drainage renewals and expenditure:* Expenditure on track and earthwork drainage renewals will increase from around £50 million in the previous price control period to around £70 million in the current period.

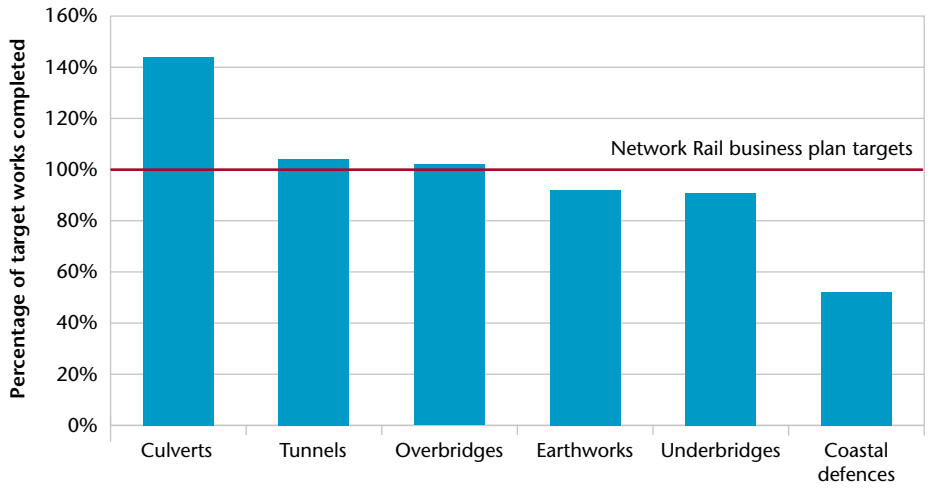
53 The adaptation plans were piloted for the Western route.
54 ORR (2013b) concluded that Network Rail should do more to embed climate resilience into its specifications for new overhead lines, track and structures. ORR also concluded that Network Rail could be more proactive in identifying interventions that would improve resilience to climate change, such as improvements to sea defences to mitigate projected changes in tidal reach.
55 Control Period 4 (2009/10- 2013/14). Control Period 5 began in April 2014 and runs until March 2019.
56 Network Rail's strategic business plan (2013b), which formed the basis of their proposal to ORR for funding in CP5, estimated the amount of expenditure required for civils in CP5 to be £2.75 billion for the whole network (i.e. Great Britain). In its Final Determination, ORR (2013b) developed a civils adjustment mechanism, which will enable more or less to be spent on civils if the need is identified and agreed during CP5.

- *Bridge and tunnel renewals and expenditure:* The number of overbridges being renewed is set to double[57] and there is a 50% increase in the renewal of underbridges planned in England and Wales.[58] A significant (159%) increase in tunnel renewals has been forecast compared to the previous period.[59]
- *Coastal defences and culverts:* The volume of renewals of these assets is set to increase by 84% and 61% respectively.[60]

Progress reporting

Network Rail prepares annual reports on the progress in delivering a wide range of outputs including measures which improve resilience, such as asset renewals. The Annual Returns report on progress against the outputs established with the regulator through the price control process. This includes detailed activity volumes on asset renewals. The company has generally made good progress with delivering renewals for most of its structures (Figure 3.9), over-delivering in some assets (such as tunnels and culverts), but not meeting its forecasts for others (for example coastal defences).

Figure 3.9: Planned and completed renewals of civil engineering structures in the rail sector over the first four years of Price Control Period 4 (2009/10 to 2012/13)



Source: Network Rail Annual Returns (2010 to 2013).
Notes: Network Rail publish Annual Returns that report on the volume of renewal works completed in comparison to forecasts for the year. The economic regulator (Office for Rail Regulation) regularly reviews Network Rail's progress and publishes summaries in the quarterly Network Rail Monitor.

57 A bridge crossing over the railway. This includes bridges for roads, footpaths, services or industrial use. Planned volume of renewals was 43,000 m² in CP4 and is 89,000 m² in CP5.
58 Bridges that allow passage under the railway. Planned volume of renewals was 386,000 m² in CP4 and is 583,000 m² in CP5.
59 Planned volume of renewals was 79,000 m² in CP4 and is 205,000 m² in CP5.
60 Planned volume of renewals of coastal defences was 6,000 m in CP4 and is 11,000 m in CP5. Planned volume of culvert renewals has risen from 8,000 m² in CP4 to 13,000 m² in CP5.

Strategic roads

Risk assessment

The Highways Agency has broadly identified the main vulnerabilities of the strategic road network to climate change, but has yet to produce more detailed action plans. To date, the Highways Agency has:

- published a Climate Change Adaptation Framework in 2009 and ARP report in 2011, which identified key vulnerabilities and made a commitment to develop plans for specific assets. However, to date, these more detailed plans have not been published.
- trialled a flood risk assessment in one of its regions in 2012, and is updating its assessment of river scour on its structures. The Agency has also developed a database on the location, but not the condition, of its drainage assets.
- updated several technical standards including drainage standards allowing for increases in rainfall intensity of 20%, and road surface specifications better suited to high temperatures, similar to those applied in the south of France.

Resilience measures

There is no publicly available information on spending plans to improve the resilience of the strategic road network. The Highways Agency currently plans to invest over £4 billion between 2015/16 and 2020/21 to repair and renew the strategic road network. This investment, which will include resurfacing 80% of the network, provides an opportunity to ensure that strategic roads are resilient to a changing climate and to address drainage issues.[61] However, the Highways Agency does not provide any breakdown of planned expenditure on resilience measures, such as drainage.

Progress reporting

Progress with implementing resilience measures is not reported for the strategic road network. This may change as part of the Government's proposal to create a strategic highways company. As part of this reform, the Government plans to publish a road investment strategy at the end of 2014, with associated funding commitments. The Government also plans to appoint the Office for Rail Regulation as economic regulator, and the research organisation Passenger Focus as a user watchdog and a cost monitoring organisation. The Office for Rail Regulation intends to publish a quarterly publication ('Strategic Road Network Monitor') on the model of the information it provides on rail. Both the preparation of a funding strategy and the appointment of an independent watchdog may provide more transparency on resilience planning.[62]

61 HM Treasury (2013b).
62 The investment strategy is part of the proposed reform of the Highways Agency in 2015, which will make it a government-owned contractor-operated company (GoCo).

Water

Risk assessment

The water regulator (Ofwat) has put a standard in place to encourage companies to develop a consistent business case for flood protection works for the current price control period (2010-2015). Ofwat developed an analytical framework[63] outlining how to assess the risks from flooding and identify appropriate options for increasing resilience. Its methodology paper for the current price control period (2010-2015)[64] asked companies to review the risk to their critical assets from flooding and to identify whether further investment is necessary.

Ofwat did not require water companies to undertake risk assessments in relation to any other climate hazards such as subsidence or coastal erosion.

Resilience measures

Around £414 million has been allocated for major network resilience schemes in the water sector during the current price control period (2010-2015).[65] After critically assessing the companies' business plans in the previous price review process (PR09), Ofwat concluded that many companies had a detailed knowledge of their assets and the vulnerability of their services.[66] Funding was agreed for the protection of more than 150 critical assets at risk, which if delivered should benefit some 9.6 million customers with increased service resilience to external hazards such as flooding.[67]

Ofwat has been able to identify the amount of investment water companies have been allowed to spend on asset resilience in the current price control period (2010-2015), but it is unlikely to be able to do the same for the next price control period (2015-2020). In the current Price Review process (PR14), Ofwat is being less prescriptive about the way in which water companies should set out their business cases for future investment and allocate costs to defined drivers. There is therefore no requirement on water companies to identify resilience proposals through a specific investment category, which will make it harder to compare the performance of different companies and assess the uptake of resilience measures across the industry as a whole.[68]

In both the current and next price control periods, beyond the basic legislative requirements,[69] there is no agreed definition of resilience. Each company decides the level of service failure risk that their customers are prepared to accept, using a 'willingness to pay' valuation. Ofwat has published a report[70] on principles for resilience planning to help companies to understand how to make robust business cases, but the limited available

63 Halcrow (2008).
64 Ofwat (2008).
65 Ofwat (2010).
66 *Ibid.*
67 *Ibid.*
68 In the first submissions, some companies have chosen to retain specific resilience outcomes, while others have chosen to consider the subject alongside wider service delivery outcomes.
69 Water Industry Act (1991). Sections 37 and 68, Security and Emergency Measures Direction (1998).
70 Mott McDonald (2012).

data relating to the impacts of natural hazards (Section 3.1) may make this valuation more challenging.

Progress reporting

There is some evidence on the progress made to implement resilience measures during the current price control period (2010-2015), but Ofwat is not planning to explicitly monitor resilience performance during the next price control period (2015-2020). In preparation for the current price review (PR14), Ofwat asked companies to report on their actual expenditure, including against a specific resilience definition.[71] This submission was a one-off data request to assist the modelling of future required costs. During the next price control period (2015-2020), Ofwat will monitor the performance of companies against their own defined outcomes.

Ofwat noted in 2010 the lack of data and monitoring on the overall level of resilience in the water sector to weather impacts. It suggested this could be achieved by monitoring actual failures, recording network or asset characteristics that enhance resilience, and tracking resilience investment.[72] This has not been taken forward, either collectively by companies, or by the regulator, in order to allow water companies greater flexibility in how they manage the resilience risks that they face.

However, any upcoming water company reports under ARP later in 2014 may provide more information on the level of resilience investment that will be delivered by water companies in the next price control period (2015-2020) and the reductions in risk that will be achieved. Most, but not all, companies have voluntarily agreed to report.

Ports

Risk assessment

The ports sector has no agreed national standard of protection against tidal surge, although the Department for Transport has started to address this issue. Any detailed climate change risk assessments are not in the public domain. The Department for Transport is currently considering developing a business continuity planning template for tidal surge events, and held a number of workshops with ports operators in 2013. The Department has also compiled data on port assets and the energy, transport and telecommunications networks that they depend on. However, this assessment is not shared directly with port operators due to licensing agreements and security concerns.

Twelve major ports reported under the Adaptation Reporting Power. The reports assessed climate risks to their operations to be 'low-to–medium'.

71 Companies' updated cost and performance (August submission) data.
72 Ofwat (2010).

Resilience measures

The recent flooding and tidal surge events have prompted many ports to take further action and commit additional resources to improving their resilience to extreme weather. Following the December 2013 tidal surge the Association of British Ports (ABP), which represents four of the largest English ports, has undertaken a detailed flood risk assessment of its critical infrastructure and hinterland connections, and commissioned an independent review of its business continuity plans.

Progress reporting

The ARP reports by port operators do not contain detailed information on resilience investment programmes, but some reports state that these will be conducted in the future. Those operators that choose to voluntarily report in 2015 under the second round of ARP may provide more information in these areas.

Airports

Risk assessment

Most airports have assessed flood risk from rivers, and identified the need to better understand risks from surface water and groundwater. Seven English airports reported under the ARP. Heathrow assessed its fluvial flood risk up to 2030, and set out in its ARP report the need to conduct a detailed risk assessment of groundwater flooding. As part of the planning application for a runway extension, Birmingham Airport conducted a detailed flood risk assessment and designed engineering and drainage works to ensure the runway will be protected to a 1-in-100 year standard, including a 30% climate change allowance. ARP reports compiled by Stansted, East Midlands and Luton airports all describe actions to ensure their surface water management plans account for increased rainfall projections.[73]

Resilience measures

Airports are able to demonstrate recent investment in resilience, but the action plans set out in their ARP reports have either uncertain or long implementation timescales, which may leave risks unaddressed in the short-term. The operators of Gatwick airport for instance spent £20 million on flood prevention between 2009 and 2014, mostly to protect its South Terminal, and published a flood risk management and reduction plan alongside its ARP report. The airport still suffered disruption during the 2013/14 winter storms. On Christmas Eve three of the electrical sub-stations serving the airfield and North Terminal were flooded. Ensuing investigations[74] identified that some important adaptation actions identified in Gatwick ARP report had not yet been implemented, including the relocation of critical assets to less vulnerable areas and the protection of facilities where relocation is not practical. Following this review, the operators of Gatwick airport pledged

73 Birmingham Airport, Heathrow Airport Limited, London Luton Airport, London Stansted Airport, Manchester Airport Group (2011).
74 McMillan D. (2014).

an additional £30 million to protect the airport's critical assets against a 1-in-100 year flood and rainfall event.[75] The business plan for Heathrow airport[76] predicts investment of over £17million in a storm water catchment project.

Progress reporting

Most, but not all, airport operators who reported in 2010/11 under the ARP have voluntarily agreed to report a second time on their progress. These reports, due in 2015, should provide more detailed information on what has been achieved to date.

ICT

Risk assessment

The Department of Business, Innovation and Skills (BIS) conducted a flood risk assessment for critical telecommunications assets, and found them to be at low risk, while the design and location of large data centres account for a range of natural hazards. However, in both cases it is not clear whether climate change projections are accounted for.

Unlike other sectors, data centres can rely on virtualised back-ups to improve their resilience. Firms commissioning new data centres and asset owners state that decisions regarding the design and location of new assets account for a range of natural hazards, including flood risk and subsidence.[77] However, it is not clear whether the assessments account for projected changes in climate.

BIS assessed flooding risk to critical telecoms assets in 2009, as part of the sector resilience planning process coordinated by the Cabinet Office. The assessment concluded that all key assets are adequately protected by either community-scale defences or asset-level defences that are in satisfactory condition. The results of this assessment are not public and it is not clear whether climate projections were considered.

Telecommunications providers, BIS and the regulator (Ofcom) assessed the risk of disruptions from extreme weather[78] and considered it to be a risk with low likelihood that can be managed through standard business continuity planning. This assessment found the largest risk to telecommunications operations to be interdependencies on other sectors, in particular transport networks preventing access to affected sites during periods of severe weather. Ofcom emphasised similar points in its report under the first round of ARP.[79] OpenReach, the largest owner of fixed-line infrastructure in the country, has produced a voluntary adaptation report which identified high-level climate risks to its operations based on existing literature, but did not contain a detailed risk assessment.[80]

75 Gatwick Airport (2014).
76 Heathrow Airport Limited (2013).
77 TechUK.
78 Joint BIS/Cabinet Office workshop with the telecoms industry on extreme weather conditions (2010).
79 Ofcom (2010).
80 Jude et al. (2013).

The telecommunications providers' resilience group, Electronic Communications – Resilience and Response Group (EC-RRG), voluntarily reported on climate change adaptation and concluded that climate change is "not too challenging an issue" [81] because of three factors:

- the rapid turnover of technology meaning that hardware that is not well-adapted will be quickly replaced;
- the procurement of equipment to international standards, which are designed to function in more extreme climates than the UK; and
- the structural redundancy of the network, specifically in the core of the fixed-line infrastructure.

Resilience measures

The structural redundancy in telecommunications networks is a source of resilience, but the fact that it may not be fully understood potentially stores up problems for the future. Beyond relying on structural redundancy, it is unclear whether any specific action is taking place to improve the resilience of ICT to climate change.

For the fixed-line telecommunications infrastructure, built-in spare or back-up capacity is more important to resilience than the physical resistance of assets to natural hazards. Examples of this 'redundancy' include:

- back-up operation centres for fixed operators and four major mobile providers;
- cabling and routing back-up cabling through a different physical location; and
- fitting of switches dual-routing or alternatives switches.

However, a report for Ofcom highlighted that the complexity of telecommunications networks can make it difficult to identify vulnerabilities:[82]

- providers rely on others' networks in order to connect with subscribers, and each network comprises many different makes and models of both hardware and software; and
- there is a lack of understanding of how many redundant links are being used and where they are located.

We could not find information on whether resilience measures have been identified by any operator to deal with the residual risks of a changing climate, or whether investment in resilience measures is taking place.

81 Electronic Communications-Resilience and Response Group (2014).
82 Detica and BAE Systems (2013).

Progress reporting

Resilience plans and progress are not reported in a way that can be assessed, but several companies have agreed to report voluntarily under the second round of ARP. The telecommunications sector has also been engaging with Government and local authorities on resilience issues.

The trade association for the UK technology sector (information and communications technology, including data centres), TechUK, and the owner of the largest distributed communications network, OpenReach, have both agreed to report voluntarily under the second round of ARP. These reports should provide more visibility on the level of action actually taken. In addition to their voluntary report on adaptation through the Electronic Communications-Resilience and Response Group, telecommunications operators have established sub-groups within each local resilience forum to act as a body of expertise.

ICT has inconsistent coverage by Government policy on resilience and adaptation. The Government commissioned research on adaptation of the ICT sector[83] and included the sector in its Vision for a Climate-Resilient Infrastructure and in the Climate Change Risk Assessment.[84] Even though, the National Adaptation Programme recognises the "pivotal role of ICT", it states that "further consideration needs to be given to such disruption, along with further evidence to better understand the issues" and does not build on the summary of climate risks in the Government's 2011 Vision. ICT operators were also not requested to report in the first round of the Adaptation Reporting Power. Only the communications sector (telecoms, postal and broadcast) is classified as Critical National Infrastructure and as such subject to the Civil Contingency Act requirements for sector resilience plans. Digital information technologies (broadband, data centres) are not included in the definition of Critical National Infrastructure.

Role of regulators

The Government's Infrastructure and Adaptation project[85] found that regulators are well-placed to facilitate action within their existing mandates, in particular the protection of short and long-term customer interests and the security of supply. They are also equipped with a range of instruments to encourage adaptation, such as incentives and penalties, setting standards and regular price controls.

Economic regulators have different statutory duties, but there has recently been a move to make them more accountable for network reliability and resilience. The Pitt Review recommended that a duty should be placed on economic regulators to build resilience in critical infrastructure.

83 AEA (2010).
84 The CCRA concluded that any decrease in productivity and revenue due to ICT loss or disruption was too uncertain to assess. Baglee et al. (2012).
85 PwC (2010).

- The 2014 Water Act introduced a primary duty for Ofwat to account for long-term resilience.[86] Ofwat must promote action to respond effectively to pressures on the environment (including climate change), and ensure long-term planning and investment. The duty could encourage Ofwat to take a more systematic approach to the monitoring of asset resilience and weather-related disruption.
- For ICT, the revised EU Electronic Communications Framework (2009) and the 2010 Digital Economy Act have given Ofcom duties and powers to ensure providers deliver appropriate security and availability, and report any significant problems.[87] As part of these duties, Ofcom has been producing annual reports to the Government since 2011 on the UK's communications infrastructure, and will publish updated guidance on security requirements in 2014. The new reporting requirements will aim to address the issue of under-reporting and the bias of over-reporting towards fixed line networks.[88]

Incentive and penalty schemes run by the regulators do not account for the impacts of extreme weather events when they assess the performance of infrastructure operators. This may be serving as a disincentive for operators to invest in resilience measures.

- If Network Rail has missed its performance targets during periods of severe weather, the Office for Rail Regulation will substitute days when severe weather occurred with an "average" day for that time of year, to either annul or adjust financial penalties.
- Severe weather events are exempted from Ofwat's minimum Guaranteed Standards Scheme (GSS). What constitutes a severe weather event is not defined. However all disruptions are included in the Service Incentive Mechanism (SIM) which provides rewards or penalties depending on the responsiveness of customer service.
- Ofgem's Interruptions Incentive Scheme (IIS) does not include extreme weather events. Since 2001/02, most distribution network operators have received financial rewards through this scheme.
- For all the existing schemes, the definitions of weather 'extremes' may not remain fit for purpose as extreme weather events increase in frequency and in severity. The Government, together with regulators have committed to review definitions[89] but this has not yet been taken forward.

Economic regulators have started working together to tackle the challenges of resilience. Cross-sector discussions have taken place since 2006 through the UK Regulators Network (formerly Joint Regulators' Group) to improve the consistency of economic regulation and benefit from other sectors' experiences. The UKRN's 2014 work programme includes assessing cross-sector network resilience with the aim of:

- Ensuring best practice in resilience decision-making by companies and regulators, and sharing data standards between sectors.

86 Defra (2014c).
87 Amendments to the Section 105 parts A-D and Section 134 A and B of the Communications Act (2003).
88 Ofcom (2013b).
89 HM Government (2011).

- Tackling interdependencies by encouraging information-sharing at the local level. This could include a pilot scheme involving a sample of local resilience forums.

Role of engineering design standards

Although not all existing standards account for future climate changes, these are being reviewed at the European level. In conjunction with maintenance and retrofit regimes (Section 3.3) and planning new infrastructure (Section 3.4), design standards have an important role to improve the resilience of infrastructure assets to climate change.

There are ten sets of technical rules harmonised at the European level on civil engineering works and construction, known as Eurocodes. Technical guidance on amending the Eurocodes to take into account climate change is due to be published in 2015.[90] Specifications for the consideration of climate change vary depending on the area covered by Eurocodes and other standards in use (Box 3.4).

Box 3.4: Incorporation of climate change into engineering design

- Eurocode 1 on structural design (including wind and snow loading) is the most codified and has specific provisions for the consideration of climate change.
- Eurocode 7 on geotechnical design (foundations, slopes) is less prescriptive and treatment of climate change effects will be left to the designer's judgement.
- The British maritime structures code (BS 6349) does not give specific guidance in regard to sea level change, but refers to UKCP09 (Clause 8.4).
- Standards for flood protection are not codified by either British or European standards, but are based on cost-benefit considerations, priority scoring, and the availability of funds. Project developers generally use the Environment Agency and Defra flood and coastal erosion risk management appraisal guidance (FCERM-AG) for any large projects such as ports.
- Some areas are still being researched such as the effects of climate change on wave loads at coastal structures (mostly determined by water depth and hence sea level rise) and wind loads, for which climate projections are highly uncertain.

Some standards have been modified recently. For instance, the Highways Agency introduced new road surface specifications, similar to those applied in the south of France, to adapt to higher temperatures and new drainage standards allowing for increases in rainfall intensity of 20-30%.

For some other sectors, evidence shows that current standards will be able to withstand future climate. For energy transmission and distribution, the Met Office EP2 project found no evidence to support adjusting network design standards for overhead line conductors. In general, components are sourced internationally, and are designed to function in climate conditions more extreme than in the UK.

Source: Hall, J; Simm, J; pers. comm. (May 2014), Environment Agency (2008).

90 European Commission (2012). Report prepared by the European Committee for Normalisation (CEN), the European Committee for Electrotechnical Standardization (CENELEC), and the European Telecommunications Standards Institute (ETSI).

3.4 Building new resilient infrastructure

New nationally important infrastructure will be built across all sectors in the coming decades. Over £375 billion of new investment is planned in the UK's infrastructure over the course of the next decade. Much of this will be new large scale developments such as power generating stations (including new nuclear sites, CCS and wind farms), electricity transmission and distribution networks, gas pipelines, enhancements to the strategic road and rail networks and the expansion of airports, harbours and ports. Major new rail networks are being created or proposed (for example Crossrail and HS2).

The development of new infrastructure provides an opportunity for infrastructure providers to ensure that climate adaptation measures are fully incorporated into decisions on design and location. This will often be more straight-forward and more cost-effective than having to retrofit measures when upgrading and renewing existing networks.

The current regime for national infrastructure planning is fairly new but has already processed a number of significant development applications. The current regime was introduced by the 2008 Planning Act[91] in response to concerns that the length of time required to make planning decisions acted as a barrier to delivering nationally important infrastructure.[92] Developers are required to undertake extensive pre-application consultation with local councils, communities and organisations before submitting an application. Once submitted, the Planning Inspectorate has up to six months to carry out an examination. Inspectors then have three months to make a recommendation to the Secretary of State, who must announce a decision within three months.

As of March 2014, a total of 14 applications for Nationally Significant Infrastructure Projects (NSIPs) had been through the planning regime.[93] Most of these have been smaller-scale nationally significant applications, such as the upgrading of motorway junctions and some rail corridor enhancements. The most significant application that has been consented to date is a new nuclear power station at Hinkley Point C, Somerset.

The Government's National Policy Statements require planning applications for new infrastructure to consider a wide range of climate hazards and to account for how these may change in the future. Decisions on nationally significant infrastructure projects are guided by a National Policy Statement (NPS) specific to each infrastructure sector. These are produced by the relevant lead government department and provide the framework within which Examining Inspectors consider a proposal.

91 The 2008 Planning Act aimed to streamline the process for major infrastructure applications, following a number of lengthy public inquiries such as into Heathrow Terminal 5, which lasted for nearly four years. The Act established an independent body, the Infrastructure Planning Commission, to review, scrutinise and make decisions on applications. The IPC was abolished by the 2011 Localism Act and its powers transferred back to the Secretary of State.

92 According to a KPMG survey (2013) for the CBI, planning is considered a significant barrier to the development of infrastructure in the UK by 71% of businesses.

93 There have been 40 applications for Nationally Significant Infrastructure Projects (NSIPs) since 2010, when the new planning regime established by the 2008 Planning Act began. Of these, 14 applications had been through the whole process to decision by March 2014. The number has since increased to 45 applications with 19 decided by June 2014.

The NPSs set out how decision makers should consider policy objectives on the national need for new infrastructure to meet current and expected future demand. They also describe the weight that should be given to assessing whether any adverse local impacts, for example on flood risk or biodiversity, outweigh the national need for the development when examining applications for NSIPs. Examining Inspectors therefore consider only land use planning matters when deciding whether to recommend approval, not the Government's strategic policies for the relevant infrastructure. Decisions on the operational design of new infrastructure have to be approved by other bodies.[94]

To date, the Government has produced sector-based NPSs covering energy generation and distribution,[95] transport,[96] and water and waste[97] infrastructure. Most of the NPSs are not spatial on the basis that it is for the market to decide, in line with Government policies, where best to site new infrastructure to meet demand. The exception to this is the Nuclear NPS, which provides preferred locations for new nuclear power stations as well as describing the national requirement.

All of the published NPSs state that applicants must consider the impacts of climate change when planning the location, design, build, operation and decommissioning of new infrastructure.[98] Evidence must be provided regarding:

- how the latest climate projections have been applied, with the applicant being required to apply the high emissions scenario where the infrastructure has safety critical elements; and
- whether the proposal may be seriously affected by more radical changes to climate beyond that projected in the latest climate projections, taking into account the latest credible scientific evidence.

As set out in the NPSs, applicants are required to assess whether the proposed development may give rise to consequential impacts elsewhere, for example on flooding, water resources or coastal change. This assessment will include consideration of the potential cumulative effects of other major infrastructure developments (including those for which applications have been made, but which have not yet been approved). The spatial extent to which cumulative impacts are considered is at the discretion of the Examining Inspectors.

94 For example, the type of nuclear reactor to be installed in a new nuclear power station would not be a matter for the National Policy Statement but licenced by the Office for Nuclear Regulation.
95 There is an overarching Energy NPS along with sector-specific NPSs on Renewable Energy, Fossil Fuels, Nuclear Power, Oil and Gas Supply and Storage and Electricity Networks.
96 A ports NPS has been designated, and a National Networks NPS is currently in draft form.
97 Hazardous Waste and Waste Water Treatment NPSs have been designated. A Water Supply NPS is intended to be developed.
98 The 2008 Planning Act requires Ministers to have regard to the desirability of mitigating, and adapting to, climate change when drafting National Policy Statements.

Climate change appears to have been accounted for in recent applications for major infrastructure projects. Those nationally significant infrastructure projects that have been through the planning process to date have carried out detailed Flood Risk Assessments that account for current and future flood risk from rivers and the sea.[99] In most cases, surface water flood risk was also assessed, although it less clear how applications have accounted for projected increases in heavy rainfall events. The risk from coastal erosion was not always explicitly assessed for coastal applications.

The potential vulnerability of the Hinkley Point site to the effects of climate change and sea level rise was recognised. However, the Government had already come to the view that the site was defendable when selecting it in the Nuclear NPS. This meant the Planning Inspectorate focussed on the more detailed aspects of the site's design. In doing this, climate change projections were applied to determine whether the development may increase flood risk elsewhere or have any impact on coastal processes in the Severn Estuary.

The proposed High Speed 2 rail line is not covered by the nationally significant infrastructure project planning regime as it will be subject to the specific consent of Parliament.[100] The accompanying Environmental Statement for the scheme has taken a comprehensive approach to assessing current and future climate hazards (Box 3.6).

The understanding of both applicants and Examining Inspectors on how they can best account for future climate is likely to improve over the next few years as the planning regime matures. It appears that approaches to assessing future river and coastal flood risk are already well embedded, but more could be done to better account for other risks. The comprehensive approach taken by the HS2 Environmental Statement to the full range of climate risks serves as an example of good practice. The NPSs set out the climate change adaptation and resilience issues that should be considered by applicants and by the Examining Inspectors, but do not give detailed guidance on approaches that applicants should take to account for the range of projections of future climate risks.

99 We reviewed the relevant Secretary of State decision as well the report from the Planning Inspectorate for the 14 applications determined by March 2014. Flood risk was not an issue for some of these applications, particularly off-shore wind farms. See HR Wallingford (2014d) for the ASC for further details.

100 This is through a process known as a Hybrid Bill, which has to be approved by both Houses of Parliament. An Environmental Statement is produced to help inform Parliamentary debate. The HS2 Hybrid Bill was laid before Parliament in November 2013.

Box 3.6: Climate risk and resilience assessment for HS2

The Environmental Statement for the High Speed 2 rail scheme includes a climate risk and resilience assessment that has applied the 2009 UK Climate Projections for a wide range of climate hazards over a 120 year time period. This has identified two high risks: flooding of track, tunnels and cuttings, and the overheating of tunnels. Adaptation measures have been identified in the design of the scheme to mitigate these risks, including:

- design of the railway to remain operational during the best estimates of a 1-in-1,000 year flood event, with 1m of freeboard to prevent track washout;
- designing drainage to accommodate 1-in-100 year rainfall events, including a 30% allowance for climate change; and
- provision of adequate space in the design of tunnels to allow for additional cooling and ventilation if required in the future.

There has also been an assessment of whether the scheme could potentially increase the vulnerability of adjacent communities and biodiversity to climate impacts. Measures identified to mitigate any adverse effects include:

- incorporation of adaptation principles ('bigger, better, joined') into the design of the Proposed Scheme to minimise any fragmentation of habitats that could affect the ability of wildlife to respond to a changing climate;
- incorporation of measures, where necessary, to mitigate impacts on water resources. Where appropriate, monitoring will be conducted prior to, during and post construction to ensure that mitigation measures are effective. For example, a Management Strategy and Monitoring Plan are being undertaken, and will be agreed with the Environment Agency in consultation with the water company, to protect groundwater in the Chilterns from construction related turbidity (and other contaminants), which could have temporary implications for the public water supply; and
- identification of replacement flood storage areas where the proposed scheme crosses the floodplain, to fulfil the aim of no increase in flood risk to vulnerable receptors as a result of the construction of the scheme. The proposed flood storage areas have been designed to accommodate projected increases in peak river flow and rainfall.

Source: HS2 (2013).

The national infrastructure planning process relies heavily on the Environment Agency to provide expert assessment of climate hazards and ensure resilience measures are implemented. Our review of applications has demonstrated that in all cases the Environment Agency plays a pivotal role in providing impartial and expert advice on the assessment of climate hazards, particularly flooding. It is clear that the Examining Inspectors rely heavily on the Environment Agency's representations and expertise on such matters when examining applications. However, as noted in Chapter 2 of this report, the Environment Agency has 40% fewer staff engaged in planning and development control than in 2010. This may have implications for the ability of the organisation to deliver the necessary level and quality of advice.

Furthermore, the regime can place responsibility on the Environment Agency, other statutory bodies and local councils to ensure that requirements contained within a Development Consent Order are discharged and complied with. These may be requirements related to flood risk mitigation, or the design and impact of the development. However, neither the Environment Agency nor local councils are provided with funding from central Government to deliver this compliance role. The enforcement of requirements in DCOs is relatively untested and it raises questions as to whether developers will necessarily deliver the required measures.

It is unclear whether sector-based National Policy Statements adequately require the assessment of cumulative impacts of locating new infrastructure in areas exposed to climate hazards. The NPSs are sector-based and produced by the relevant lead government department. With the exception of the Nuclear NPS, and, to a degree, the waste water NPS, they do not provide any indication of the broad geographical areas where major new infrastructure should be located. Instead, they are based on the premise that location decisions for new infrastructure should primarily be led by the market.

Strategic decisions on the location of new infrastructure are effectively being made on a 'first-come-first-served' basis, with minimal account being made of the potential adverse cumulative effects of separate developments at a sub-national level. This could result in the building up of systemic risk, particularly if new infrastructure is clustered in areas of the country that are projected to be increasingly exposed to climate change impacts, such as along stretches of coastline or in areas at risk of water stress. This is an issue that will be explored in more detail when the evidence report for the next Climate Change Risk Assessment is produced in 2016.

England is the only country of the UK not to have a national spatial strategy for infrastructure. The lack of an effective mechanism for assessing the cumulative impacts of infrastructure development at a sub-national scale raises questions as to whether the sector-based NPSs provide a coherent and joined-up strategy for delivering the country's long-term infrastructure needs.

3.5 Conclusions and policy advice

The importance of incorporating adaptation to climate change in the design and delivery of national infrastructure is widely recognised by infrastructure operators, government, regulators and professional institutions. Following damaging and disruptive extreme events, steps are being taken to improve the resilience of national infrastructure and prepare for a changing climate. However, the progress being made varies across sectors and within most sectors it is difficult to quantitatively assess. This means that the climate risks to national infrastructure are not fully understood and the progress being made on adaptation can only be assessed for a minority of the nation's critical infrastructure networks.

Our analysis highlights three broad areas where government policy on the provision of national infrastructure could be strengthened to improve resilience to future climate impacts.

Not all infrastructure sectors appear to be comprehensively assessing risks from climate change, taking action to build resilience, and reporting on their progress in a transparent manner. The Cabinet Office Civil Contingencies Secretariat should work to improve the consistency and transparency of resilience planning across both regulated and non-regulated sectors.

Due to its role in coordinating Sector Resilience Plans, the Cabinet Office Civil Contingencies Secretariat is well-placed to work with lead government departments and industry representatives to ensure that:

- current disruptions from weather events are recorded and monitored in a nationally consistent manner, as this is a key first step towards understanding exposure to climate hazards;
- consistent standards are agreed for proportional adaptation in each sector to current and future climate impacts, taking into account the level of risk and potential for nationally significant disruption; and
- the progress being made against those standards is regularly and transparently reported, including to allow appropriate incentive mechanisms to be put in place.

The Cabinet Office already encourages individual sectors to tackle interdependencies (Section 3.1) but it is unclear how work to date has influenced planning and asset management. A third of local resilience forums also report they have not sufficient information from infrastructure operators regarding the location and criticality of local infrastructure assets (Chapter 6).

In light of the requirement within the 2004 Civil Contingencies Act to co-operate and share information within the Local Resilience Forum framework, the Civil Contingencies Secretariat could facilitate information-sharing pilots at the local level, to explore how interdependencies could be mapped within an area.

Infrastructure UK specialises in advising on the delivery of new infrastructure and large renewal programmes and could assist by ensuring that good practices are embedded in new investment in infrastructure.

Regulated sectors are generally more transparent and accountable with regard to adaptation than non-regulated sectors, although there are some inconsistencies in their approaches. The relevant regulators (energy, water, telecoms and rail) should work through the UK Regulators Network to ensure a consistent approach to assessing the case for resilience and adaptation measures in the price control process.

As part of the review of cross-sector network resilience it is planning to undertake in 2015, the UK Regulators Network should ensure that:

- major regulated infrastructure owners and operators have resilience plans in place, setting clear targets and putting forward business cases for investment as part of periodic price reviews;
- processes are established within each regulated sector to review whether climate risks are being addressed by resilience plans; and
- the system of incentives and penalties in place to encourage resilience is proportionate to the potential scale of disruption and knock-on impacts of infrastructure failures.

The national infrastructure planning regime appears to be ensuring that decisions on the design of new infrastructure are accounting for climate change. However, the regime is still in its infancy and as such it is too early to be fully confident that it is delivering resilient new infrastructure. As part of the ongoing development of the regime, DCLG and other relevant departments should:

- provide guidance for applicants and the Planning Inspectorate on the use of climate projections and updates to climate science when interpreting the National Policy Statements. This is to ensure that new infrastructure development accounts for the full range of future climate risks;
- commission an independent assessment of whether the Environment Agency is able to continue to deliver technical advice that ensures that climate impacts are being fully accounted for when applications are being assessed by Examining Inspectors; and
- review the enforcement of requirements included within Development Consent Orders to ensure that the local planning authorities and other statutory bodies have the resources necessary to deliver their compliance duties under the planning regime.

The sector-based National Policy Statements do not appear to be enabling a strategic assessment of the cumulative effects of separate infrastructure developments at a sub-national or national scale. This could result in the build-up of systemic risk to future climate change.

- DCLG should consider introducing a cross-cutting assessment of the cumulative build-up of climate risk that may occur as a consequence of new development, to complement the sector-based National Policy Statements and the National Infrastructure Plan.

Annex 3.1: Physical description and average lifetime of major infrastructure systems covered in Chapter 3

Sector	Sector	Physical description (in England, unless otherwise stated)	Average design life (years)
Energy	Gas and electricity transmission and distribution	25,000 km of transmission cables, 800,000 km of overhead lines and underground cables, 1,500 transmission ('grid') substations, 5,000 primary high voltage ('primary') and 230,000 low voltage distribution substations	Towers: 40-60, Substations: 40-80, Overhead lines: 20, Control equipment: 15-25
	Electricity generation	134 power stations	40, up to 100 or more for nuclear
Transport	Rail	32,000 km of track, 38,000 bridges, 14,000 km of embankments and cuttings, 350 km of tunnels, 240km of sea walls, 2,500 stations.	Signalling: 20, Track: 20, Structure: 125
	Strategic roads	7,500 km of motorways and trunk roads, 9,000 bridges, 9,000 other earthworks structures, 34,000 drainage assets.	Culverts, Bridges, Tunnels: 110; Drainage: 60, Concrete pavement: 40, Signs and signals: 15
	Ports	12 major ports above ARP reporting thresholds (10 million tonnes of freight per year)	Quay: 50
	Airports	16 major airports serving more than 1 million passengers per year	
Water	Clean water supply	1,000 reservoirs, 2,500 water treatment works, 9,000 sewage treatment works. 700,000 km of underground mains and sewers.	Reservoirs: >100, Pipelines: 80, Civils: up to 60
	Waste water services	624,200 km of sewers (UK), 1,900 treatment plants serving agglomerations of more than 2,000 people	
ICT	Telecoms	75 million miles of cable, 3.5 million telegraph poles, 200,000 manholes, 92,000 street cabinets, 5,500 exchanges	Overhead lines: 20
	Information technologies	250-300 data centres with a combined power demand of 2-3TWh per year	Data centres: 20

Source: Network Rail, Highways Agency, DfT, Water UK, OpenReach.
Note: Power stations operational in 2013.

Annex 3.2: Summary of climate hazards, their impacts on infrastructure and projected changes

Climate hazards	Main impacts on infrastructure	Projected changes (CCRA/ UKCP09)	Confidence
River and coastal flooding Surface water flooding	Flooding of power stations, substations, water treatment works, underground copper and fibre optic cables, data centres, train stations, airports, ports, roads and railway track. Tidal surges/high waves damaging infrastructure in coastal areas, particularly ports.	Heavy rainfall events (>40mm) projected to increase in frequency by almost two times.	Medium
		Peak river flow in the 2050s (medium emissions scenario), projections vary from 'no change' to increases of 48%. Under the full range of emission scenarios in the 2080s, projected in increases in peak flow vary from 7% to 60%.	High
		Projections indicate absolute sea level rise from 13cm to 76cm by end of century (not including land movement).	High
Bridge scour	Bridge collapses or closures.	Road and rail bridges built with footings in rivers and estuaries are at risk of scouring. This may be exacerbated with projected increases in peak river flow.	Medium
Subsidence	Subsidence from shrinking and swelling of clay soils causing damage to buildings, railway lines, roads, underground cables and pipelines, pylons and telecommunication masts.	Changes to shrink-swell risk may occur due to changes in rainfall patterns and higher temperatures.	Medium
Coastal erosion	Instability/failure of rail and road earthworks and embankments. Risks to other infrastructure assets such as pipelines and underground electricity cables.	Sea level rise and greater loading from wave action are projected to increase the rate of coastal erosion.	High
Strong winds	Damage to overhead power lines, pylons, telecommunication masts, wind turbines and transport infrastructure due to fallen trees and windborne material. Very strong winds can cause structural damage from the force of wind alone.	Small changes (increases or decreases) for average wind speed, and no projections for extreme winds. Little change in storm frequency over the UK in winter, despite a projected southward shift in the North Atlantic storm track.	Low
Snow/ice	Damage to overhead power lines/pylons. Rail points freezing. Disruption to road and air transport.	Likely to decrease but cold spells will still occur through the century.	Medium
Fog	Disruption to road, air and shipping transport.	Reductions in fog of at least 50% projected for all regions except southern Britain in winter, where increases of up to 30% are projected.	Low

Annex 3.2: Summary of climate hazards, their impacts on infrastructure and projected changes

Climate hazards	Main impacts on infrastructure	Projected changes (CCRA/ UKCP09)	Confidence
Lightning	Damage to electricity transmission and distribution.	Increases in all regions and seasons.	Low
High air temperature and solar radiation	Thermal loading of bituminous surfacing of roads can cause deformation. Rail buckling. Sagging of overhead power lines. Reduced efficiency (electricity transmission and ICT wireless transmission).	Regional changes for summer are between -2°C to +10°C compared to the 1961-90 baseline.	Medium to High
Water scarcity	Reduced freshwater availability for cooling power plants.	Reductions of between 10-20% in summer river flow under 2020s 'dry' scenarios. Reductions of up to 50% under 2050s dry scenarios.	Medium to Low
High water temperature	Reduced effectiveness of cooling for power plants. Impact on water treatment processes, with water treatment works' effluent required to be at a higher quality.	Expected that water temperatures will rise with increase in air temperatures. Extent of warming is highly dependent on number of factors so no regional estimates of change have been projected.	High

Source: CCRA evidence report (2012), UKCP09.

Annex 3.3: Current and future demand for infrastructure

Sector	Current demand	Future demand
Road	The strategic network consists of 2% of UK roads by length but carries 1/3 of all traffic and 2/3 of freight traffic.	+45% traffic between 2003 and 2035 on interurban roads.
Rail	4 million passenger journeys per day There has been a 100% increase in passenger traffic since 1993.	+14% in passenger traffic and +4% in freight traffic by 2019
Ports	95% of goods in weight and 75% in value in and out of UK moved by sea	+182% in container unit traffic and +100% of RoRo traffic (tonnes) by 2030
Aviation	220 million passengers per year £116 billion worth of goods including trade both within and outside of European Union	+1-3% per year in passenger traffic and +0.4% per year in freight traffic by 2050
Energy	343 TWh generated in 2013 +36% of electricity supplied over 1986-2007, then -9% since due to a decrease in generation	380 TWh by 2030 (DECC reference scenario)
Water	145 lites per day per person (England average)	Scenarios range from -15 to +35% (mains water England average)
ICT	18.6 million residential broadband connections	Uncertain

Source: HM Treasury (2013a), quoting DECC (2013), ONS (2013), DfT(2013), Environment Agency (2013a).
Note: Roll-on/roll-off (RoRo) ships are vessels designed to carry wheeled cargo.

Annex 3.4: Current susceptibility of major infrastructure assets in England to a range of natural hazards (excluding river and coastal flooding)

	Hazard				
	Surface water flooding	**Groundwater flooding**	**Subsidence**	**Landslide**	**Coastal erosion**
	Threshold				
Asset	**1 in 100 probability of a mid-depth (0.3cm – <1.2m) flood**	**High susceptibility with estimated return period of 1 in 200 years or more frequent**	**Ground conditions predominantly high or very high plasticity**	**Slope instability problems are probably/ certainly present**	**Area of erosion risk in short term (0-20 years)**
Power stations (> 1MW)	0	6 (23%)	0	0	0
Transmission substations	61 (14%)	102 (24%)	55 (13%)	3 (<1%)	3 (<1%)
Category 1 rail	184 km (12%)	285 km (18%)	347 km (22%)	1 km (<1%)	0
Large train stations	5 (<1%)	93 (20%)	135 (29%)	0	0
Major roads	593 km (2%)	3,919 km (11%)	3,162 km (9%)	230 km (1%)	5 km (<1%)
Clean water treatment sites	44 (3%)	262 (15%)	174 (10%)	0	0
Waste water treatment sites	786 (7%)	2,587 (26%)	841 (8%)	0	5 (<1%)
Telecommunication towers	–	–	17,644 (14%)	311 (<1%)	18 (<1%)
Underground gas pipelines (High criticality)	–	–	35m (<1%)	–	608 km (10%)
Underground electricity cables (132 KV – 400 KV)	–	–	264 km (35%)	–	49m (<1%)
High voltage electricity pylons (>400 KV)	–	–	1193 (8%)	117 (1%)	0
Wind farms (20-99MW per wind farm)	0	1 (5%)	1 (5%)	0	0

Source: HR Wallingford (2014c) for the ASC.

Chapter 4

4.1 Context
4.2 Flood risk to businesses
4.3 Reduced water availability for industry
4.4 Risk to business supply chains
4.5 Business opportunities from adaptation
4.6 Conclusions and policy advice

Chapter 4:
Business opportunities and risks

Key messages

Climate change is expected to increase the risk of interruption and financial loss to businesses, but may also present opportunities for those able to take advantage of changing market conditions.

- Climate change is expected to lead to an increase in the frequency and severity of some extreme weather events. Storms and flooding, as well as heatwaves and drought, already cause significant difficulties for businesses.
- A changing climate presents opportunities for businesses in the provision of adaptation technologies, goods and services. In addition, resilient businesses that are better able to anticipate and cope with climate change and extreme weather than their competitors may be able to benefit commercially.

The main risks to business from climate change are likely to come from flooding, changes in water availability, and the disruption of supply chains reliant on goods sourced in the UK and from overseas. Disruption to infrastructure services due to climate change also presents a risk to business (Chapter 3). These are amongst the largest risks to business identified in the 2012 UK Climate Change Risk Assessment. When businesses are disrupted, business activity can transfer to competitors rather than be lost to the economy. This means the impacts of climate change on individual businesses and regions will be more severe than on the UK economy overall.

- There are 260,000 business units employing 3.2 million people currently located in areas susceptible to flooding from rivers or the sea, of which around 28,500 business units employing 280,000 people are in areas at a greater than 1-in-30 chance of flooding in a given year. With climate change the number of employees working in areas at a high likelihood of flooding may double by the 2050s.
- A combination of climate change and increasing demand for water from a growing population is projected to increase the risk of water scarcity for the chemical manufacturing, paper manufacturing, and mining and quarrying industries, which are amongst the largest industrial abstractors of water. Nearly half (46%) of the water abstracted by the paper manufacturing industry and over one-third (36%) by the chemical manufacturing sector is from catchments where there is already insufficient water to meet demand during an average summer. These proportions are projected to increase by the 2050s.
- Risks to business supply chains are difficult to assess at the national level, but our analysis highlights several products and sectors that are more reliant than others on imports from countries vulnerable to climate impacts. The risk of disruption appears to be highest further upstream in supply chains, yet businesses often only consider risks to their immediate suppliers.

Sales of adaptation goods and services by UK companies have grown in recent years, and at a faster rate than general growth in the UK economy. UK companies provide key adaptation goods and services such as flood protection and resilience measures, professional services including architecture and engineering, and finance and insurance products and services. But the sector remains small and sales by UK companies appear to have grown more slowly than those of competitors in other countries.

- Sales of adaptation goods and services by UK companies were £2.1 billion in 2011/12, having grown by an average of 2.3% per year since 2009/10. In total, adaptation goods and services sales represent less than 0.1% of all sales by businesses in the UK.
- Recent growth in sales of adaptation goods and services by UK companies is the lowest amongst the ten main global adaptation providers. Sales growth has been at least twice as high in, for example, Germany, Brazil, India, China and Italy.

Key messages

There is some evidence that large multi-national companies are assessing climate risks and taking steps in response. However, businesses are highly diverse, and the general picture is hard to determine as publicly available data are limited. Evidence of action by small and medium-sized enterprises is particularly scarce. There are 4.3 million businesses located in England that are highly varied in terms of the goods they sell or services they provide, their size, and their location. Limited publicly available evidence of action in some cases may be due to commercial sensitivities, but may also signify a lack of awareness.

The Government has started to help businesses address the risks from climate change, for example through the Environment Agency's Climate Ready Support Service. Further action by Government and other agencies, such as business associations, may be helpful to increase the pace of action by businesses.

- **Resilience to flooding.** There is limited evidence that businesses are taking action to protect their premises from the risk of flooding. After evaluating the 'repair and renew' grant scheme, announced by the Government after the winter storms of 2013/14, Defra and the Environment Agency should consider ways to encourage businesses in high risk areas to address their resilience and fit property-level protection measures where appropriate.
- **Water resource management.** Some businesses in large water abstracting industries are taking action to improve their water efficiency and manage water sustainably but it is not clear to what extent businesses overall are planning for future water scarcity. Trade associations could play a role in sharing best practice. The Government should proceed with the proposed reforms to the water abstraction regime, to create a more responsive licencing system that allows the available water to be used efficiently whilst protecting the environment.
- **Supply chain management.** Some large multi-national companies are already assessing and managing the risks to their supply chains from climate change. These are mainly in the food and drink sector, which is likely to be at greater risk due to a reliance on agricultural products. The Environment Agency should extend its Climate Ready advice service to other sectors reliant on products sourced from countries at comparatively high risk from climate change, such as clothing and manufacturing. The Environment Agency should also review the success to date of the Business Resilience Health Check tool, aimed at smaller companies, to help them conduct supply chain risk assessments.
- **New business opportunities.** The Government has a range of support mechanisms and initiatives involved in the promotion of export markets, such as advice to businesses provided by UK Trade & Investment. Defra and UK Trade & Investment should explore the reasons for the recent slow growth in sales of adaptation goods and services by UK companies.

4.1 Context

Climate change is likely to increase the risk of interruption and financial loss to businesses, but may also present opportunities for those able to take advantage of changing market conditions. Climate change is expected to lead to an increase in the frequency and severity of some extreme weather events (see Chapter 1). Storms and flooding, as well as heatwaves and drought, can have significant impacts on businesses. For example, the floods in 2007 were estimated to cause businesses £740 million in damages out of £3.2 billion in economic costs overall.[1] A changing climate also presents opportunities for businesses in the provision of adaptation technologies, goods and services.

Climate change does not necessarily present different risks, but a change in the risk profile faced by businesses. Businesses can therefore use many of their existing tools and practices to manage the potential for climate impacts. Businesses adept at identifying and managing risk on a day-to-day basis can draw on existing tools and

1 Environment Agency (2010).

integrate the risks posed by climate change into current practices. Tools include risk assessments, investment appraisal and business continuity management.

Assessing the extent to which businesses are preparing for the risks from climate change is challenging. Businesses are diverse organisations and publicly available data are limited. There are 4.3 million businesses located in England that are highly varied in terms of the goods they sell or services they provide, their size, and their location.[2] This makes it difficult to draw general conclusions on the overall level of preparedness for climate change. There are also gaps in the publicly available evidence on the actions being taken by businesses. This may in part be due to commercial sensitivities. Some of these gaps are being addressed through corporate disclosure initiatives such as the Carbon Disclosure Project, but these cover a relatively small number of businesses in England at present.

This chapter considers the extent to which businesses are preparing for the risks from flooding and water scarcity, and for risks to supply chains reliant on goods from abroad. We also consider potential opportunities presented by further growth in the adaptation goods and services sector. Floods, water scarcity and supply chains are some of the largest risks to businesses that were identified in the 2012 UK Climate Change Risk Assessment[3] (CCRA) and feature as priorities in the Government's National Adaptation Programme (Box 4.1).

We have not considered the risks to farming businesses in this chapter as these were assessed in a previous progress report.[4] Other risks to businesses were also identified within the CCRA, such as the risk to UK financial institutions from global climate impacts. We have not considered these here and further research is needed.

Box 4.1: National Adaptation Programme: Business chapter

The Government's National Adaptation Programme (NAP) sets out a vision for UK businesses to be resilient to extreme weather and prepared for future risks and opportunities from climate change. To realise this vision and achieve the objectives set out in the business chapter, the NAP provides a list of actions that can be categorised into the following five themes:

- Raising awareness of existing resources and tools available to businesses, such as the Business Resilience Health Check tool.
- Providing new guidance to businesses, such as the Cabinet Office's *Business Continuity for Dummies* and the Environment Agency's guidance on assessing and managing climate risks to supply chains.
- Developing adaptation skills in businesses, particularly SMEs, through a climate resilience training programme and developing professional standards on building the adaptation business case.
- Promoting and facilitating international commercial opportunities for UK companies with adaptation expertise through UK Trade & Investment and the Foreign and Commonwealth Office.
- Undertaking research on climate economics with long term investors, to improve economic modelling of extreme climatic events.

Some of these actions target particular types of business. For example, as part of the Environment Agency's supply chain guidance the Agency will work closely with the food and drink sector. Similarly, some of the training provided is aimed at SMEs as they are likely to have a lower adaptive capacity than larger businesses.

Source: HM Government (2013).

2 BIS (2013).
3 Defra (2012a).
4 ASC (2013a).

4.2 Flood risk to businesses

Flooding imposes significant costs on businesses, both in terms of damage to assets and in disruption to business activity. For example, businesses incurred around a quarter of the economic damages from the 2007 summer flooding in England, in clean-up costs and in lost business. Between 7,000 and 8,000 commercial buildings are thought to have been affected.[5] On average, it took affected businesses half a year (26 weeks) to return to full capacity, with some businesses closing down permanently.[6]

Around 260,000 business units[7] employing 3.2 million people are located in areas susceptible to flooding from rivers or the sea, after taking account of existing community-level defences (Figure 4.1**).** The majority of these business units (168,300) are located in areas at a low likelihood of flooding, that is, with between a 1-in-100 and 1-in-1000 annual chance of flooding. Around 28,500 business units are located in areas at a high likelihood of flooding, with a greater than 1-in-30 chance of flooding in any given year. An estimated 60,000 business units employing 469,000 people are in areas at risk of surface water flooding. Of these, around 4,200 business units are in areas at a high likelihood of surface water flooding.[8]

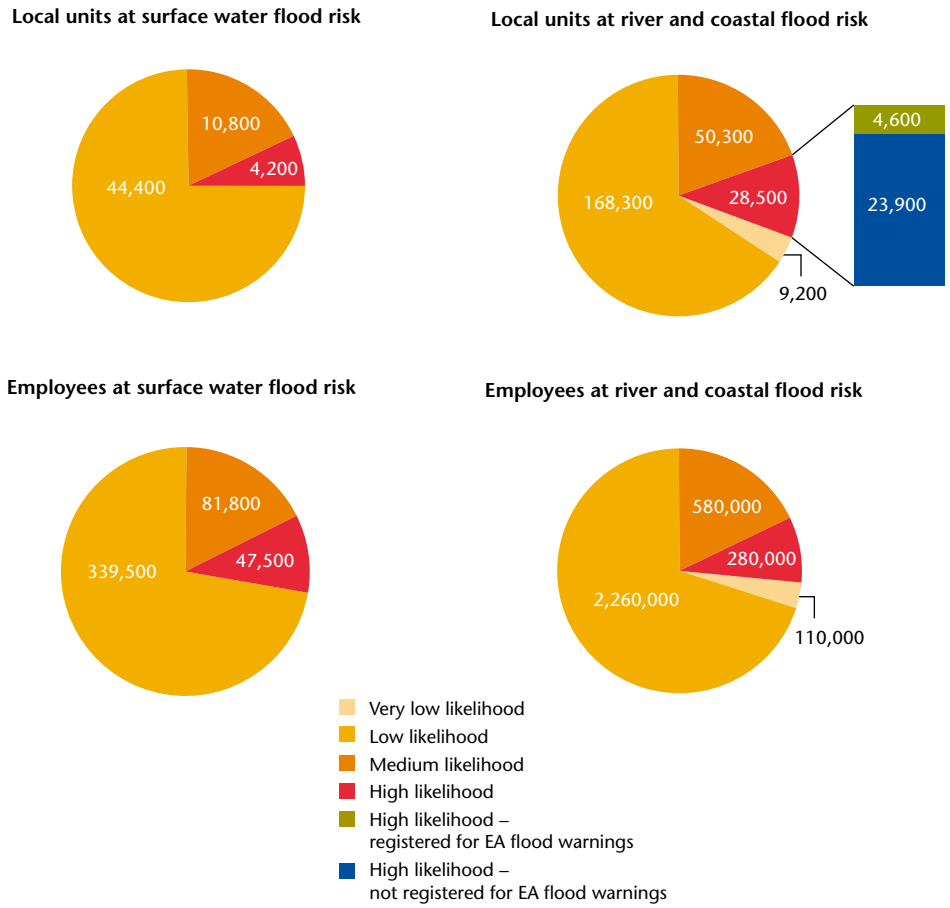
Climate change is expected to lead to a rise in flood risk, increasing the number of businesses and employees in areas at a high likelihood of flooding (Figure 4.2**).** Assuming the number and location of businesses stay constant, by the 2020s up to 40,000 (40% more) business units could be located within areas at a high likelihood of flooding from rivers and the sea. Around 100,000 business units employing nearly 1.2 million people may be at a medium likelihood of flooding in the 2020s. The number of business units projected to be at high or medium likelihood of flooding in the 2050s is estimated to be 50,000 and 120,000 (employing 500,000 and 1.45 million people) respectively.

There are a number of steps that businesses can take to assess, prepare for, and reduce their risk of flooding. Such steps will enable businesses to understand their level of risk and limit their losses in the event of a flood.

- A range of no or low cost measures are available, such as completing a flood risk assessment, signing up for flood warnings, checking insurance arrangements, and developing a business continuity plan. Around four-fifths of firms that have a business continuity plan in place and have had to implement it in the past 12 months consider the benefits of having a plan to exceed the costs of producing it.[9]

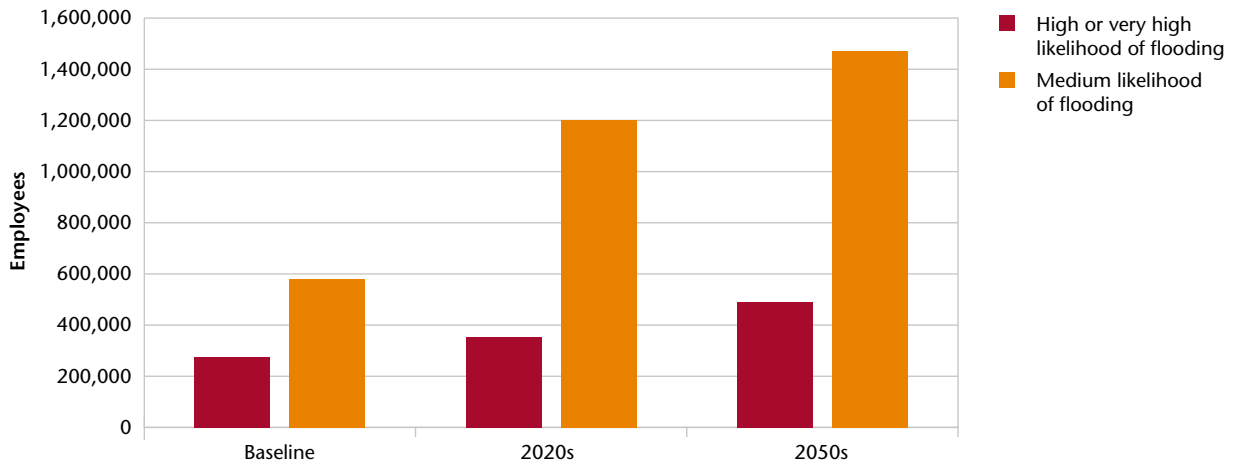
5 Environment Agency (2010).
6 Environment Agency (2013c).
7 Our analysis considers individual commercial properties and business units, rather than organisations that may operate from many locations. As an example, our analysis will count individual supermarkets located in flood risk areas rather than the number of supermarket chains. This number refers only to businesses which are required to register on the Interdepartmental Business Register. For companies that fall below the VAT threshold, registration is voluntary. Around 2.4 million of the 4.3 million businesses in England lie below the VAT threshold. These employ 2.6 million of the 21.3 million people employed in England. Therefore, our estimates of employees at risk of flooding provide a better estimate of the value at risk.
8 Our work contains statistical data from ONS which is Crown Copyright. The use of the ONS statistical data in this work does not imply the endorsement of the ONS in relation to the interpretation or analysis of the statistical data. Our work uses research datasets which may not exactly reproduce National Statistics aggregates.
9 Chartered Management Institute (2013).

Figure 4.1: Business properties and employees in England at river and coastal, and surface water flood risk



Source: HR Wallingford for the ASC, using Environment Agency and Office for National Statistics (ONS) datasets.
Notes: These charts use post code level business data from the ONS Business Structure Database. This database includes VAT registered companies and companies that are below the VAT threshold that have voluntarily provided employment and location details. The business properties are local units as opposed to enterprises. For example, each individual supermarket of a food retailing enterprise is counted as a separate property. These data have been mapped against the Environment Agency's 2013 National Flood Risk Assessment (NaFRA), and the 2013 updated Flood Map for Surface Water (uFMfSW). High likelihood translates to a 1-in-30 year probability (3.3% annual chance) or greater of flooding; medium likelihood is between 1-in-30 and 1-in-100 probability (1-3.3% annual chance); low likelihood is between 1-in-100 and 1-in-1000 probability (0.1-1% annual chance); and very low is 1-in-1000 or lower probability (less than 0.1% annual chance). Surface water flood risk is based on flooding of a depth greater than or equal to 0.3 metres. The dispersed and fragmented nature of surface water flooding means that estimates of the number of properties at risk can vary considerably depending on the method used. The method used by HR Wallingford differs from the one used by the Environment Agency, and leads to a lower number of properties being identified as being susceptible to surface water flooding. Data on active registration by businesses for the Flood Warnings Direct service (FWD) was provided by the Environment Agency. The number of businesses actively signing up for flood warnings within each postcode was summed and then matched to postcodes derived from NaFRA data. More businesses in high flood risk areas may be in receipt of flood warnings as a result of the 'opt out' Extended Direct Warnings. However, the Environment Agency is unable to tell whether telephone numbers they hold as a result of the Extended Direct Warnings service belong to households, businesses, or other organisations.

Figure 4.2: Number of employees in areas at risk of flooding from rivers and the sea, in the 2020s and 2050s



Source: HR Wallingford for the ASC, using Environment Agency and ONS datasets.
Notes: This chart shows the projected number of employees working in areas at medium to very high risk of flooding in the 2020s and 2050s. The projections of future flood risk have been estimated using the same method used in the 2012 UK Climate Change Risk Assessment. An uplift has been made to the present day probabilities of flooding in the National Flood Risk Assessment according to projected changes in peak flows for river basins, and sea level rise in coastal regions, using UKCP09 data. The 2020s and 2050s represent projections over a 30 year time period of 2010-2039 and 2040-2069. The analysis assumes no increase in the extent of flooding, only a changes in annual likelihood. The increases in river flows have a baseline period of 1961-90, and there is little evidence to suggest that peak river flows have changed significantly since then as a result of climate change (see chapter 6 of the CCRA for more information). Business units are assumed to remain in the same location across the periods and current flood defence standards are assumed to be maintained, but not improved.

- Businesses can investigate whether improved community-level defences are planned for their area. They may be able to influence the scope and timing of works by contributing towards the costs of projects under the Partnership Funding approach.[10] The Environment Agency publishes details of schemes in the pipeline on their website, including in map form.[11] Improved flood protection may influence the price businesses need to pay for insurance cover against flood losses and business disruption.
- Businesses may be able to influence the local flood risk management strategy prepared by the relevant Lead Local Flood Authority (LLFA, the county council or unitary authority for the area). Under the 2010 Flood and Water Management Act each LLFA is required to publish a summary of the local strategy (see Chapter 2). The strategy should assess flood risk from all local sources (surface and ground water, and from local watercourses), set objectives for managing local flooding, and specify the measures proposed to meet these objectives. Cost and benefit information, and how measures will be paid for, should also be included. Such information will help businesses assess whether more needs to be done to avoid the potential for damage.
- Businesses can reduce the chance of flooding further by implementing property-level protection measures. There is also the potential to make business premises more resilient to flood water should it enter, and to limit losses and disruption by moving valuable stock and equipment away from areas at risk.

10 Defra (2011a).
11 Environment Agency (2013e).

Evidence suggests there has been some increase in the number of businesses taking steps to prepare for flood events, but uptake of flood warnings and other low-regret measures is far from universal.

- The number of businesses that have actively registered for the Environment Agency's Flood Warning Direct (FWD) scheme has increased from 24,600 in 2007 to 63,800 in 2013. The launch of the Extended Direct Warnings service (EDW) means a greater number of businesses in areas at a high risk of flooding will receive a warning ahead of a flood event.[12] However, our analysis suggests less than 20% of businesses in high risk areas have actively opted-in to receive the full FWD service (Figure 4.1). Growth in net registrations for FWD has fallen considerably since 2010; in 2012 there was only a 1% increase in registrations. This suggests a low awareness of flood risk amongst the remaining businesses in flood risk areas. In addition, the Environment Agency is encountering difficulties in signing up both households and businesses for flood warnings as a result of reduced usage of landline telephones.[13]
- The proportion of private sector organisations saying they have a business continuity plan in place increased from 42% to 58% between 2008 and 2013.[14] Larger businesses are more likely to have a business continuity plan. For example, in 2013 around three-quarters of large businesses reported to have a business continuity plan in place compared to 59% of small (11-50 employees) and 44% of micro (1-10 employees) organisations.[15] The Cabinet Office, in partnership with the Business Continuity Institute and Emergency Planning Society, has published *Business Continuity for Dummies* which includes guidance for SMEs on how to deal with challenges such as flooding. The British Standards Institution, in partnership with the Environment Agency, has published guidance on integrating risks from climate change into existing business continuity management standards.[16] There are no comprehensive data on whether continuity plans in flood risk areas explicitly cover the risk of property damage and business interruption from flooding.
- The Environment Agency, Climate UK and Business in the Community have launched the Business Resilience Health Check website. So far this has been accessed over 1,200 times. The Chartered Insurance Institute has trained almost 200 insurance brokers and business advisors in using the tool.[17] Regional climate change partnerships have also been offering training in business resilience.

There is relatively little evidence of businesses taking steps to reduce the physical risk of flooding.

- Based on responses from flood protection manufacturers, the uptake of property level protection measures by businesses appears to be low. Better information at the national level is needed to determine the full extent of uptake of these measures by businesses.

12 In response to the Pitt Review (2008a), the Environment Agency launched the Extended Direct Warning service to automatically register fixed line telephone numbers of premises identified as being within flood risk areas (customers are able to 'opt out' if they wish). EDW telephone numbers are held in the same register as for FWD, however details are anonymised. As such the Environment Agency cannot determine whether an EDW customer is a business or household. Customers in the EDW scheme are invited to join FWD, which offers a number of additional benefits.
13 The Environment Agency is working with mobile network operators to increase the penetration of flood warnings.
14 Chartered Management Institute (2013).
15 *Ibid.*
16 BSI Group (2014).
17 Data provided by the Environment Agency.

- Contributions from businesses towards the costs of flood defence projects have been limited to date. Of the £148 million in contributions in the pipeline for the current spending period (2011/12 to 2014/15), £37 million (25%) are set to come directly from the private sector. The majority of contributions are arising from the public sector, primarily local authorities. However some contributions from businesses may be hidden within the sums received via local authorities.
- Permeable paving used in hard surfacing around business premises can improve drainage and reduce the risk of flooding. However, whilst the use of permeable paving within the commercial sector has increased in recent years, it remains a relatively small part of total paving activity. Impermeable paving remains the dominant paving type in commercial projects, with 86% of block paving supplied for commercial sector projects in 2013 being impermeable (see Chapter 2).[18]

4.3 Reduced water availability for industry

Water is used for a variety of purposes by industry and is an important input in production. Without sufficient water, production in many enterprises would have to be reduced or stopped. Industry uses water for a number of reasons, including: cooling and heating, washing products, dissolving chemicals, suppressing dust, and also as a direct input to products. Water is vital for the functioning of these processes and without precautions reduced water availability can have significant consequences for production.

The analysis in this section focusses on the chemical manufacturing, paper manufacturing and mining and quarrying sectors. These are three of the largest industry abstractors of freshwater.

- In previous reports we considered the risk of water scarcity to the public water supply,[19] and to agriculture.[20] Chapter 3 of this report assesses the risks of water shortages for electricity generation. Chemical manufacturing, paper manufacturing and mining and quarrying are three of the largest abstractors of freshwater in the remaining industry sectors. In the case of paper manufacturing, our analysis considers paper mills only.[21]
- In 2011, freshwater abstractions by the chemical manufacturing, paper manufacturing and mining and quarrying industry were estimated to be 156, 47 and 41 million cubic metres (m^3) respectively.[22] Compared to abstractions for electricity generation and public water supply this is relatively small.[23] However, production processes in these three industries depend on being able to abstract and consume water.

18 Jenco and Climate Resilience Ltd (2014) for the ASC.
19 ASC (2012).
20 ASC (2013a).
21 We also do not consider the water abstracted and moved to other areas through the dewatering of quarries. The Government has consulted on including this activity in the licence regime.
22 WRc (2014) for the ASC. These are estimates of direct abstractions and exclude water taken from public water supply by these industries.
23 Water abstractions from freshwater sources in 2011 for public water supply and the electricity supply industry were 5,175 and 8,239 million m^3 respectively.

- Within each industry there are large variations in the water intensity of sites. For example, the water intensity of paper mills in England varies from 4m^3 per tonne of output to 300m^3 per tonne.[24] This is partly due to the different products being made at each mill, with mills that produce packaging being better positioned to re-use low grade water in production than specialist producers that require high quality water. This variation means different adaptation measures will be suitable in each site.
- Of the remaining industry sectors, the food and drink sector is also a relatively large freshwater abstractor. The National Adaptation Programme contains a specific action to reduce water demand in food and drink manufacturing sites by 20% by 2020 through the Federation House Commitment voluntary agreement. We will return to this and other sectors in our first statutory report on the NAP, which will be published in July 2015.

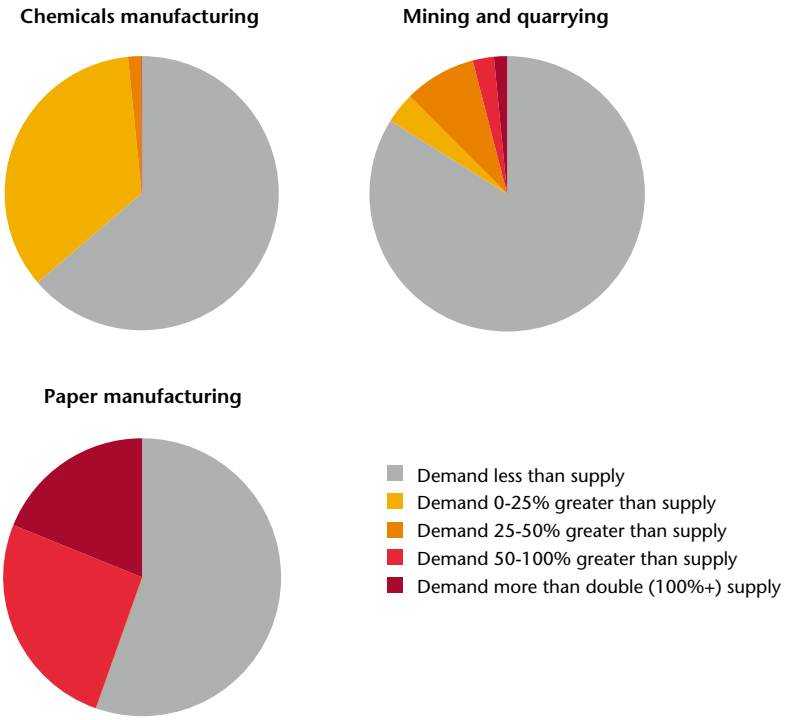
The chemical manufacturing, mining and quarrying, and paper manufacturing sectors provide important materials and products for the economy. In total the three industries employ 235,000 people in the UK and account for nearly 5% of Gross Value Added to the UK economy.[25]

The three industries studied each abstract freshwater from areas where the total demand for water already exceeds supply during an average summer (Figure 4.3**).** Demand for water in these areas will include the requirements of a range of business sectors, including for public water supply, as well as the need for some water to remain in the catchment to avoid damage to the environment.

- Nearly half (45%) of abstractions by the paper manufacturing industry are from catchments where demand for freshwater currently exceeds supply during an average summer. This reflects the fact that a large proportion of the paper manufacturing industry is located in the North Kent and Medway catchments in south east England, where there is already pressure on water resources. As well as the risk of not being able to take water from freshwater resources in these areas, lower river flows will mean there is reduced dilution available for effluent discharge into rivers.
- Around one-third (36%) and one-sixth (16%) of abstractions by the chemical manufacturing and mining and quarrying industries are in areas where demand for freshwater currently exceeds supply during an average summer. The lower proportion for the mining and quarrying sector partly reflects the more geographically dispersed nature of the sector.
- These supply and demand proportions appear to have remained relatively constant in recent years, however it has not been possible to develop a long, consistent time series due to changes in the licencing regime.

24 Figures provided by the Confederation of Paper Industries.
25 ONS Annual Business Survey. This includes all people employed in the sector. The number of people employed at the sites that abstract water will be lower as not all businesses in each of the sectors will abstract water directly from freshwater sources.

Figure 4.3: Abstractions from catchments in England where demand for freshwater exceeds supply during an average summer



Source: Environment Agency (2013) and WRc for the ASC.
Notes: The volume of freshwater abstracted by each industry has been estimated by matching each individual licence in the Environment Agency's abstraction licence database to the relevant ONS Standard Industrial Classification code. This is based on estimates of direct water abstractions by the three industries and excludes water taken from public water supply. Each licence has been mapped onto the catchment areas used in the Environment Agency's Case for Change analysis, which classifies catchments in terms of the supply-demand balance for the whole catchment based on 6-year average annual returns. This includes meeting the needs of the environment to avoid degradation. Red, orange, and yellow colours represent instances where there is insufficient freshwater available to satisfy the demands of abstractors while maintaining protection of the environment. The assessment above relates to summer flows, termed Q70, as the balance between available resource and demand for abstraction is of greatest significance during the summer.

Businesses located in areas where water is scarce are more likely to have to reduce or stop abstraction due to river flows or groundwater levels being low. There are relatively few examples of this occurring at present but this may be because most abstraction licences do not currently include restrictions on abstraction when water is scarce. For these abstractors, the only limiting factor will be whether water is physically available.

Of the chemical manufacturing, paper manufacturing and mining and quarrying abstraction licences analysed, only 6% have 'Hands off Flows' restrictions. These are conditions that limit or prevent abstraction during periods when flows, or levels of the river or groundwater sources that the sites are abstracting water from, fall below critical thresholds in place to prevent abstraction damaging the environment. In some instances when these conditions have been enforced, businesses have reduced the impacts on their operations by using storage reservoirs and, where possible, using other sites in the country where water is not a limiting factor.

The 2012 Climate Change Risk Assessment identified a high level of uncertainty associated with risks to future water availability, but there is some risk of a deficit in most regions in the near term.[26] Climate projections generally suggest there will be increases in winter precipitation and decreases in summer rainfall. In addition, other pressures such as a rising population will put additional strain on water resources.

Despite this uncertainty in the climate projections the risk of reduced water availability for the three industries is expected to increase (Figure 4.4**).** The Environment Agency's Case for Change study provides projections of current and future water availability in the 2050s across four socio-economic and four climate scenarios, and three different levels of environmental protection.[27] For each industry and scenario, we have considered how the risk of reduced water availability is expected to change assuming the industries remain in their current locations.

- For mining and quarrying, and paper manufacturing, there is expected to be a material increase in water scarcity in areas where these industries are currently located. In some scenarios, by the 2050s, nearly 10% of abstractions by the mining and quarrying sector would be in areas where there is insufficient supply of water for the environment in an average summer even before water abstraction demands are considered.
- The chemical manufacturing industry may see a similar proportion of abstraction in water scarce areas as at present, but with water availability falling further in areas where it is already scarce. The overall proportion of abstractions in areas where demand exceeds supply remains at similar levels across many of the scenarios. In two extreme scenarios, a supply deficit is projected to emerge in the Weaver and Dane catchment in the north west of England, where a large chemicals cluster is located, leading to a near doubling (to nearly 70% – as indicated by the top of the error bar in Figure 4.4) in the proportion of water abstracted by the chemical manufacturing industry in areas at risk.

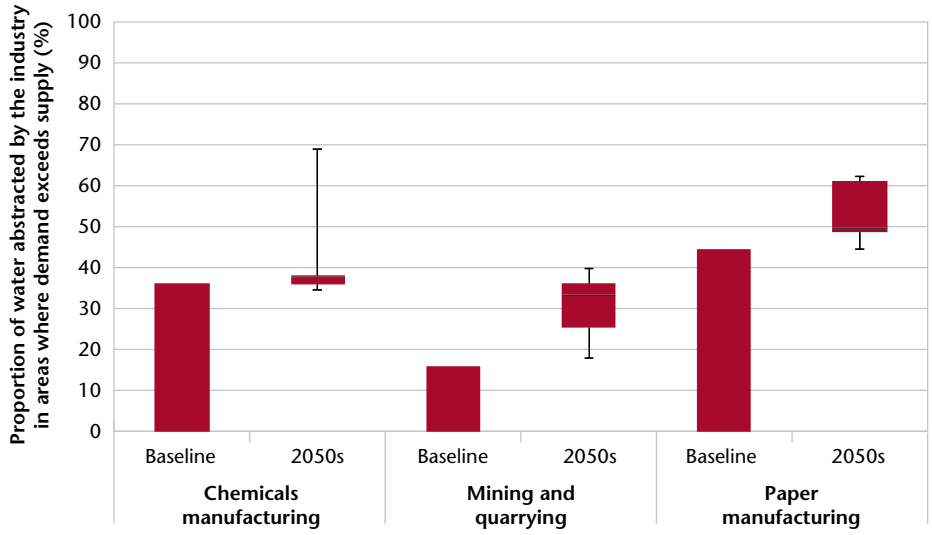
Business can respond to the risk of reduced water availability by managing water more effectively or by locating business units in areas where there is less pressure on water resources. Businesses can also contribute to better water management in catchments under stress. The ability of firms to move businesses to alternative locations may be limited by several factors. For example, the mining and quarrying facilities are located where minerals are available to extract. Similarly, the benefits from the clustering of firms may act as a barrier to moving businesses elsewhere.

There are mechanisms already in place to support businesses in identifying and implementing best practice in water use.

- The EU Integrated Pollution Prevention and Control Directive (IPPCD) and Industrial Emissions Directive (IED) set frameworks to promulgate Best Available Techniques (BAT) in each sector to manage water consumption. A list of Best Available Techniques has been published for the paper manufacturing industry, with a revised list due to be published in 2014. Revised lists for other sectors are due to follow.

26 The supply-demand deficit projections were assigned a medium confidence rating in the 2012 CCRA Evidence Report. There is more confidence in projections of future changes in average supply-demand deficits than in future changes in drought frequency and intensity.
27 Environment Agency (2013a).

Figure 4.4: Current and projected water abstraction in areas where demand exceeds supply during an average summer



Source: Environment Agency (2013) and WRc for the ASC.
Notes: Businesses within the relevant catchments are assumed to remain in their current location. The baseline figures are taken from Figure 4.3. The box plots for the 2050s summarise the results of sixteen socio-economic and climate change scenarios used in the Environment Agency's Case for Change analysis, as follows:
– Each scenario is ranked from 1 (lowest percentage) to 16 (the highest percentage) in terms of the proportion of freshwater abstracted by the industry from catchments where demand for water exceeds supply during summer months.
– The median value from the scenarios is presented as a black line in the centre of the bars.
– The 'floating' red bars show the interquartile range, with the bottom representing the lower quartile of estimates in the scenarios and top representing the upper quartile.
– The error bars represent the lowest and highest estimates within the scenarios.

- Other initiatives, such as the Rippleffect delivered by the Waste Resources Action Programme, provide guidance to businesses on how to identify measures to save water and the benefits these measures provide. To date, over 2,000 businesses have registered for the scheme. Of these, 11 are in the chemical manufacturing sector, 5 in the paper manufacturing sector and 1 is in the mining and quarrying sector.

Data on the uptake of Best Available Techniques are not systematically collected, but there is evidence that some sites are taking steps to minimise their current water use. As sites are re-licenced under the Industrial Emissions Directive to revised BAT standards, performance should improve further.

- The Environment Agency recently completed a series of audits of water management practices in 17 paper mills. These found some sites were monitoring water use comprehensively, with water re-use technologies in place to reduce overall abstraction. However, in some sites simple measures such as identifying and addressing leaks or turning off pumps and sprays were not being fully implemented. These measures can pay for themselves over very short periods of time and represent a low-regret adaptation measure.[28] Sites that had senior level oversight of water management were generally managing water better, especially where monitoring was in place and targets were set.

28 WRc (2014) for the ASC.

- A recent survey by the Chemical Industries Association (CIA) found only around a half of its members had a water minimisation plan in place. The same survey found around three-quarters of sites had processes that met the Best Available Techniques as defined in the Environmental Permitting legislation. The remaining quarter had a site improvement plan in place. This is based on self-reported data, so it may not fully reflect the current situation in the industry.
- Some large companies in the mining and quarrying sector provide information to the Carbon Disclosure Project (CDP) on their water use. These data are also self-reported and tend to present a global perspective of water use by the company rather than focussing on the use of water resources in England.

The extent to which industries are planning for future changes in water availability is also unclear. We have found little evidence that the businesses in these sectors are actively considering the risks to their businesses from climate change. This may in part reflect the limited site-level data available to assess the extent of action. It may also reflect the relatively short planning horizons of some businesses that are driven by other factors that affect their long-term financial viability.

There are some signs that the relevant trade associations, with the help of the Environment Agency, are starting to encourage their members to consider the risks from climate change to their operations.

- The Environment Agency has recently published guidance for paper manufacturers on the steps to take to assess and prepare for the risks from climate change, which has been published on the Confederation of Paper Industries website.
- In the chemical manufacturing sector, the pan-European trade body (Cefic) has launched an initiative to develop key performance indicators to track risks and action associated with water use by chemical manufacturing plants in water stressed regions.
- The mining and quarrying industry is due to launch a water strategy shortly.

Changes to the abstraction regime may provide clearer incentives to businesses to manage water efficiently. Charges for water abstraction currently tend to be based on the administrative cost of issuing a licence rather than the amount of water used. Licences allow up to a specified maximum volume of water to be abstracted, frequently without additional charges based on actual usage. The ASC has previously recommended that the price paid by abstractors for water should reflect the amount used, and its scarcity.[29]

The Government recently consulted on reforming the licencing regime, to create a more flexible and responsive system that uses the available water more efficiently.[30] But final proposals are unlikely to be implemented until the early 2020s. In the meantime the 2014 Water Act aims to encourage greater 'upstream' trading by water abstractors. If sufficient safeguards are put in place to avoid over-abstraction, the increased trading of allocations should help put a price on water and provide greater incentives for water conservation.

29 ASC (2013a).
30 Defra (2013c).

4.4 Risk to business supply chains

Through their international supply chains, UK businesses are exposed to extreme weather risks from around the world. Businesses in the UK operate as part of the global economy and as such are heavily reliant on goods and services sourced from and sold to overseas markets. The value of UK imports has risen from £149 billion in 1990 to £527 billion (nominal prices) in 2012. Exports have increased from £139 billion to £493 billion (nominal prices). As a proportion of GDP, UK international trade (imports plus exports) increased from 50% in 1990 to 65% in 2012. This demonstrates the increasing reliance of UK businesses on overseas markets as part of their supply chains.

Disruptions to supply chains can have significant negative consequences for businesses. Studies have found that share prices can fall by between 7% and 30% on average following failures in the supply chain. Disruptions to supply chains can affect business operations in a number of ways, including losses to revenue, loss of productivity and damage to reputation. These impacts can translate into a significant fall in share prices relative to benchmark companies, and they do not necessarily recover after the event.[31]

Adverse weather such as flooding and storms, and drought, are common causes of supply chain disruption. A recent survey found adverse weather was the third most frequent cause of disruption for UK companies, with around 75% of respondents reporting to have been affected at some point over the past 12 months.[32]

Climate change is expected to increase the risk of weather-related disruptions, particularly for supply chains that involve more vulnerable countries. The UK's trading partners face diverse and often more severe risks from climate change than the UK. There are no consistent data, but the available evidence suggests that developing countries in South and South East Asia, along with Sub-Saharan Africa, are amongst the most vulnerable countries.[33] Supply chains involving these countries are therefore most likely to be at risk.

We have undertaken a preliminary national-level analysis to identify particular sectors that may be more vulnerable to supply chain disruption with climate change. The analysis uses trade data and an international input-output model to estimate the value generated (gross value added) within each country for goods and services consumed in the UK. An assessment of the climate vulnerability of each country is then applied to identify which products consumed in the UK may be at risk.

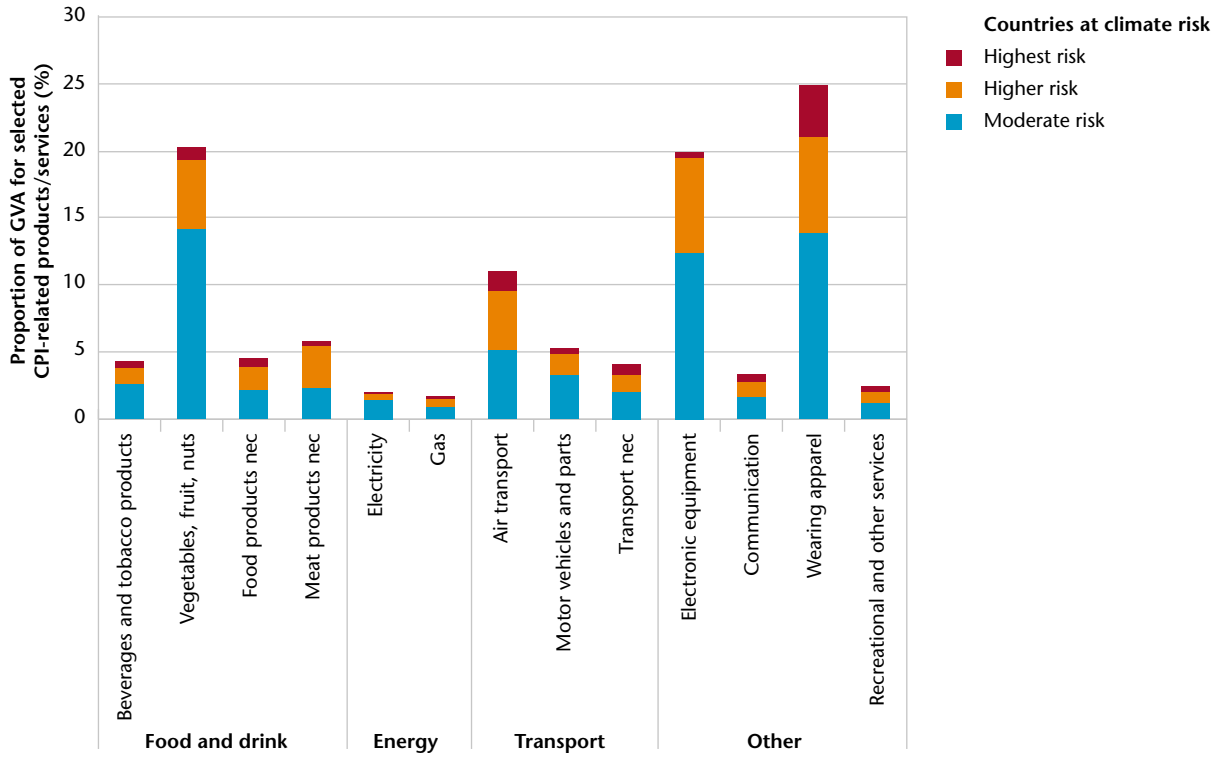
The stages in the supply chain further upstream (or lower tiers) are likely to involve raw materials and natural resources such as fossil fuels and plants being consumed or processed. Later stages refine and combine components using power and other inputs, or involve sales to wholesalers, retailers and ultimately final consumers. Goods evolve as they pass through different countries on their way to the final product being ready for sale in the UK.

31 Based on figures reported in PwC (2008), Zurich (2013) and World Economic Forum (2013).
32 ASC analysis of UK private sector responses to Business Continuity Institute (2013).
33 The conclusion derives from a series of global vulnerability indicators, including the Climate Change Vulnerability Index (CCVI); GAIN index; DARA Climate Vulnerability Monitor; and an index compiled by PwC. It is important to note that although a country may be ranked amongst the least exposed/vulnerable to climate change, it may still experience disruptive impacts associated with climate change.

As an illustration for the clothing sector, the input-output model calculates the value generated in India by Indian cotton being used to produce fabric, which may then be transported to South East Asia where further value is added in using the cotton in the production of clothing. The finished clothes may then be shipped to the UK for packaging, adding further value, before sale to consumers, which also adds value in the mark-up charged by retailers. In this example, disruption to the cotton harvest in India, in the production of cotton material, or in the manufacturing sites in South East Asia, would disrupt the supply of clothing to the UK and would have implications for the revenue generated in the UK from clothing distribution and retail.[34]

According to our analysis, food, clothes and electronic equipment are important UK consumption goods which appear to be at comparatively high risk from international supply chain interruptions. Figure 4.5 highlights the 'embedded climate risks' for a range of sectors that are important to UK consumers.[35] For each sector, the chart shows the extent to which UK consumption is reliant on countries likely to be amongst the most

Figure 4.5: Gross Value Added for products/services consumed in the UK arising from countries most at risk of climate impacts



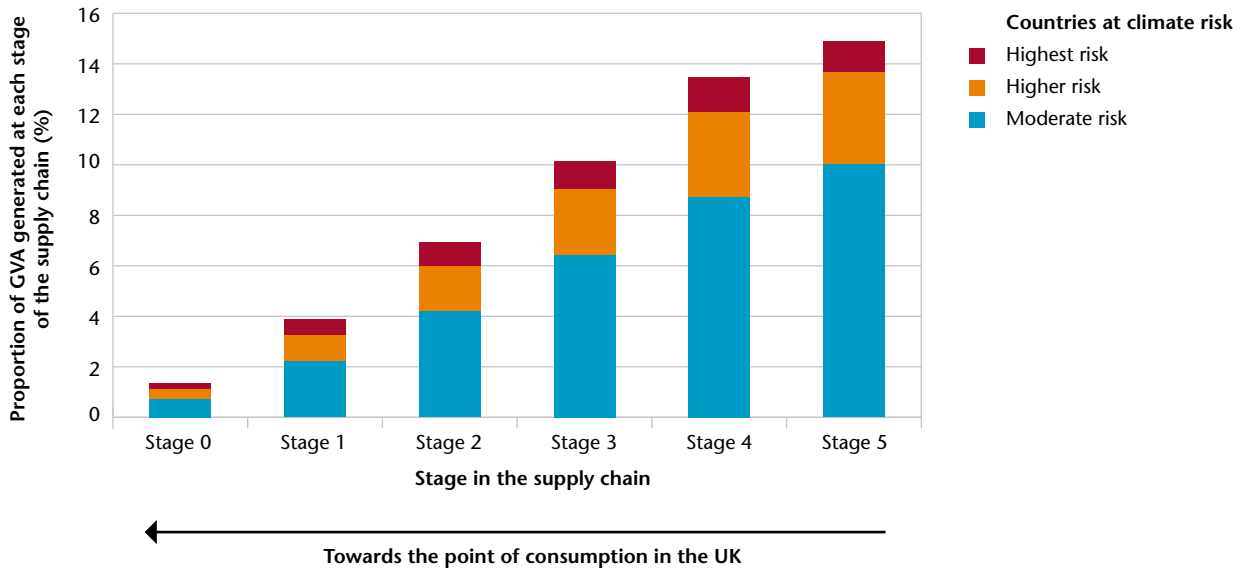
Source: University of Leeds (2014) for the ASC.
Notes: The figure shows the percentage of the total GVA for goods and services consumed in the UK arising in countries assessed as being more exposed or vulnerable to climate impacts than others. The goods and services listed are intended to align with those included in the calculation of the Consumer Prices Index (CPI). Together the goods and services shown form about 20% of total GVA from UK consumption. The risk assessment for countries is based on a number of indicators (see main text). Countries have been ranked according to their average 'risk' score, and then divided into quintiles. The share of total GVA generated in the countries at highest risk (5th quintile), higher risk (4th quintile) and moderate risk (3rd quintile) are shown. Adjustments to some regions were made to reflect similarities in their average risk score. For example, the four advanced Asian economies of Hong Kong, Japan, Singapore and South Korea were aggregated to a group as they consistently were within the first quintile of countries at risk, unlike other Asian economies. As an example, the figure shows that approximately 12% of total GVA for electronic equipment bought in the UK is generated in countries which are assessed as being at moderate risk of climate impacts (ie. in the third quintile of all countries). 'nec' means 'not elsewhere classified'.

34 The extent of the disruption to UK GVA would depend on a number of factors, including the substitutability of cotton from other countries.
35 These are sectors that feature prominently in the representative consumption basket used to calculate the Consumer Prices Index (CPI).

exposed and vulnerable to climate change. These findings are similar to previous studies on sectors at greatest risk from climate change. For example, Foresight concluded the commodities most likely to experience the greatest impacts from climate change would be in the agricultural sector.[36] A report by PwC found UK imports of apparel and clothing, and fruits and vegetables to be among the most exposed to climate change of the main import sectors.[37]

The largest climate risks to supply chains appear to be in the earlier stages of product manufacture (Figure 4.6)**. These tiers of the supply chain are less likely to be understood and managed by UK businesses.** Our analysis suggests a larger proportion of value in the earlier stages of production is generated in countries that are at a moderate or higher risk from climate change. Evidence suggests that disruptions in the earlier stages of supply chain are common. For example, a recent survey by the Business Continuity Institute (BCI) found that 42% of supply chain disruptions originated below the first tier of immediate suppliers.[38] Findings from the Chartered Institute of Purchasing and Supply (CIPS) suggest that many British firms do not fully understand supply chain complexity and that "inadequately trained supply chain professionals" amount to a skills gap.[39]

Figure 4.6: Proportion of GVA generated at each stage of the supply chain in countries more at risk of climate impacts, for goods and services consumed in the UK



Source: University of Leeds (2014) for the ASC.
Notes: The chart shows the proportion of total GVA for products/services consumed in the UK at each stage in the supply chain arising in countries classified as being amongst the 60% most exposed or vulnerable to climate change. Stage 0 represents the sale of a finished product to consumers and stages with higher numbers represent inputs into the production of a good or service.

36 Government Office for Science (2011).
37 PwC (2013a).
38 Business Continuity Institute (2013).
39 Chartered Institute of Purchasing and Supply (2014).

It is possible to manage and reduce the risks of supply chain disruption. Some companies are already doing this, for example by working with their current supply base to help make them more resilient (Box 4.3)**, but many others are not.** Evidence, largely based on survey responses, suggests that half of businesses have considered the risk from climate change to their supply chains.[40] In the case of water use, the Carbon Disclosure Project found less than half of large multi-national business required suppliers to report water use, risk and management.[41]

Box 4.3: Case studies of good practice in managing climate risk in supply chains

There is recognition amongst some firms that there is a need to assess and manage the risks to their supply chains from a changing climate. Action is most common amongst large multi-national companies operating within the food and drink sector, supported by the Food and Drink Federation and the Environment Agency.

- Asda has recently worked with PwC to map the risks to its supply chain from climate change. The supermarket chain has identified risks – in terms of sourcing, processing and logistics – to 95% of its fresh produce. Its work has included an assessment of risks both to its own operations as well as those of its suppliers. Following this exercise, the company plans to look in more detail at the products identified as the most vulnerable and to provide targeted training where it is needed.
- In reports to the Carbon Disclosure Project, Nestlé has highlighted action being taken as it seeks to reduce the amount of water abstracted per tonne of product by 40% (on 2005 levels) by 2015. Nestlé is also working with suppliers to improve the resilience of its cocoa supplies. Cocoa is grown on relatively fragile plants in a small number of countries, meaning that it is at a comparatively high risk from climate change. Some of the actions being taken by Nestlé include: training for soil preparation, water conservation and responsible use of fertiliser; techniques for more efficient land use; and distribution of plants that are more resilient to drought and disease.

There has also been action in other sectors:

- Unilever has an objective to significantly reduce the water used by its global factory network (halving water abstraction in new factories, when compared with its 2008 baseline). Actions include metering of water usage, water audits, and rainwater harvesting. To date the company reports reducing water abstraction by 13 million cubic metres in its global factory network between 2008 and 2012 (a 25% reduction per tonne of production). The company has also recognised the need to improve water efficiency through to external suppliers of raw agricultural product. It seeks to minimise water use amongst suppliers as part of its goal to source 100% of products sustainably by 2020.
- In a report published by Climate Ready, Camira Fabrics highlighted action to increase its supply chain resilience. Actions include: building a network of many small suppliers across different geographic localities; developing effective two-way communications with suppliers (to pinpoint risks to supply and demand-side trends); developing a full risk and opportunity assessment to feed into a climate change resilience plan; and diversifying products to include more resilient and sustainable materials.
- A number of car manufacturers have collaborated with Achilles to map their supply chains and share information. One particular output, Supply Chain Mapping, a tool led by Toyota Motor Europe, invites suppliers to join a programme which creates a link between product codes sold and product codes bought. The programme allows a buyer at any point of a supply chain to view their suppliers and associated tiers of sub-suppliers to identify which manufacturing sites are at risk from natural disasters, as well as broader supply chain risks. Toyota Motor Europe has highlighted the benefits of collective action on the supply chain, and the difficulties associated with interdependency which make individual action challenging.

Source: ASC discussions with individual companies, Carbon Disclosure Project (2013), Nestlé (date unknown), Unilever (2014), Environment Agency (2013b), Achilles (2013) and Asda (2014).

40 Defra (2013e).
41 Carbon Disclosure Project (2013).

There is evidence of business continuity planning taking place to cope with supply chain disruption. The Business Continuity Institute reports that in excess of 75% of businesses surveyed have continuity plans that deal with supply chain disruptions.[42] However the picture amongst smaller firms is mixed. PwC have reported that only half of FTSE 350 firms engage with suppliers and highlighted the lower levels of action by smaller firms.[43] The World Economic Forum (WEF) Supply Chain Risk Initiative recommends that firms undertake scenario-based exercises to develop a baseline and possible future operating environments to help understand the implications of viable states of the world. It also highlights the need for trade resumption plans, or business continuity plans, to deal with inevitable disruptions.[44]

Ultimately, it is very difficult to build a complete picture of actions being taken to address supply chain risk, as data are generally limited to those reported by larger multi-national companies. This is discussed in a forthcoming paper produced by researchers at the London School of Economics.[45] Amongst its conclusions, the study states that: it is unclear whether broad company-level objectives translate into actions at a local level; it is difficult to understand whether actions relate to short-term resilience or long-term adaptation; and it is difficult to assess the impacts, at a local level, following action at the corporate level. The Environment Agency recently launched guidance to help businesses identify and manage the risks to supply chains from climate change. It has been working with the food and drink sector primarily to test this guidance and promote its adoption.

4.5 Business opportunities from adaptation

In addition to risks, climate change presents opportunities to businesses from the development of the adaptation goods and services supply chain.

- Increases in the frequency and the awareness of climate-related events are likely to lead to a rise in the demand for adaptation goods and services both at home and abroad.
- The conditions for supplying some goods could also improve with climate change. For example, rises in global temperature in excess of 1°C above pre-industrial levels could be beneficial for agriculture in higher latitude countries such as the UK (if water is not limiting), although it could also have an overall negative impact.[46] The impact of climate change on the supply of agricultural products was covered in our 2013 progress report.[47]

42 Business Continuity Institute (2013).
43 PwC (2013b).
44 World Economic Forum (2013).
45 Grantham Institute at the London School of Economics (forthcoming a).
46 IPCC (2014c).
47 ASC (2013a).

There are some policies in place to help UK businesses take advantage of these opportunities. These are described in the National Adaptation Programme (see Box 4.1). For example, Defra and the Technology Strategy Board have run two rounds of competitions to find innovative designs for adaptation in infrastructure. Climate UK is working with Local Enterprise Partnerships to raise awareness and support best practice in assessing opportunities from climate change within local economies. UK Trade & Investment (UKTI) is responsible for promoting exports of goods and services, which includes adaptation goods and services.

The available evidence suggests that the adaptation goods and services market is relatively small; however building a complete picture is difficult.

- Adaptation goods and services are sold by a variety of different industry sectors, and national statistics agencies in the UK and globally do not collect data on sales. This makes it difficult to determine the size of the market using publicly available data.
- Global sales of adaptation goods and services were estimated to be £69 billion in 2011/12.[48] This estimate is based on a number of simplifying assumptions, but it represents the best data currently available.[49]
- The UK is the seventh largest producer of adaptation goods and services globally, with sales by UK companies in 2011/12 of £2.1 billion, of which £0.3 billion were exports. This compares to turnover by all UK businesses of more than £3 trillion[50] and exports of £493 billion in 2011.[51]

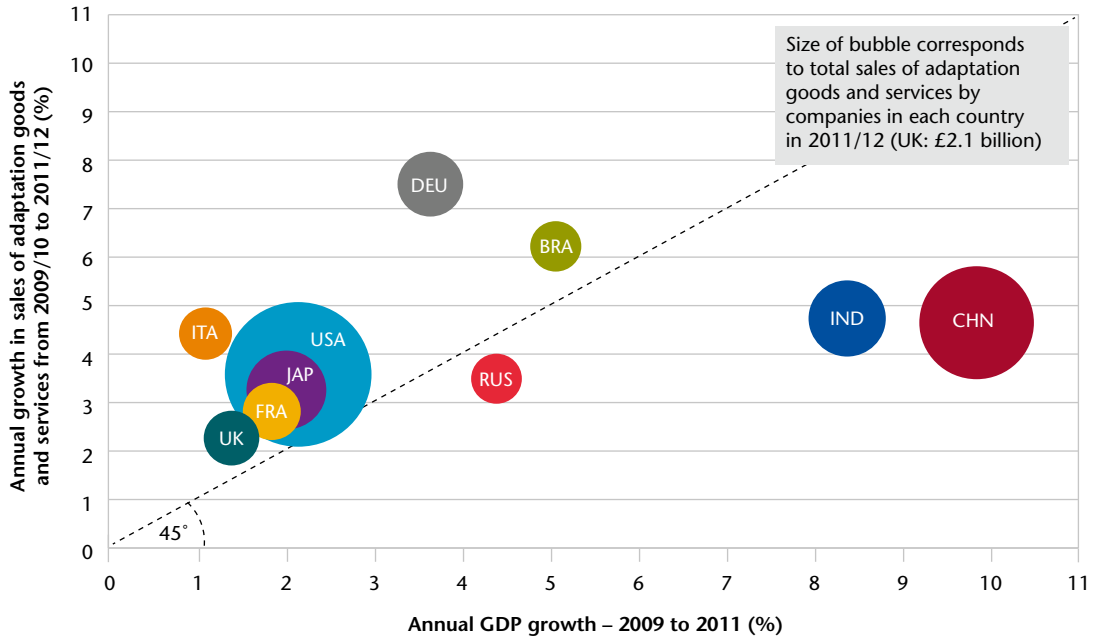
Over the past three years sales of adaptation goods and services by UK companies have grown faster than the economy as a whole, but UK growth has lagged behind growth in adaptation sales amongst overseas competitors (Figure 4.7**).** Our analysis shows that annual growth in sales of adaptation goods and services by UK companies between 2009/10 and 2011/12 was 2.3%. This is higher than annualised economic growth of 1.4%. However, sales growth by UK companies has been behind those in all of the other top ten largest producers.

Businesses in the UK have considerable expertise in producing adaptation goods and services, suggesting they could take advantage of any future growth in this market (Table 4.1**).**

- Qualitative assessments by PwC[52] and GHK[53] based on consultation with business experts have found the UK is already a key provider of some adaptation goods and services – in particular in climate modelling, professional services including architecture and engineering, and finance and insurance products.

48 This estimate is based on research by K-Matrix for the Department for Business, Innovation & Skills which used data from Companies House records, national statistics and sector case studies to assess the value of the adaptation goods and services sales. K-Matrix (2013).
49 K-Matrix is currently updating this data for a project for the Greater London Authority. This revised data includes a broader definition of adaptation goods and services and is likely to show higher sales of these goods and services. We will consider any changes to the data in our next report in 2015.
50 BIS (2011).
51 ONS (2013b).
52 PwC (2013a).
53 GHK (2010).

Figure 4.7: Growth in adaptation goods and services sales in the top 10 producing countries



Source: K-Matrix (2012) for BIS, K-Matrix (2013) for BIS and World Bank Data Portal (2014).
Notes: The chart shows annualised GDP growth and growth in the sale of adaptation goods and services, between 2009 and 2011. The countries included represent the largest producers of adaptation goods and services, and the value of sales by companies in each country is represented by the size of the bubbles. The 45 degree line has been plotted to distinguish countries where the average growth rate of the adaptation goods and services sector exceeds (above the 45 degree line) or falls short of (below the 45 degree line) the average growth in GDP of that country. For the UK, the chart shows that growth in sales of adaptation goods and services by UK companies has been strong relative to growth in the overall economy but has been comparatively weak when considered in context of the other countries plotted. The following countries are included in the chart: United Kingdom (UK), France (FRA), Japan (JAP), USA, Italy (ITA), Germany (DEU), Brazil (BRA), Russia (RUS), India (IND) and China (CHN).

- Businesses in the UK already export goods and services that require similar skills and technologies to adaptation goods and services. For example, the UK's exports of financial services in 2011 were £40 billion and accounted for one-fifth of all financial services exports globally. The UK has a comparative advantage relative to other countries in this sector and this is true across many of the sectors requiring similar skills and technologies to the adaptation goods and services sector.
- The number of patents registered each year by UK companies for technologies used to manage the demand and supply of water increased by around 80% between 1990 and 2010. The proportion of all water-related adaptation patents registered globally by UK companies is higher than their share of all world patents, suggesting companies in the UK have a relative advantage in the development of these technologies.[54] Patent data provides an indication of the capacity of the UK to develop ideas which could in turn be converted into commercial opportunities.

54 Grantham Research Institute (forthcoming b).

Table 4.1: UK strengths and export potential in adaptation goods and services

Adaptation goods and services sector	Estimated adaptation sales by UK companies in 2011/12	Estimated UK comparative advantage	Highlighted as a strength in the PwC and GHK reports on opportunities from climate change	ASC assessment of export growth potential
Architectural	£270m	High	Yes – Building design	
Climate Change Management	£80m	Medium	Yes – Climate modelling and development of tools and techniques	
Construction & Retrofit	£660m	Low	Yes – Flood protection products, construction sector experience managing construction projects and strengths in monitoring and control systems for heating and cooling	
Enviro Finance	£220m	High	Yes – Financial services	
Finance Investment & Insurance	£190m	High	Yes – Financial services and insurance industry products	
Risk Management & Business Continuity	£100m	High	Yes – Flood risk assessment and planning	
Sustainable Drainage & Water Management	£120m	No data available	Yes – Water and waste water treatment with niche suppliers, for example, in sustainable drainage, sensors and leakage control	
Transport Infrastructure	£490m	No data available	No – This adaptation sector includes heat resistant tracks which were not identified as an export opportunity in the reports	
Water Irrigation	£10m	Medium	Yes – Water resources and hydrology consultancy services	

Source: K-Matrix for BIS (2013), UN COMTRADE, PwC (2013) and GHK (2010).
Notes: The adaptation goods and services sectors used in this table use the K-Matrix definitions. The sales figures in the second column are total sales by UK companies of adaptation goods and services, and includes sales to customers in the UK and exports. The revealed comparative advantage (RCA) provides an indication of the relative advantage a country has in exporting a given product. To calculate these figures we have matched the K-Matrix adaptation goods and services sectors to international trade sectors. For product A, the RCA has then been calculated by dividing the share of product A in UK exports by the share of product A in world exports over the past three years. A sector has been given a 'Low' score if the RCA is less than 1 (no revealed comparative advantage), a 'Medium' score if the RCA is between 1 and 3, and a 'High' score if the RCA is above 3. The overall export growth potential scores have been estimated using a multi-criteria scoring system, with equal weight given to the RCA score and the identification of expertise in the GHK and PwC reports cited. A full dark green circle represents a high growth potential and a full white circle represents a lower growth potential.

4.6 Conclusions and policy advice

It is ultimately a business decision for firms to determine their strategy for adapting to climate change. Our analysis suggests that some businesses are taking steps to identify and manage specific climate risks to their business operations and financial performance. This is more likely amongst the large multi-national companies and less likely for smaller enterprises.

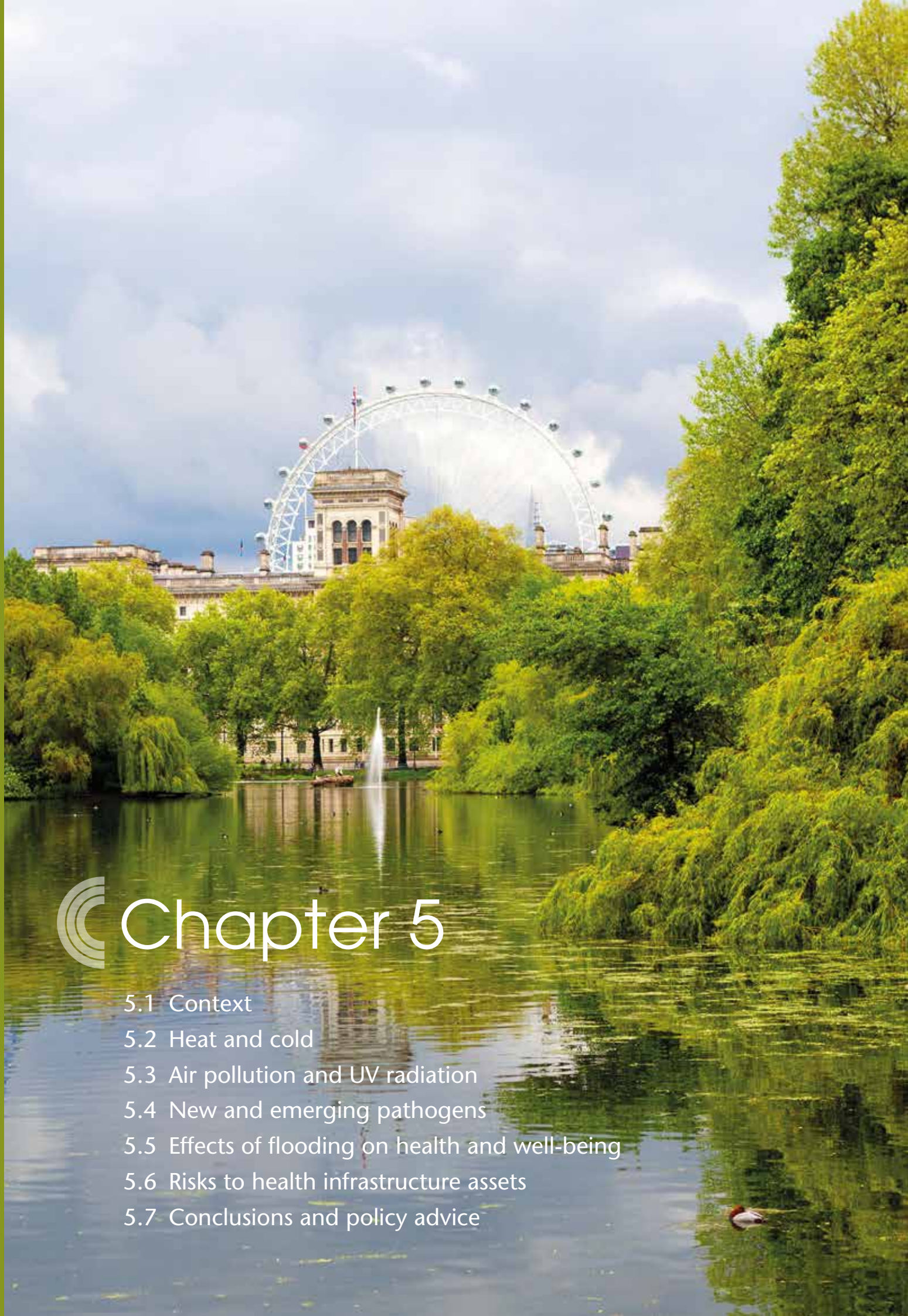
While there is some evidence that businesses are improving their awareness and preparation for flood events, there is little evidence that they are taking action to reduce the physical risk from flooding. The Government and Environment Agency should consider ways of encouraging an increase in the uptake of property-level protection measures. Defra should evaluate the 'repair and renew' grant launched after the winter storms of 2013/14, to understand in particular the level of business take-up, the types of measures it has funded, and the value for money achieved.

Some businesses in large water abstracting industries are taking action to manage current risks to water availability, but it is not clear to what extent they are taking account of how this risk may change in the future. There is an important role for trade associations in encouraging members to consider these risks, and initiatives already in the pipeline provide an opportunity to highlight them to members. The Government should proceed with reform of the abstraction licensing system, so water can be allocated more efficiently and to encourage more sustainable water use.

Some large multi-national companies are already assessing and managing the risks to their supply chains from extreme weather and climate change. These are mainly in the food and drink sector, which is likely to be at greater risk due to its reliance on agricultural products. The Environment Agency should extend its Climate Ready advice service to other sectors reliant on products sourced from countries exposed or vulnerable to climate change, such as clothing and some manufacturing sectors. The Government should build on the analysis undertaken in this report to understand how disruptions to particular sectors might manifest, and the impacts that such disruptions might have across all sectors within the UK.

Firms should act to improve their understanding, and the flexibility, of their supply chains. It is clear that some supply chains will be at a greater degree of risk from climate change than others. Climate change is just one of a number of risks that businesses face when sourcing goods. The additional cost of considering climate risk is likely to be small when assessing supply chains. Doing so may complement other actions which improve supply chain resilience and ultimately the financial performance of a company.

Sales of adaptation goods and services by UK companies have grown in recent years, and at a faster rate than general growth in the UK economy. But the sector remains small and is growing more slowly than in other countries. Defra and UK Trade & Investment, together with the Foreign and Commonwealth Office and the Department for Business, Innovation & Skills, have responsibility within the National Adaptation Programme to promote and facilitate international commercial opportunities for UK companies with adaptation expertise. Defra and UKTI should explore the reasons for the slower growth of UK companies in this market.



Chapter 5

5.1 Context
5.2 Heat and cold
5.3 Air pollution and UV radiation
5.4 New and emerging pathogens
5.5 Effects of flooding on health and well-being
5.6 Risks to health infrastructure assets
5.7 Conclusions and policy advice

Chapter 5:
Well-being and public health

Key messages

Climate change is likely to alter risks to public health and well-being in England. Understanding of these risks has improved since the first UK Climate Change Risk Assessment was published in 2012.

Cold-related mortality is likely to decline slightly with rising mean temperatures, but is projected to remain the largest weather-related risk to health in the future. Due to an ageing population, approximately 40,000 excess deaths per year are still expected in the 2050s as a result of cold weather compared to 41,000 today. Without adaptation, the number of additional deaths and illness associated with heat is likely to increase. Current estimates, based on increasing mean temperatures only rather than extremes, suggest approximately 7,000 excess deaths per year in the 2050s; a tripling of the current average.

The impacts of climate change on health from flooding, changes in air quality including ground level ozone, UV radiation and pathogens are uncertain, but could be substantial. Impacts in terms of illness and well-being could be large, but are harder to project, measure and assess.

Changes in the built environment, together with a growing and ageing population, are increasing exposure and vulnerability to heat. Exposure to cold is likely to be declining though vulnerability is increasing due to an ageing population. Trends in exposure and vulnerability for other health-related climate risks are less clear.

- Exposure to heat is already an issue for health. Types of hospital ward that are vulnerable to overheating currently make up 90% of the total stock. Up to 20% of homes could already be overheating, even in a cool summer. Flats, which are generally more at risk of overheating than houses, now make up 40% of new dwellings compared to 15% in 1996. The number of people aged over 75, who are more vulnerable to heat, has increased by 0.8 million to 4.1 million over the last 20 years. Urban greenspace delivers a range of benefits including mitigating the urban heat island effect, but the total area of urban greenspace has declined by 7% since 2001. Two-thirds of this decline has been caused by the paving over of front gardens.
- The housing stock is becoming more resilient to cold temperatures. The average SAP (Standard Assessment Procedure for thermal efficiency) rating for housing has risen from less than 45 in 1996 to over 55 in 2011. The number of homes with a damp-related problem has halved from 10% in 2003 to 5% in 2011. However, the UK still has a high level of cold-related mortality compared to other north-western European countries.
- Ground level ozone concentrations, that exacerbate respiratory illnesses, are unlikely to be affected substantially by higher temperatures in the future. However, changes in the frequency of prolonged high pressure weather systems over the UK, or a change in the mean wind direction, could have a substantial impact. The ability to model these effects is improving, but projections of future changes are still uncertain.
- Health and social care infrastructure assets differ in their susceptibility to weather-related hazards. Between 10 – 14% of emergency service stations and 6 – 8% of hospitals, care homes and surgeries are located in areas that are potentially susceptible to river and coastal flooding, though after accounting for community defences the majority are in low or moderate risk areas. The uptake of site-level resilience measures for these assets is unclear.
- Trends in mental health and well-being impacts from flooding are currently unknown.

Key messages

Further action by the Government and others is needed to avoid increasing health risks associated with climate change, particularly heat.

- **The Heatwave Plan.** The plan is the Government's main policy for dealing with health risks from heat. Evaluations of the Heatwave Plan for England in 2007 showed that awareness of the plan is generally high amongst healthcare managers and inspectors. However, around 30% of care home inspectors and Primary Care Trusts reported that action was only being partially taken, or not taken at all. A review of the 2013 Heatwave Plan is about to be published. Independent evaluations of the Heatwave Plan should be undertaken, as has happened for the Cold Weather Plan. Health and Wellbeing Boards should also consider how to enforce and report on actions set out in the Heatwave Plan for health and social care facilities such as care homes.
- **Overheating in hospitals.** The Care Quality Commission (CQC) should consider setting standards for maximum temperatures in hospitals and investigate how many wards do not have the means to control temperatures. Actions being taken to manage overheating in hospitals could also be reported to the Sustainable Development Unit through Sustainable Development Management Plans.
- **Cost-effective cooling of existing homes.** External shading and reducing internal heat gains are cost-effective to retrofit in existing homes compared to air conditioning, but the uptake of measures and public awareness is currently very low. The Government should consider how to build awareness of options and encourage their uptake through better information provision to householders.
- **Passive cooling in new homes.** Around 20% of the homes that will exist in 2050 have yet to be built. Including passive cooling measures in buildings at the design stage is more cost-effective than retrofit, but the health benefits of these measures will fall to the householder while the developer incurs the up-front costs. As such, a standard or other requirement is likely to be the best lever to ensure appropriate action. A major barrier to introducing requirements for cooling measures in new homes has been the inability to quantify the costs and benefits in terms of health and well-being. This evidence is now emerging; for example a modelling study for the 2050s shows that if adaptation measures were effective at reducing internal temperatures by 1-2°C, heat-related mortality could be reduced by 30 – 70%. The Government should review the evidence and evaluate options for a standard or other requirement on overheating.

More data is needed to understand the level of preparedness for other health-related risks from climate change.

- **Pathogens.** Public Health England (PHE) should continue to consider priorities for detection, surveillance and control of pathogens likely to be become more common or be introduced with climate change. PHE should focus resources on regions and pathogens that are thought to pose the greatest risk, so that changes can be detected early.
- **Health infrastructure assets.** Asset managers, Directors of Public Health or Health and Well-being Boards as appropriate should collect and publish information on asset resilience to weather-related risks. Actions within the NHS should also be reported under Sustainable Development Management Plans or the Adaptation Reporting Power in 2015.
- **Air pollution.** Continued research is needed to assess how changing wind patterns or changes to air pressure systems over the UK could affect air pollution levels, including the concentration of ground level ozone.

5.1 Context

A healthy population with high levels of well-being is important for individuals, society and also the economy.

Improved socio-economic conditions also lead to higher levels of health through better housing, sanitation, access to clean water, improved nutrition, education and the ability to pay for health and social care.[1]

1 Bloom and Canning (2008).

Life expectancy in the UK is in line with the European average and the general health of the UK population is improving over time. Health and social care spend and resources per capita in the UK are lower than other north-western European countries.

Average life expectancy for the UK in 2012 was 82 years, which is higher than the OECD average and in line with other north-west European countries. The health of the nation is improving, with life expectancy increasing by 4 years since 2000.[2]

UK health and social care expenditure in 2011 was £142 billion.[3] Expenditure in real terms grew by 5.7% per year between 2000 and 2009, but this has slowed to 3.4% in 2011. Per capita spend on health and social care in the UK is slightly higher than the OECD average, but lower than all other north-west European countries apart from Finland. The level of resource per head of population (e.g. numbers of doctors and hospital beds) is less than the OECD average.[4]

Alongside physical health, mental health and socio-economic factors are important determinants of well-being. The OECD uses a number of metrics to measure well-being including income, housing, work-life balance and health status. In 2011, people in the UK scored more highly than the OECD average on personal earnings, job tenure and basic dwelling facilities, and average on other aspects of wellbeing.[5]

The National Health Service is the fifth largest employer in the world. It has undergone a substantial re-organisation under the 2012 Health and Social Care Act.

The National Health Service (NHS) employs over 1.7 million people and supports over 1 million patients every 36 hours.[6]

The way that health and social care is delivered in England has been substantially re-organised through the 2012 Health and Social Care Act (Box 5.1). The new system has been designed to increase decision making power at the local level, create a greater focus on health outcomes, and place patients and clinicians at the centre of decision making. Given the increased pressures from a growing and ageing population, there is also a shift occurring away from hospital-based care to more emphasis on prevention and care in the community.

2 http://data.worldbank.org/indicator/SP.DYN.LE00.IN/countries
3 Office of National Statistics (2013).
4 http://www.oecd.org/health/health-systems
5 OECD (2013).
6 http://www.nhs.uk/NHSEngland/thenhs/about/Pages/overview.aspx

Box 5.1: The Health and Social Care Act (2012)

The Health and Social Care Act (2012) has altered the organisational structure for health and social care delivery in England, with a strong focus towards localised decision making and greater emphasis on prevention of disease. The intention of the Act is to enable the NHS and public care system to cope with rising demand from a growing and ageing population; improve aspects of care that lag behind the rest of Europe; and make the health and social care system more efficient and cost-effective.

Since April 2013, clinician-led Clinical Commissioning Groups (CCGs) have replaced Primary Care Trusts (PCTs). CCGs are responsible for the majority of the NHS budget of around £65 billion per year. NHS England is responsible for commissioning health care such as acute care hospitals (£13 billion) and specialist care (£12 billion). The NHS delivers this care through a number of NHS Foundation Trusts.

Responsibility for public health has been split from the NHS and now sits within local authorities, who have responsibility for spending £2.7 billion per year on public health. Every local authority has a Director of Public Health who sits on a Health and Wellbeing Board. Health priorities for the local population are set out in Joint Strategic Needs Assessments (JSNAs) which aim to ensure consistency between the priorities of CCGs and local authorities. It is not yet clear how effective this process will be at ensuring consistency.

The Health Protection Agency (HPA) has been subsumed into a new organisation called Public Health England (PHE). PHE advises Government, conducts research, and assists local authorities and the NHS in developing the public health system. PHE has a key role in long-term planning for and reduction of the health effects of climate change.

There are two regulatory bodies for health and social care delivery. Monitor is responsible for authorising, monitoring and regulating NHS Foundation Trusts. The Care Quality Commission (CQC) is responsible for regulating health and adult social care services.

The National Institute for Health and Clinical Excellence (NICE) was given legislative responsibility under the Act to produce quality standards for the commissioning of health and social care.

NHS England and Public Health England fund the Sustainable Development Unit (SDU). The unit aims to ensure that the health and care system fulfils its potential as a leading sustainable and low carbon service, including through adapting to climate change.

Source: https://www.gov.uk/government/publications/the-health-and-care-system-explained/the-health-and-care-system-explained and Kings Fund (2013).

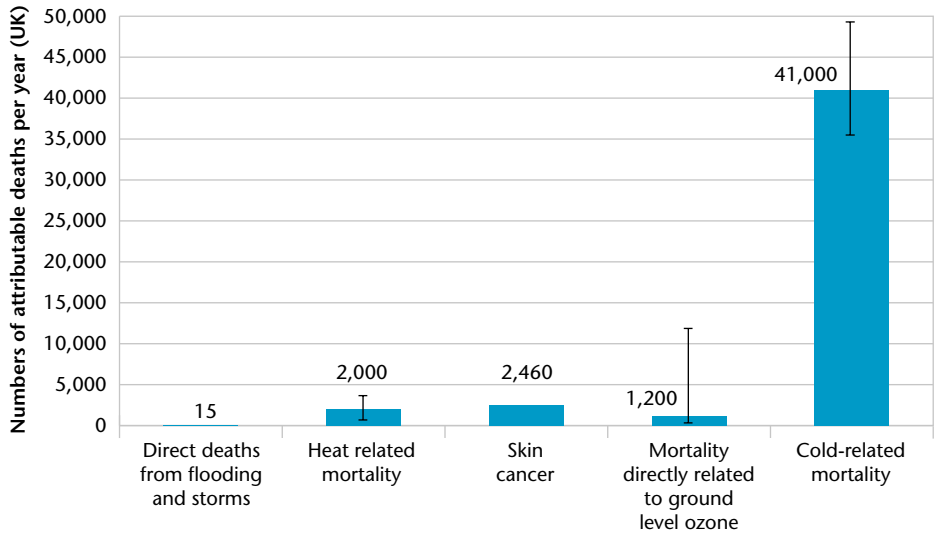
Factors that contribute to ill-health, and are likely to be affected by climate change, already contribute to a substantial number of deaths per year. Mortality is only a partial measure of impact.

Figure 5.1 shows the estimated numbers of deaths currently brought forward in the UK related to factors that are likely to be affected by climate change. While deaths as a direct result of flooding or storms are very low, heat-related deaths, skin cancer and respiratory illnesses exacerbated by ground level ozone each contribute to between 1,000 and 2,500 deaths per year (central estimates). Cold contributes to around 41,000 deaths in the UK in a single year, or 7% of total mortality from all causes.[7] The elderly, very young and those with existing cardiovascular or respiratory illnesses are particularly at risk.

There are limitations with using deaths as a metric of comparison. Mortality estimates do not provide a measure of the number of life-years lost, or the economic cost or burden of disease. They also do not measure wider impacts on health such as well-being. However, mortality tends to be the only easily-comparable metric across different weather-related causes and gives some indication of the relative scale of different risks.

7 There were around 567,000 deaths in the UK in 2012 (ONS, 2012).

Figure 5.1: Deaths brought forward for selected conditions where climate change could alter the mortality burden in the future



Source: Heat and cold-related mortality: Hajat et al. (2014). Annual estimates are based on data for years between 2000-2009. Direct deaths from floods and storms: Hames and Vardoulakis (2012). Annual estimates are based on data since the 1990s. Deaths from skin cancer: ONS (2012). Value given is for 2012. Not all of these deaths will have been caused by outdoor UV exposure, some may be attributable to the use of sun beds for example. Mortality directly related to ground level ozone: Health Protection Agency (2012). Estimates are based on data for 2003.
Notes: Figures show the number of deaths for the UK where a weather-related factor has been a contributing variable. Skin cancer may be caused by exposure to outdoor UV radiation, but can also be caused by other factors such as the use of sunbeds. Skin cancer and respiratory deaths from ground level ozone are classified as risks from long-term exposure, whereas heat, cold and flooding/storms are risks from short-term exposure only.

Climate change is likely to alter the burden on physical health from weather hazards across England, and will have an impact on well-being that is not currently quantified.

Although the impacts of climate change on health in England are not projected to be as high as health impacts in low and middle income countries, they will remain substantial.[8] Climate change is likely to impose both direct and indirect risks and opportunities to the health of the population. It will also have implications for the national and public health services in how they provide care.

Uncertainties in projecting future impacts on health are large, due to a lack of understanding of current vulnerability; the effects of changing weather patterns on exposure; and uncertainties over the extent to which people will adapt physiologically to higher temperatures. While the direct risks to health from factors such as temperature are the easiest to quantify, indirect risks such as effects of flooding on mental health and socio-economic well-being, changes to food production (in the UK or abroad), or food pricing may pose the greatest risk to health and well-being in the long-term.

Annex 5.1 outlines risks where current vulnerability is high; where the projected impacts of climate change are large; and/or where decisions on managing these effects have long lead times or long-term effects. These risks and opportunities are where action is most urgently needed now and are the focus for this chapter. The risks and opportunities where large uncertainties mean that the scale of future risk is uncertain (but could be large) are also discussed.

8 IPCC (2012), Health Protection Agency (2012).

The National Adaptation Programme (NAP) healthy and resilient communities theme focusses on actions to reduce deaths from severe weather, promote resilience in the health and social care sector, and minimise the impacts of climate change on vulnerable groups.

Box 5.2 sets out the key actions related to health under the healthy and resilient communities theme of the NAP. In our first statutory report to Parliament in 2015, we will report on the extent to which these actions have been implemented, and whether they are likely to reduce exposure or vulnerability to the risks associated with climate change.

Box 5.2: National Adaptation Programme: healthy and resilient communities chapter

The healthy and resilient communities chapter contains a list of actions aimed at reducing risks from severe weather, protecting vulnerable people, and enhancing the resilience of the health and social care system. The actions focus on promoting adaptive capacity within the health and social care system and enhancing existing guidance, tools and policies, as follows:

- Health and well-being boards to consider factors that impact on health and well-being, which could include consideration of climate change and extreme weather.
- Directors of Public Health to promote preparedness for climate change and extreme weather.
- Sustainable Development Unit to publish sustainable development management plans and associated adaptation guidance.
- Public Health England and Department of Health to enhance the Heatwave Plan to include advice on UVR exposure, safeguarding vulnerable people and explore the relevance of this approach to other extreme weather events.
- Public Health England and Department of Health to promote and implement the Cold Weather Plan.
- A range of bodies to integrate health impacts into the National Flood Emergency Framework, and promote information on the health impacts of flooding.
- Environment Agency to pilot the health adaptation tool.
- Environment Agency to support the LGA's climate local initiative to help councils address health risks.
- Public Health England and partners to maintain and expand UVR monitoring.
- Department of Health and the NHS to promote and implement NHS emergency planning guidance.
- Department of Health to include flooding and extreme temperatures in the premises assurance model (PAM).
- Department of Health, NHS, Environment Agency and Public Health England to further develop the Strategic Health and Asset Planning Evaluation toolkit (SHAPE).
- A range of bodies to review national guidance on making healthcare facilities resilient to flooding and extreme temperatures.
- NHS estates to report on resilience measures.
- Environment Agency and National Council for Voluntary Organisations to share information and promote understanding of the risks to vulnerable groups.
- UKCIP, Good Homes Alliance and NHBC to disseminate guidance on overheating risk.
- DECC to review the Standard Assessment Procedure in relation to overheating.

Source: HM Government (2013).

5.2 Heat and cold

Cold-related mortality and morbidity

Cold is the largest weather-related contribution to mortality in England. After accounting for differences in winter temperatures, cold-related mortality in the UK remains higher than for other north-western European countries such as France, Germany, the Netherlands and Finland.

Estimates of annual attributable deaths from cold weather in the UK are between 35,500 and 49,400 premature deaths per year (mid-range estimate 41,000, about 7% of all annual deaths), with large inter-annual variability.[9] Estimates for morbidity are more difficult to quantify due to the confounding effects of winter illnesses that are not caused by cold such as influenza. Excess winter mortality in the UK is higher relative to all other north-western European countries such as France, Finland, Germany, Denmark and the Netherlands.[10] The reasons for the comparatively high risk in the UK are related to poorer thermal efficiency, higher levels of damp in housing, and higher rates of fuel poverty.[11] The majority of deaths related to cold are from respiratory and cardiovascular causes, rather than hypothermia.[12] Cold weather also increases the number of falls and subsequent fractures. People over 75, children under 5, those with existing medical conditions and people living in deprived circumstances (in particular, those living in fuel poverty) are especially at risk.[13] The Government has a Cold Weather Plan that is implemented every winter to raise awareness of the risks from cold weather and put in place measures to protect the most vulnerable.

The temperature threshold below which cold-related mortality starts to rise is difficult to ascertain, but some estimates put it at a mean outdoor temperature of between 10°C and 13°C depending on the region.[14] However, estimates vary between studies.

Future projections of risk for cold-related mortality

The overall burden from cold weather should decline over time as average temperatures increase. However, an ageing population will counter this effect to some degree, resulting in an overall reduction in mortality of 1,000 (2.4%) per year approximately by the 2050s. Continued action to increase the thermal efficiency of housing is therefore important.

9 Hajat et al. (2013).
10 Fowler et al. (2014)
11 Healy (2003).
12 Hajat et al. (2013).
13 Public Health England (2013a).
14 Health Protection Agency (2012).

These estimates take account of a growing and ageing population but no other changes in vulnerability, and assume no adaptation (Figure 5.2). There are several reasons why the cold-related mortality burden may not decline as much as might be expected given the expected increase in mean temperatures by 2050:

- An ageing population may increase the overall burden. This could mean that the total number of deaths actually increases in the near future, and only declines slightly by 2050.[15]
- There is uncertainty over whether current policies to increase energy efficiency in homes will achieve their goals, particularly in relation to solid-wall insulation.[16]
- Despite an increase in average temperatures, temperature variability will remain and may increase, and the population may be less prepared for cold snaps due to their increasing rarity. This will also have implications for emergency planning (see Chapter 6).

For these reasons, it is important that effort is maintained through current policies to improve the resilience of the building stock to cold.

The energy efficiency of England's building stock has risen over the last ten years, while levels of mould and damp have declined. At least £800 million is being spent per year on policies to improve energy efficiency in homes.[17]

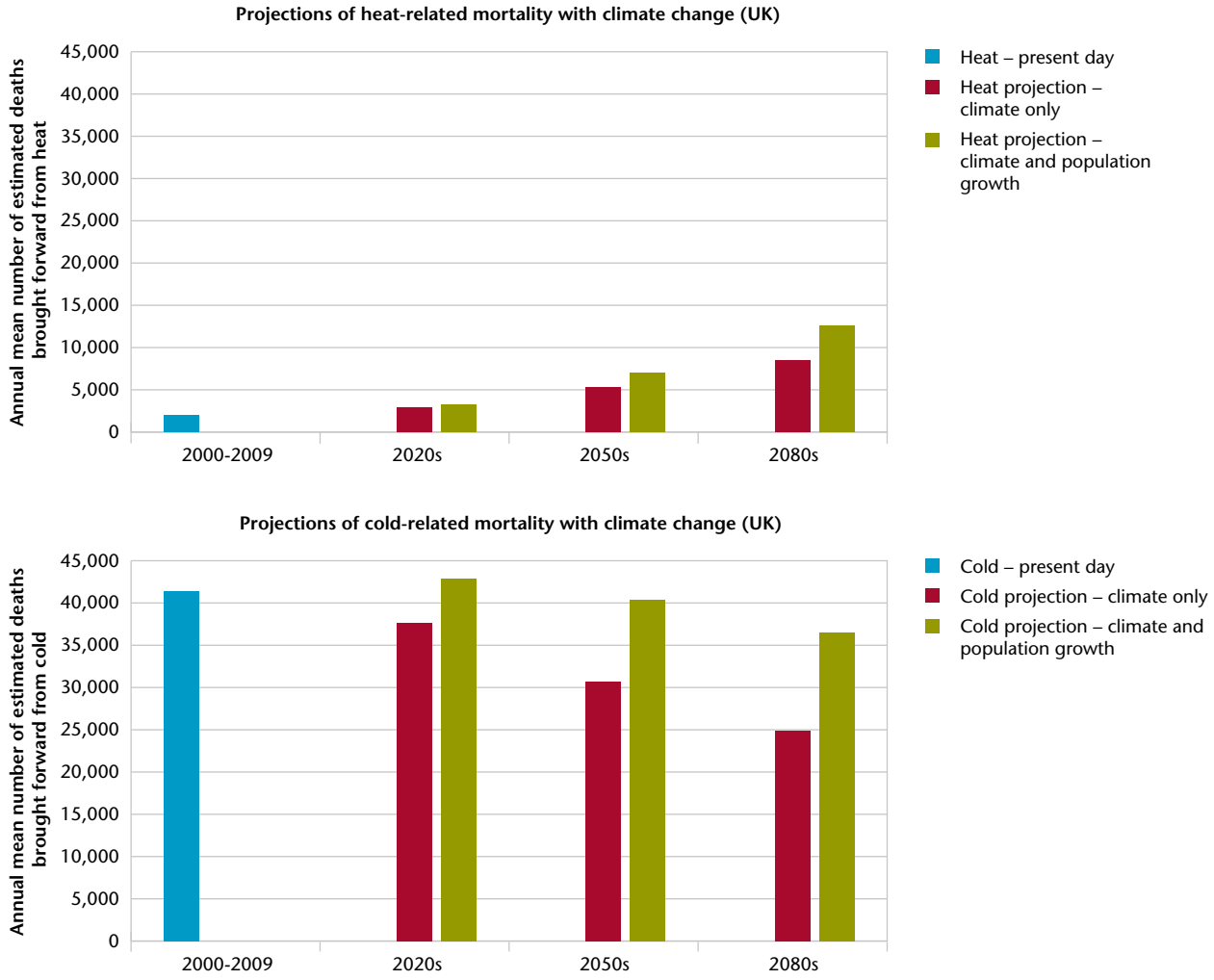
The Standard Assessment Procedure (SAP) is used to measure the thermal efficiency of the building stock. A higher score indicates a more energy-efficient building. A score of 100 indicates that no heating or hot water costs are required for that building. The average SAP rating for the housing stock in England has risen from less than 45 in 1996 to over 55 in 2011. At the same time, the number of homes with a damp-related problem have halved from 10% in 2003 to 5% in 2011.[18]

Over the first carbon budget period (2008-2012) a large number of homes were insulated under three main policies (the Carbon Emission Reduction Target, Community Energy Saving Programme and Warmfront). For example, around 5 million lofts and more than 2 million cavity walls were insulated under the schemes. However, insulation rates have dropped off sharply since early 2013 with the introduction of a new energy efficiency policy framework.

The Energy Company Obligation was introduced in early 2013 and will run until 2017, with around 60% of the funding envelope (around £900 million per year for Great Britain) aimed at low-income households. In addition, the Green Deal was launched in 2013. It is a new financing framework to facilitate energy efficiency improvements in homes and non-residential properties, funded by a charge on electricity bills that avoids the need for consumers to pay upfront costs. To provide incentives for early adopters, the Green Deal also received a £200 million support package from the Treasury which was used for cashback incentives and to support local authorities. New incentives are available from June 2014 through the Green Deal Home Improvement Fund but the Government has only committed to support the Fund for one year and rates are only guaranteed for the first £50 million of the fund. If these measures have the desired impact, indoor exposure to cold is likely to decline further over time.

15 Hajat et al. (2013).
16 Committee on Climate Change (2014).
17 Committee on Climate Change (2013b).
18 HR Wallingford (2014b) for the ASC.

Figure 5.2: Future projections of annual UK heat- and cold-related mortality with climate change



Source: Hajat et al. (2014)
Notes: Mortality estimates for the baseline are estimated for a single year, but based on mortality data from 2000 – 2009. These estimates assume no physiological adaptation.

Heat-related mortality and morbidity

Heat contributes to about 2,000 premature deaths per year in the UK. The average outdoor temperature thresholds at which populations begin to show heat-related mortality vary regionally from around 17°C to 20°C.

Because of regional differences in the population response to heat, northern parts of England have lower thresholds for excess mortality than further south. The threshold for the north-east is around 16.6°C, while for London it is about 19.6°C.[19] Different studies give slightly different thresholds. These relatively low thresholds demonstrate that mortality from heat is sensitive to differences in mean temperatures as well as the intensity and frequency of heatwaves. A significant burden of heat-related mortality occurs outside of recognised heatwave events.[20]

19 Hajat et al. (2013).
20 AECOM (2012).

Warm temperatures cause the heart to work harder, and can lead to dehydration from sweating. Older people and those with existing illnesses are most at risk, particularly those with illnesses that compromise thermoregulation, mobility, awareness and behaviour. At high temperatures otherwise healthy people can also be at risk, especially if they are physically active during hot weather.

Some, but not all, of the deaths that occur during heatwaves are linked to episodes of high air pollution. Analysis of the 2003 heatwave found, for example, that 20 – 40% of excess deaths in the first two weeks of August 2003 were associated with elevated levels of ground level ozone and particulate matter.[21]

Hospital admissions for respiratory and renal causes have also been shown to increase in hot weather.[22]

A mortality displacement effect is currently observed with heat-related deaths in the UK, but this is likely to decrease in more extreme temperatures.

The overall mortality impact of heat or cold will be related to the life-years lost as well as the total number of deaths. There is evidence for the UK that shortly following a period of hot temperatures, there is a slight dip in overall mortality compared to what would be expected. This suggests that the people that died due to the heat would have done so shortly afterwards from another cause. Therefore, the total effect of heat on mortality in terms of life years lost is not as large as is implied by looking at number of immediate deaths alone.[23] This displaced mortality effect was observed for the deaths that occurred during the 2003 heatwave in the UK, though not in Paris where temperatures were higher.[24] The displacement effect is thought to be less strong in heatwave conditions. It is generally not observed in the pattern of deaths during and after cold spells.[25] Even with a mortality displacement effect, deaths from heat are classed as avoidable, and measures should therefore be taken to prevent them.

Future projections of risk for heat-related mortality

The effects of increased mean temperatures and population growth are projected to increase deaths in summer to approximately 7,000 per year in the 2050s across the UK (Figure 5.2**).**

These estimates take account of a growing and ageing population but no other changes in vulnerability or exposure, and assume no physiological adaptation.

Physiological adaptation is likely to occur in response to gradual increases in summer mean temperature.

Many studies that consider future mortality from temperature with climate change use mean temperature increases only as a metric and assume no physiological adaptation.[26]

21 Stedman (2004).
22 Kovats et al. (2004).
23 Hajat et al. (2005).
24 Kovats and Hajat (2008).
25 Braga et al. (2001).
26 Hames and Vardoulakis (2012).

There are several indications that people could begin to adapt to gradual rises in mean temperature:

- The UK population has different regional levels of physiological adaptation depending on the mean temperature in that region, suggesting that people can adapt to changes in the mean temperature of their surroundings.[27]
- Different populations around the world have different levels of physiological adaptation which are not due to genetic characteristics, again suggesting that humans have a range of coping limits which are shaped by the climate they live in.[28]
- Healthy people in general can cope with increased temperatures up to a point.[29] The largest jump in mortality also occurs at the start of a warm period, which could indicate that people adapt over time if temperatures remain high.

There is evidence that an increase in the intensity of heatwaves, and increased variability in temperature could have an impact on mortality in the future.

Although people may adapt physiologically to gradual increases in mean temperature, it is less likely that this will occur in response to more extreme temperatures, particularly if overall temperature variability increases.[30]

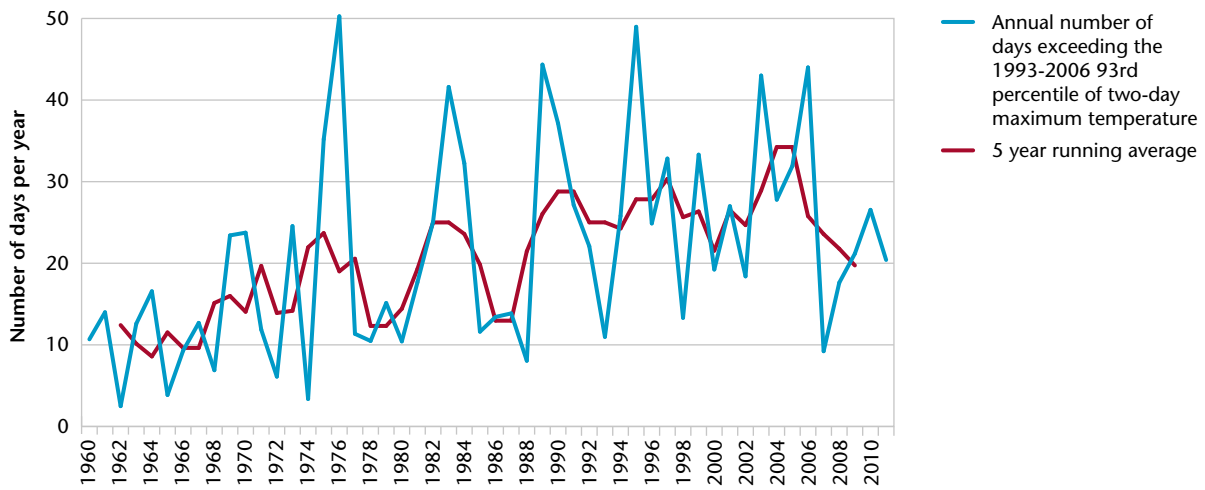
Recent modelling studies on the effects of temperature on health have started to include a heatwave component. An update to the analysis used in the 2012 Climate Change Risk Assessment (CCRA) found that including heatwave projections alongside changes in mean temperature for the UK resulted in an estimated additional 64% increase in heat-related mortality in the 2020s compared to the 2000s for London, though statistically significant differences were not found for other regions.[31]

Modelling studies suggest that extreme temperatures are likely to increase, though the degree of future variability between the mean and extreme temperatures in the future is very uncertain for the UK. One study found that the intensity of heatwaves in Europe is projected to increase in the future by between 1.4°C and 7.5°C for a rise in global mean temperature of 2°C. These projections are sensitive to assumptions made about how much soil drying will occur in hot weather in the future.[32]

There has been a slight increase in the total number of very hot days occurring in England each year since 1960, though it is unclear if this also equates to an increase in overall temperature variability or heatwave intensity and duration (Figure 5.3).[33]

27 Ibid.
28 Braga et al. (2001).
29 Hajat et al. (2005).
30 Braga et al. (2001).
31 Health Protection Agency (2012).
32 Met Office (2014b).
33 HR Wallingford (2014b) for the ASC.

Figure 5.3: Time series showing the number of annual hot days per year for England (1960-2011)



Source: HR Wallingford (2014b) for the ASC.
Notes: The graph shows the number of days per year that the population-weighted daily maximum temperature exceeds the 93rd percentile of the two-day average daily maximum temperature (the day in question plus the next day) for the period 1993-2006 (blue line). The 5 year running average is also shown, which is the average of the 2 years previous, the current year and the 2 years after (red line). Temperature measurements in each area have been weighted by the size of local population in order to show the trend in temperatures where people are living. Census data from 2011 was matched to temperature data for each 5 x 5 km grid square across England. The 93rd percentile of the 2-day mean daily maximum temperature for 1993-2006 ranges from 20.9˚C in the north-east to 24.7˚C in London. The England figures shown here has been produced by averaging out the results for the English regions, again using population weighting.

Trends in vulnerability to heat

The population in England is growing and ageing, which is increasing overall vulnerability to heat.

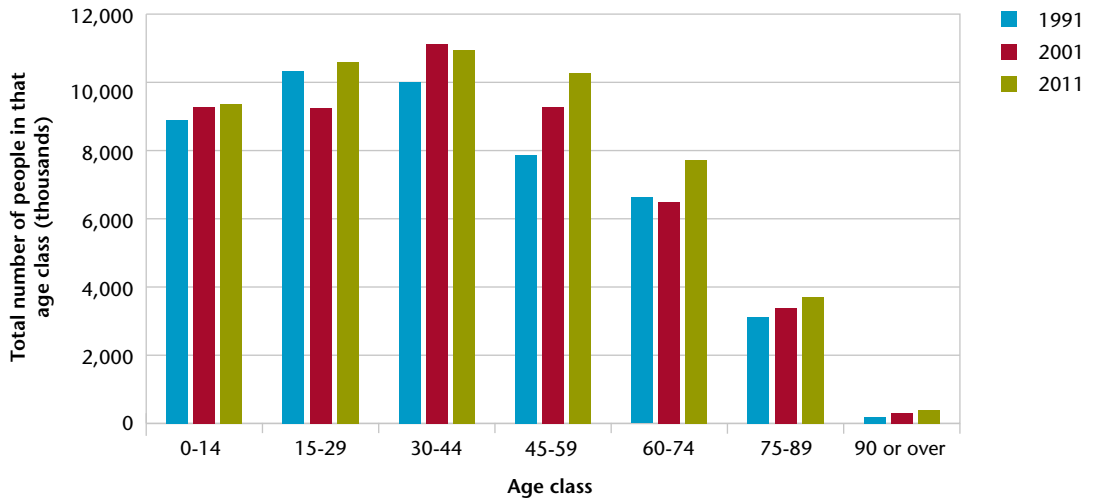
Figure 5.4 shows how the UK population has aged between 1991 and 2011. Between 2010 and 2035, the percentage of the population made up of over-75s is projected to increase from 8% to 12%.[34] People over 75 years of age are particularly vulnerable to hot weather. This is mainly due to physiological changes with age that prevent sweating to cool the body, but could also be caused by older people potentially having less control over their environment (for example, because they are in a care home, are less able to move to cooler locations, cannot actively maintain hydration levels, or have less capacity to find other means to cool themselves).

Currently, 883,000 people over the age of 75 live in urban areas, making up 9.5% of the urban population.[35] In the over-70 age group, 713,000 live in urban or suburban flats. Around 377,000 over-70s live in flats with a total area of less than 50m^2, and 348,000 with only two habitable rooms or fewer.[36] These people are likely to be at high risk from heat due to a combination of age and characteristics of the buildings they live in, which is discussed in more detail below.

Few studies have tried to monitor temperatures in homes across the country. One study that has measured internal temperatures found that 21% of homes studied exceeded overheating thresholds in a cool summer.

34 Office of National Statistics (2014b).
35 HR Wallingford (2014b) for the ASC.
36 BRE (2014) for the ASC (unpublished).

Figure 5.4: UK population by age class between 1991 and 2011



Source: HR Wallingford (2014b) for the ASC.

Given that people in the UK spend 90% of their time indoors, it is reasonable to assume that indoor temperatures have a strong bearing on health impacts from heat.[37] Controlling the internal environment to reduce exposure is also much easier than controlling the outdoor environment.

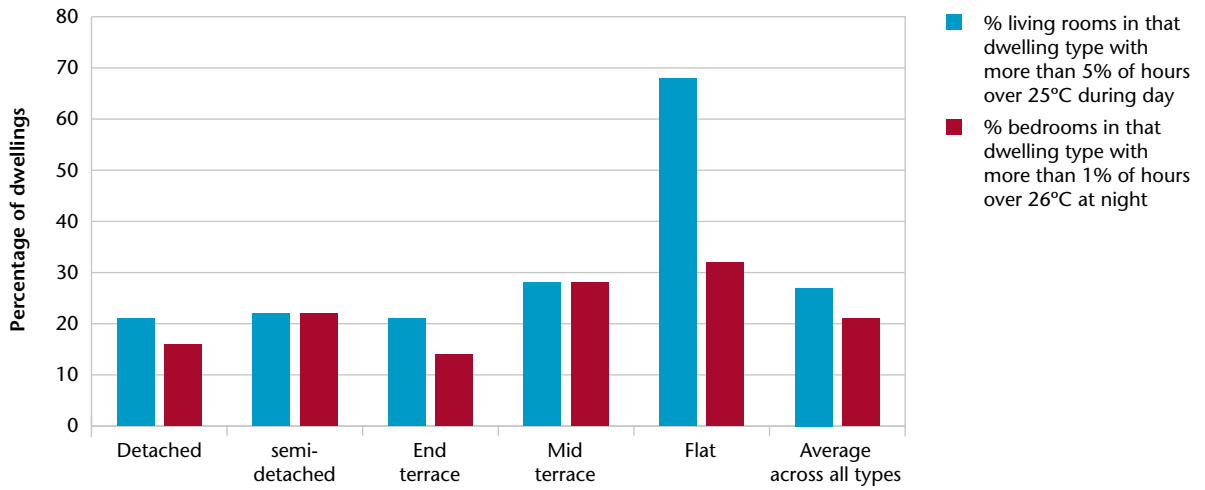
Based on results of the English Housing Survey, BRE found that 122,000 homes (0.5% on the English housing stock) displayed physical characteristics that would make them particularly at risk of overheating.[38] This study was limited as it is based on inspections rather than actual monitoring of internal temperatures. In recognition of the need for more data, from 2014/15 the English Housing Survey will include a question on whether occupants experience overheating even when heating is off and windows are open. Asking people is considered to be a robust measure for assessing thermal comfort,[39] although it is less clear how relevant this is as a measure of health impacts of overheating more generally.

There are relatively few studies that directly monitor indoor temperatures, but those that have suggest that there could be a substantial problem from overheating in the existing building stock.[40] Figure 5.5 shows results from an empirical study of temperature monitoring in homes. It concluded that approx. 21% of bedrooms exceeded 26°C at night for more than 1% of night time hours, despite relatively cool external summer temperatures.[41] This was particularly the case in homes built after 1990. If scaled up, this would equate to 4.8 million homes at risk across England in a cool summer.

Flats and terraced housing – particularly those built before 1920, in the 1960s and post-1990s – tend to be the most prone to overheating. The number of flats is increasing as a percentage of the total housing stock.

37 AECOM (2012).
38 BRE (2014) for the ASC.
39 CIBSE (2013).
40 AECOM (2012).
41 Beizaee et al. (2013).

Figure 5.5: Percentage of dwellings found to overheat in summer 2007 (a relatively cool summer)



Source: Beizaee, Lomas and Firth 2013 – National Survey of summertime temperatures and overheating risk.
Notes: The sample of 207 homes was made up of detached (34%), semi-detached (32%), end of terrace (7%), mid-terrace (17%), purpose built flat (8%), converted houses (1%) and other (1%).

Purpose-built or top floor flats and terraced houses tend to have the highest risk of overheating due to their physical characteristics. This includes being single aspect which prevents through-flow of air; absorbing heat from adjoining properties; their small size; and inadequate external insulation in roofs to protect attic flats. Uninsulated loft conversions in pre-1919 buildings, and flats built after the 1990s tend to have the highest risk, though 1960s buildings also show a higher than average risk.[42]

For example, a recent small survey of 120 environmental health officers by the Good Homes Alliance identified 90 cases of overheating, 48% of which were in homes built after 2000.[43] Examples of causes of overheating included improperly ventilated communal areas in blocks of flats, and an inability to open windows. Small flats in particular were at risk. This is of particular concern given that new homes are becoming smaller to help cope with rising housing demand, and are currently the smallest in western Europe.

The number of flats and maisonettes being built has increased from around 15% of all new registrations in 1996 to around 40% in 2013, with a mirrored decline in the number of detached homes being built[44]. As would be expected, 93% of all flats (and 95% of all high rise flats) are located in urban areas. With pressure from a growing population on housing, this trend is likely to continue.

Overheating is also a potentially serious issue in hospitals, with one study suggesting 90% of wards are of a type prone to overheating.

Overheating in hospitals is a serious issue given the vulnerability of patients. Research carried out under the De2RHECC research programme has shown that temperatures in some hospital wards can exceed 30°C when the external temperature is only 22°C. While

42 AECOM (2012) and BRE (2014) for the ASC.
43 Good Homes Alliance (2014).
44 NHBC (2013).

Victorian "nightingale" wards were fairly resilient to overheating, other more modern wards were at greater risk and exceeded temperatures of 26°C on a number of occasions.[45] Further analysis to be published in 2014 suggests that around 90% of wards are of a type that are prone to overheating (based on total square footage rather than number of buildings). The project also considers cost-effective measures that can be instigated to cool hospital wards.

More data is needed on actual incidences of overheating in hospitals to better understand the scale of the issue. NHS Trusts are required to report on whether they are preparing adaptation plans under the Estates Return Information Collection (ERIC); 69% of NHS Trusts reported in 2012/13 that plans were in place. The work under these plans could include recorded incidences of temperatures exceeding a given threshold, for example.

People living in urban areas are more at risk from overheating due to the urban heat island effect (UHI). Despite an increase in mean temperature and the number of hot days annually, there have been no identifiable trends in the UHI effect to date.

People living in urban areas are at higher risk from heat due to the urban heat island effect, which can increase temperatures by an average of 7°C above that of the surrounding countryside.[46] Both increases in average temperatures, and waste heat produced by air conditioning systems in cities, could intensify this effect in the future.

Despite the increase in background temperatures, analysis of temperature station data shows no significant increase in the UHI effect to date, and in fact shows that rural temperatures are increasing faster than urban temperatures. The reason for this trend requires more study.[47]

The total area of urban greenspace declined by 7% between 2001 and 2013, though the rate of decline has slowed in recent years. The area of urban bluespace has remained constant.

Urban greenspace has been shown to have a cooling effect in cities as well as wider benefits (i.e. flood alleviation, enhancing biodiversity and well-being). There is some evidence that the cooling effect of parks extends into the surrounding urban area, though not across a whole city.[48] The current green area in London may cool the city by as much as 2 – 3°C.[49] A study looking at Manchester found that increasing the area of urban greenspace by 10% could result in cooling of 2.5°C in the 2080s under a high emissions scenario.[50] Among other benefits, urban greenspace can also play a role as part of sustainable urban drainage (see Chapter 2).

The area of urban greenspace in England has decreased by 7% from 1,028,000 ha to 954,000 ha between 2001 and 2013.[51] About 35% of this loss has been due to development of greenfield sites, while the rest has been caused by the paving over of gardens. Most of this observed loss occurred between 2001 and 2008, but around

45 Short et al. (2012).
46 Smith and Levermore (2008).
47 HR Wallingford (2014b) for the ASC.
48 Bowler et al. (2010).
49 Walker Institute (2010).
50 Gill et al. (2007).
51 HR Wallingford (2014b) for the ASC.

1,000 ha is still being lost each year. We have not been able to assess the degree of action associated with increasing urban greenspace such as tree planting.

Urban bluespace (ponds, lakes and rivers) also has a cooling effect of 2.5°C on average compared to the surrounding area.[52] The evidence on the effectiveness of different types of bluespace is limited. The total area of urban bluespace in England remained constant between 2001 and 2013 at around 20,000 ha.

Policies and action to reduce the health effects from high temperatures

Behavioural adaptations

Guidance on behavioural adaptations in response to heat and cold are set out in the Cold Weather and Heatwave Plans.

The main government policy on tackling the harm to health from heatwaves is the Heatwave Plan for England. This sets out individual and organisational actions to be taken before and during heatwave periods. A similar plan for actions to take in relation to cold spells is outlined in the Cold Weather Plan. Both plans are updated on an annual basis, incorporating new evidence and feedback from users and other stakeholders.

The Heatwave Plan includes measures to protect vulnerable people at home, in care homes and hospitals, public advice on behavioural changes to make in response to heat, and information on the types of people particularly at risk. The Heatwave Plan includes a set of measures to implement year round, and during forecasted and actual periods of hot weather. It recommends actions to be taken to reduce overheating in buildings (especially homes), and spatial planning to reduce the urban heat island effect. It also briefly indicates the potential impact of high temperatures on other sectors, for example transport and energy generation, but it does not go into detail.

The behavioural impacts of the 2006 Heatwave Plan were mixed. Research on the impact of the 2013 plan will be published later in 2014.

Evaluations of the Heatwave Plan of 2006 and 2013 (the latter not yet published) have considered mortality and morbidity trends during the heatwave period; awareness of the plan and uptake of actions. The review of the 2006 Heatwave Plan found that while media coverage was good, uptake of actions was variable across health and social care staff:[53]

- 31% of care home inspectors who responded found no evidence of action in 50% or more of the homes they inspected, with another 51% reporting that positive responses had been implemented in the majority of care homes they inspected.
- 34% of Primary Care Trusts reported the lists of vulnerable people to contact were only partially drawn up, or not drawn up at all. There were also problems in contacting everyone on the lists due to large numbers of people being classed as vulnerable.

52 Volker et al. (2013).
53 Health Protection Agency (2007).

The evaluation reported low response rates and a lack of information available on specific interventions employed. As a result, although the surveys provide information about awareness, they do not provide data on the actual actions undertaken during heatwaves, or the achieved outcomes of those actions.

An independent case study review of the 2011 Heatwave Plan found that while hospital managers were aware of the plan, frontline nursing staff were not. It also found that measures to control internal temperatures in hospitals were limited due to an absence of appropriate equipment and thermostat controls.[54] In 2012, leaflets providing information to frontline staff in hospitals and the community were developed to raise awareness of the recommended actions, but the impact of these have not been evaluated to date.

Adaptations to the built environment

Approaches vary in how internal overheating thresholds in buildings are set, if they exist at all.

Understanding the point at which internal temperatures become a problem for health is useful to monitor trends in overheating. The Department of Health sets guidelines for new healthcare buildings whereby internal temperatures should not exceed 28°C for more than 50 hours per year. Care Quality Commission guidance states that service users should be able to control temperatures, but does not set limits.[55] There are no upper temperature guidelines for workplaces, public transport or schools at present, other than that temperatures should be reasonable.

In the past, the Chartered Institute of Building Service Engineers has used fixed metrics such as staying below 1% of occupied hours over 26°C in bedrooms as a threshold for guidance on design standards for homes.[56] Current standards for building design are moving towards "adaptive comfort models", where the assumed comfortable temperature indoors increases as the external temperature increases.[57] Studies have shown that healthy people are more accepting of higher indoor temperatures when the outdoor temperature is high. These dynamic models make it more likely that naturally ventilated buildings, which tend to have more variable indoor temperatures, will conform to the standard. However, adaptive comfort models do not consider risks to health from high indoor temperatures. Because mortality starts to increase over a set threshold, dynamic comfort models may be less relevant for assessing health risks than they are for assessing comfort and productivity.

The evidence base on quantifying the costs and benefits of cooling measures in new and existing homes is improving.

A major barrier to implementing policy responses to overheating to date has been an absence of robust evidence on the costs and benefits of particular measures for homes, particularly in terms of the heat-related mortality burden. To date, the link between

54 Boyson et al. (2014).
55 AECOM (2012).
56 CIBSE Guide A – Environmental Design.
57 CIBSE (2013).

external temperatures, indoor temperatures and mortality has not been studied. Such studies are now beginning to emerge.

For example, the relationship between energy efficiency retrofit measures, external and internal temperatures by type of dwelling has been modelled for London. The study found that during a typical hot period, on average, roof insulation and window upgrades decreased peak daytime temperatures in the living rooms by 1.3°C (central estimate). However, the combination of internally insulated walls and floors was found to increase temperatures by 0.7°C (central estimate).[58] A subsequent modelling study has used this data to assess the health benefits of cooling measures in homes. It found that reducing indoor temperatures by 1 – 2°C reduced annual heat-related mortality by 30 – 70% relative to a no-adaptation scenario in the 2050s.[59] Modelling to support an impact assessment could build on this new data to assess how effective passive cooling measures and air conditioning are at reducing internal temperatures. The ASC considered the costs and benefits of passive cooling measures in terms of avoided air conditioning costs in its 2011 progress report.[60]

Around 80% of the housing stock that will exist in 2050 has already been built, so retrofitting cooling measures into existing homes will be important. Air conditioning is likely to be a costly and inequitable cooling solution for both existing and new homes.

Around 430,000 new homes have been registered in the UK since 2009.[61] Estimates of the replacement rate suggest that 80% of the dwelling stock that will be in use in 2050 has already been built, representing an adaptation challenge to the existing stock.[62]

ASC analysis suggests that if air-conditioning is used instead of passive cooling measures in both existing and new homes, it would cost society an additional £2 billion (existing homes) and £400 million (new homes) respectively over 15 years, given projected future electricity prices.[63] As well as leading to higher energy use, air conditioning units exacerbate the urban heat island effect due to the production of waste heat.

The uptake of air conditioning could also create social inequalities in response to heat, with poorer households unable to afford installation of air conditioners. This has been observed in US cities.[64]

While ventilation is a key part of ensuring buildings are able to stay cool in hot weather, ventilation on its own could become a less effective intervention for overheating if the difference between day and night time temperatures reduces in warm weather in the future.[65] Good ventilation will remain crucial in the future as a means to help control indoor air pollution.

58 Mavrogianni et al. (2012).
59 Jenkins et al. (2014).
60 ASC (2011).
61 NHBC (2013). The total dwelling stock in England is 23 million (27 million for the UK).
62 Royal Institute of British Architects.
63 ASC (2011). This figure includes the full capital costs of air-conditioning equipment, future electricity prices are based on CCC modelling.
64 O'Neill et al. (2005).
65 AECOM (2012).

External measures such as external solar shading, shutters and external wall insulation are likely to offer a win-win approach to cooling existing homes in the future. Previous ASC analysis showed that measures such as reducing internal heat gains from pipes and appliances, shutting curtains during the day, applying tinted window film, painting roofs white, and installing solar shading in new builds are all cost-beneficial in terms of avoided air conditioning costs.[66]

The uptake of measures to increase cooling capacity in existing homes is currently very low.

There is very little evidence that cooling measures, in particular external measures, are being fitted to existing dwellings.[67] This could be due to a perceived low level of current risk. For example, the public appear to perceive that heatwaves and hot weather have become less common over time while they feel that incidence of flooding has increased.[68] However, the evidence for an increase in the number of hot days is actually stronger than the evidence for an increase in flooding. The lack of action could also be due to a lack of awareness of overheating risks to health, or a lack of information and advice on how to implement cooling measures. The actions being undertaken under the National Adaptation Programme may help to increase awareness of the options for fitting passive cooling measures. We will evaluate evidence of their impact in our first statutory report to Parliament in 2015.

Around 20% of the housing stock that will be present in 2050 has yet to be built. Current building regulations include guidance to limit the effects of overheating in new homes, but these do not take climate change into account and are not designed to mitigate overheating to safeguard health.

Building Regulations Part F (ventilation) and Part L (conservation of fuel and power) include statutory guidance that relates to internal temperatures in new homes. Part F seeks to ensure that adequate ventilation standards are built in to homes with high air-tightness, to ensure standards of indoor air quality. Part L contains provisions, introduced in 2013, to ensure that solar gains are not excessive and heat gains from uninsulated pipes are controlled, in order to conserve fuel and power. There is no requirement in Building Regulations to implement measures to control overheating for reasons related to protecting health or thermal comfort.

To support compliance with Part L of Building Regulations, appendix P of the Standard Assessment Procedure contains a method for assessing excessive internal heat gains.[69] This method is based on a set of average assumptions on internal heat gains, current mean external temperature in summer, wind speed, and solar radiation. The method assumes excessive heat gains and therefore non-compliance with Part L if there is a high risk of overheating, measured as the monthly average internal temperature in summer exceeding 23.5°C. The guidance supporting Part L suggests that additional measures such as solar

66 ASC (2011).
67 ASC (2011).
68 Taylor et al. (2014)
69 BRE (2012).

shading can be built into designs to take future climate change into account, but this is not controlled under Building Regulations.

The Department for Energy and Climate Change has an action under the National Adaptation Programme to review the Standard Assessment Procedure in relation to overheating.

As well as the need to incorporate future climate extremes, increasing standards for energy efficiency may also exacerbate current overheating risks in homes.

Further strengthening of the energy efficiency standards in homes are being taken forward as a result of the Housing Standards Review and commitment to Zero Carbon Homes. While this is positive from a climate change mitigation and cold mortality perspective, increasing the air tightness of dwellings further is likely to exacerbate the overheating issue in new builds unless the risk of overheating is considered at the same time.[70] The degree of insulation has been found to be one of the most important determinants of living room temperature, for example.[71] The impact assessment for these new requirements has not quantified potential costs to health associated with overheating, though it does mention the need to consider overheating alongside improving air tightness.[72] Including summer as well as winter temperatures in DECC's "HIDEEM" cost-benefit model would help to quantify the risks to health in summer from higher air-tightness in dwellings.

A standard or other requirement that takes climate change into account is likely to be needed to prevent overheating in new homes.

The discussion above demonstrates that both exposure and vulnerability to extreme heat are increasing. Climate change is very likely to exacerbate this risk in the future. In order to reduce the risk, England's housing stock will need to be made resilient to future extreme temperatures. Installing cooling measures at the design stage rather than retrofitting later has been shown to be a more cost-effective option, highlighting the importance of ensuring that new development is built in ways that minimise susceptibility to overheating. This is particularly the case within densely built-up areas, where exposure and vulnerability to overheating are exacerbated by the urban heat island effect.

Ensuring that measures are taken to deal with overheating in new homes is likely to be best accomplished by a standard or other requirement, for example in Building Regulations, to ensure appropriate action by developers.

Table 5.1 summarises the results of our analysis on overheating in new homes, set against some common arguments as to why a standard has not been adopted to date.

70 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/291796/140313_Building_Regulations.pdf
71 Mavrogianni et al. (2012).
72 DECC (2012).

Table 5.1: ASC rationale for developing an overheating standard or requirement

Reasons why an overheating standard has not been developed to date	ASC evidence to support a standard or requirement for measures to combat overheating in new homes
Overheating only affects a small number of people/homes.	There is evidence to suggest that a substantial number of homes are already at risk of overheating even in relatively cool summers.[73] Both exposure and vulnerability to extreme heat are increasing through rising temperatures, a growing and ageing population, an increase in the number of flats and airtight dwellings being built, and a reduction in urban greenspace. This suggests that the risk of overheating will increase over time.
There is no consistent standard/threshold for overheating risk.	While there is no nationally recognised threshold for indoor overheating, the external temperature thresholds at which mortality starts to increase are well understood. Excess heat-related mortality then increases on average by 3.1% for every 1°C temperature increase.[74] The corresponding indoor temperature for these outdoor temperatures will be a factor as people spend 90% of their time indoors; particularly those who are vulnerable to heat such as the elderly. Studies are beginning to link external thresholds more explicitly to internal temperatures.[75] One study suggests that lowering the internal temperature by 1 – 2°C indoors could lower heat-related mortality by 30 – 70% in the 2050s.[76] This evidence alone could be used to quantify the benefits of cooling measures when the outdoor temperature exceeds a threshold, without the need to define a corresponding internal threshold. Other research to better understand overheating risk factors in the built environment is also underway.[77]
The best solutions are largely site specific (and therefore a blanket standard would not be effective).	Industry guidance already exists for new homes.[78] However, the costs of installing cooling measures in new homes will fall to the developer, while the benefits accrue to the householder. As such, guidance alone would not provide an incentive for many developers to bear the extra cost of building in cooling measures. Only a compulsory standard is likely to result in the required level of action in new developments.
Planning policy needs to deal with the issue of overheating.	Urban design and planning should be part of a package of measures to improve the resilience of homes to overheating. The area of urban greenspace has been in decline since 2001, though the trend has slowed in recent years. Controlling the internal temperature is much easier than controlling the outdoor temperature, and changes to urban morphology alone are unlikely to offer a complete solution to overheating in homes.[79]

A Zero Carbon Hub project will advise Government on the evidence and a range of strategies for reducing overheating risk in homes. DCLG, other government departments and industry bodies are feeding into the project.

73 E.g. Beizaee et al. (2013), Good Homes Alliance (2014), AECOM (2012).
74 Jenkins et al. (2014).
75 Mavrogianni et al. (2012).
76 Jenkins et al. (2014).
77 E.g. the new Health Protection Research Unit on Environmental Change and Health, led by the London School of Hygiene and Tropical Medicine and Public Health England.
78 E.g. CIBSE The thermal limits of comfort, and Energy Saving Trust "Reducing overheating, a designer's guide".
79 Mavrogianni et al. (2012).

Although recommendations to include the impacts of climate change on overheating risk in Building Regulations were made as long ago as 1990, [80] the Government has stated that no further action will be taken in this Parliament.[81] At the request of Government, the Zero Carbon Hub is currently developing a project to assess the case for action on dealing with overheating in homes, the results of which will be made available in 2015.

5.3 Air pollution and UV radiation

Air pollution

In the UK, between 6 and 9 million people suffer from chronic respiratory conditions that make them especially sensitive to air pollution. Best estimates suggest that ground level ozone contributes towards up to 11,500 deaths per year.

Respiratory conditions (mainly chronic obstructive pulmonary disease and asthma) currently affect 12 – 16% of the population in England and cost the NHS around £2 billion per year.[82]

The number of deaths brought forward by exposure to ground level ozone annually depends on assumptions made about the threshold concentration of ozone above which mortality starts to increase. A common threshold used is 35 parts per billion by volume (ppbv), which equates to around 1,200 deaths brought forward per year in the UK.[83] However, it is not clear whether such a threshold exists. If there were no threshold, the number of deaths could be much higher; up to 11,500. Ground level ozone can also cause damage to crops and buildings and is also a greenhouse gas.

Northern hemisphere background concentrations of ground level ozone have increased over the last 25 years. Future projections are highly uncertain due to interactions between climatic factors and emissions.

The concentration of annual mean ground level ozone at some UK urban background sites has increased by roughly 0.4 – 0.5 μg/m^3 (0.2 – 0.25 ppbv) over the last 25 years.[84] This is consistent with decreases in nitric oxide (NO) emissions in many UK cities.[85] Trends at rural background sites are more uncertain.

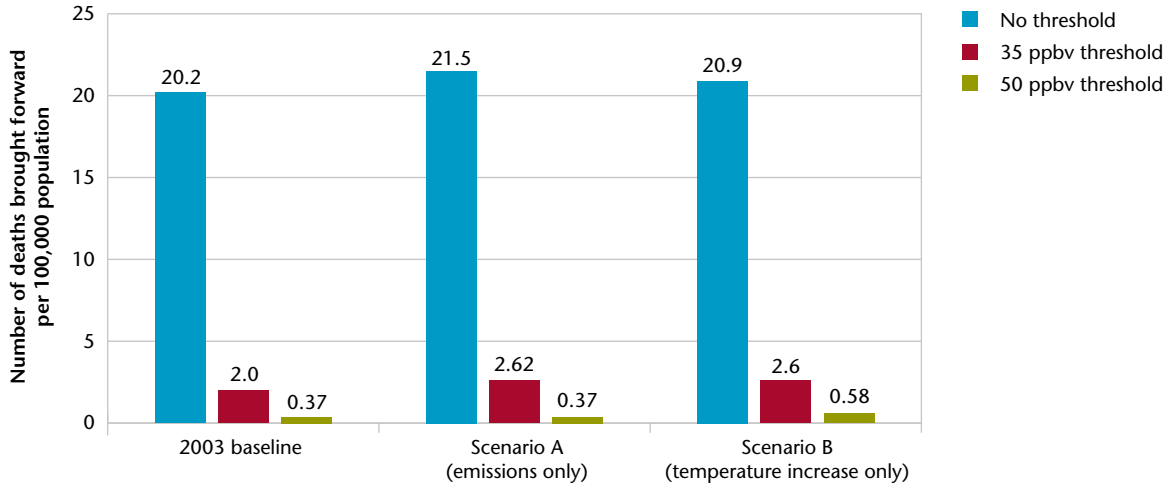
As temperatures increase the concentration of ground level ozone will also tend to increase. PHE analysis suggests that a 5°C increase in ambient mean temperature across the year results in up to 500 extra deaths attributable to ozone exposure. This assumes that deaths occur at even very low ozone concentrations and emissions of ozone precursors remain constant.

80 Department of Environment, Climate Change Impacts Review Group (1990).
81 http://www.parliament.uk/documents/commons-vote-office/March_2014/13%20March/4.DCLG-Building-regs.pdf
82 Department of Health (2012).
83 The threshold tends to vary from zero (which would equate to around 11,900 deaths per year) up to 50ppbv (which would equate to around 240 deaths per year).
84 HR Wallingford (2014b) for the ASC.
85 Ozone is removed from the atmosphere through chemical reaction with nitric oxide (NO).

This effect is small considering the increase in temperature is very large and not expected until towards the end of the century even under the higher emission scenarios. However, future emissions of ozone precursors and greenhouse gases, such as methane, will play a much greater role in determining future ground level ozone concentrations. (Figure 5.6).

Other climatic changes such as the frequency of 'blocking' high pressure weather systems over the UK, or a change in the mean wind direction could also affect concentrations of

Figure 5.6: UK projections of changes in ground level ozone-related mortality based on changes in temperature, air quality and greenhouse gas emissions



Source: HPA (2012).
Notes: ppbv= parts per billion by volume."**2003 baseline**" provides a present-day estimate of the number of deaths brought forward due to ground level ozone. The range from blue to green represents the estimated mortality for different thresholds of ozone concentration over which mortality is predicted to increase."**Scenario A**" is called "B2 + CLE" in the HPA report. It shows the projected increase in deaths brought forward for the IPCC SRES B2 socioeconomic scenario, and includes the implementation of air quality legislation prevailing from 2000. This assumes an increase in O3 concentration of 2.7ppbv by 2030 (baseline in 2003 was 39.5ppbv). This is a high end emissions projection for ozone compared to higher emissions scenarios e.g. A2 because it has a lower NOx level (which breaks down O3). Deaths increase by up to 500 under the "no threshold" scenario. "**Scenario B**" shows the projected number of deaths brought forward with a uniform 5 degree temperature increase across the whole of the UK for the whole year compared to 2003. Annual mean O3 concentration increases by up to 1.5ppbv, with summer mean increases of up to 3ppbv (and up to 10ppbv on individual days in August). Deaths increase by up to 270 under the "no threshold" scenario.
These projections assume no change in the number of people with respiratory illnesses who are vulnerable to changes in ground level ozone, or changes in behaviour or other adaptations that might decrease the overall risk.

ground level ozone. If the UK experienced more frequent winds from the south east in future, the country would become much more susceptible to pollutants blown across from mainland Europe. This occurred in April 2014 over southern England, when a combination or Saharan dust from Africa and high levels of air pollution from Europe created a very high air pollution episode for several days, measuring the maximum 10 on the daily air quality index in several regions. Projections of future changes in wind direction or high pressure weather systems with climate change are not currently available due to large uncertainties in the prediction of these atmospheric processes.

Further research is required to better understand the interactions between mitigation measures, temperature and other climatic and land use changes on ground level ozone, given the high current vulnerability of the population to air pollution.

Ultra-violet radiation

Long-term exposure to ultra-violet radiation (UVR) can cause melanoma and non-melanoma skin cancer. In the future, there could be increases in the amount of time people spend outdoors as temperatures rise. Recent increases in UVR levels, and the amount of time that people spend outdoors, are both highest in south-west England.

The number of people dying from melanoma each year is similar to the total heat-related impact on mortality, at around 2,500 annual deaths. Total levels of solar radiation across England have increased since 1990. It is not clear what the contribution is to skin cancer incidence from UVR exposure in England compared to exposure while people holiday overseas, or the contribution from other risk factors such as the use of sun beds. Some exposure to UVR is important for vitamin D production in the body, the lack of which can cause rickets. Spending time outdoors also has wider health benefits that need to be balanced against the increased risk from UVR exposure.

Future exposure to UVR will depend on solar radiation levels as well as behaviour (time spent outdoors and the degree to which people protect their skin). The South West has the highest levels of UV radiation and is also where the highest percentage of the population (>25%) visit the outdoors for recreation on a weekly basis.[86] The population also have a higher incidence of skin cancer relative to the national average.[87]

Current climate projections for the UK indicate a slight increase in net surface UVB radiation flux by the end of the century for southern England (up to 10% by the 2080s for the high emissions scenario), reducing further north. [88]

However, because of uncertainties over behavioural changes it is not currently possible to provide projections of future risk of skin cancer. [89] Our analysis would suggest that trends should continue to be monitored and action to promote protective behaviour be focussed in the south-west in particular. Policies such as the "slip slap slop" programme from Australia appear to have been successful in altering public behaviour, and a similar programme could be implemented in the UK.

5.4 New and emerging pathogens

There is uncertainty over which pathogens will pose the greatest risk to human health in the future with climate change. There are several pathogens where exposure in the UK could increase in the future.

Changes to the climate are likely to change the suitability in England for some pathogens that cause diseases in humans. Some diseases that are already present could increase in incidence, for example Lyme disease. Other diseases could be imported to the UK. The climatic suitability for some non-native invasive mosquito species is likely to alter due to warmer summers/winters and wetter periods, and with this there could be an introduction of mosquito-borne illnesses to the UK.

86 HR Wallingford (2014b) for the ASC.
87 http://www.swpho.nhs.uk/skincancerhub/addons/_8170/atlas.html
88 Murphy et al. (2009).
89 Hames and Vardoulakis (2012).

Marine pathogens such as *Vibrio vulnificus* are very sensitive to sea surface temperatures. People can catch vibrio-related infections directly from sea water or through eating contaminated shellfish. Vibrio infects a very small number of people in England each year and there has been no detectable trend in vibrio infections to date. CEFAS have started monitoring vibrio incidence in the environment in recognition of the potential risk from rising sea surface temperatures and the declines in water quality in shellfish nurseries as a result of flooding.

Table 5.2 outlines our latest understanding about the current and future spread of some key pathogens that could be affected by climate change.

Table 5.2: Changing suitability of the UK climate for pests and pathogens

Disease/Illness	Evidence of current/future range shifts
Lyme Disease	Likely to increase. Already present in UK. Primarily transmitted to human via *Ixodes ricinus* (sheep tick), which is spreading and increasing in Europe. Spread is linked to warmer temperatures at high altitudes. A changing climate will also impact on changing seasonality of ticks. Changing animal distributions and the prevalence of urban greenspace may be a stronger driver of tick exposure and changing tick distribution in the UK, however.
Dengue fever	Some risk of introduction. Transmitted mainly by *Aedes* mosquitoes; not currently present in UK, but future climate may become suitable for *A.albopictus* and other species. Breeds in containers such as water butts, and would benefit from warmer summers. Cases of infection in France and Croatia reported in 2010.
Chikungunya virus	Risk of introduction. The most likely invasive species to establish in the UK would be *Aedes albopictus*, a competent vector for Chikungunya virus.
Crimean-Congo Haemorrhagic Fever (CCHF)	Some risk of introduction. *Hyalomma marginatum* is the most important vector for CCHF. Imported on migrating birds from Africa. Not currently established in UK as spring/summer mean temperatures are too low. Warmer temperatures may increase climatic suitability in the UK, leading to establishment of imported ticks.
Infection with *Vibrio vulnificus*	Could increase. Suitability of coastal waters and in shellfish could increase with warmer sea temperatures and more coastal flooding. Can cause death if not treated immediately.
Other food poisoning	Could increase. Outbreaks linked to *Staphylococcus aureus, Bacillus cereus and Clostridium perfringens* are likely to increase with increased ambient temperatures, if food is stored incorrectly.
Norovirus	Could increase. Contamination of shellfish beds could increase in winter due to higher sewage contamination from higher river flows.
Malaria	Some risk of local transmission. Transmitted by *Anopheles* mosquitoes, six species currently resident in UK but do not carry the *Plasmodium* parasite. The climate is warm enough for transmission and warmer temperatures will increase chances of transmission. However, limited distribution of vectors, the lack of a zoonotic animal host and improved treatment for humans suggests that risk of future UK-based transmission of *P. vivax* and *P. falciparum* malaria is considered to be low. Risks from people travelling abroad are set to increase.
Tick-borne encephalitis	Unlikely to be introduced. Common in central/eastern Europe, recently reported in Scandinavia for the first time. Modelling studies suggest that risk of increased transmission in UK is small.

Source: HPA (2012).

Increased temperatures may result in increased use of recreational water and air conditioners that could increase exposure to pathogens, if systems are poorly maintained.

Adaptive measures to improve sustainability are being introduced over time. Some of these measures such as those involving the use of grey water harvesting systems may increase the potential for transmission of water pathogens. The increase in the air-tightness of houses may increase the potential for mould, though at present damp and mould incidence is declining.

At present, there is a lack of consistency in the list of pathogens being monitored, given the risks from climate change. Current efforts should be continued to create a priority list to help coordinate resources and action to ensure that changes in incidence of pathogens are detected early.

Public Health England currently spends at least £4 million of grant-in-aid on research and development relating to pests and pathogens each year, which attracts over £10 million in additional funding from partners. There are a number of collaborative agreements in place with a range of countries where monitoring data is shared, particularly within the EU and Africa. The agency expects to publish its new R&D strategy in 2014.

The agency is currently examining the drivers for seasonality and methods for examining the effects of climate change, so that there is a better understanding of the pathogens that are likely to be important under different climate scenarios. It is also developing Whole Genome Sequencing as a new tool for improving its understanding of the epidemiology of many of the pathogens, and this will also contribute to improved preparedness.

Strengthening the surveillance and monitoring systems will allow geographical and temporal trends to be monitored. This will also help to focus collaborations with other bodies (both inside and outside the UK), provide the best chance of early detection, and provide a structure for evaluating spend on surveillance. Native and non-native vectors for pathogens also need to continue to be monitored for emerging pathogens.

In addition to the direct impact of climate change on vectors, the indirect effects of adaptation through increased urban greenspace, increased wetland and flood alleviation habitat, may impact on the spread and abundance of vectors and their pathogens, and alter human exposure to infected vectors.

5.5 Effects of flooding on health and well-being

The current and projected number of deaths associated with flooding is small, but the effects on mental health and well-being are thought to be significant.

The average annual number of deaths in the UK from storms and flooding is thought to be between 10 and 20 at present, mainly due to drowning. Deaths associated with floods also occur from carbon monoxide poisoning, and road traffic accidents.[90] Flooding is not generally associated outbreaks of infectious diseases in the UK. As the risk of flooding

90 Hames and Vardoulakis (2012).

increases with climate change, the number of deaths could also increase. However, the evidence for this is very uncertain and the total risk is likely to remain low unless there is a catastrophic failure of coastal flood defences protecting a highly populated area. There is some debate that flooding could have a long-term effect on mortality (that is, increase the death rate in susceptible individuals after an event). This effect was seen in Bristol following flooding in 1968, but attempts to replicate the findings in more recent years have not found excess mortality.[91]

There is very little evidence at the national level on the impacts of flooding on health and well-being. Focussing on measures of well-being rather than trying to measure clinical outcomes, such as changes in depression and anxiety could strengthen the evidence base, as would carrying out follow up studies on people who have been flooded.

The mental health consequences of flooding was one of the largest impacts highlighted in the 2012 Climate Change Risk Assessment. Studies looking at well-being effects from flooding to date have relied largely on trying to measure changes in anxiety and depression scores on general health questionnaires. Studies conducted after the 2007 floods for example have found that those affected by flooding displayed a two- to five-fold increase in mental health symptoms.[92] Such findings need to be replicated with longitudinal data (i.e. pre-flood measures of mental health).

Flooding is also associated with significant disruption to people. For example, 4,750 households in Hull were still displaced from their homes 11 months after the 2007 flood.[93] This represented about 12% of the flooded population.[94] Time spent in temporary accommodation, time off work, or disruption to school attendance could all provide measured metrics of impact. Insurance companies are likely to have relevant data such as time spent following flooding in temporary accommodation, but this has not been collated nationally nor made available to date.

5.6 Risks to health infrastructure assets

Health and social care infrastructure are exposed to climate hazards to different degrees. After accounting for community-level defences, 10 – 14% of emergency service stations and 6 – 8% of hospitals, care homes and surgeries are located in areas that are susceptible to river and coastal flooding.

Protecting health and social care facilities from weather hazards involves not only the physical protection of the asset itself, but maintaining the ability of the asset to support and provide the services it is designed for.

Figure 5.7 shows the percentage of care homes, emergency services stations, GP surgeries and hospitals in areas that are currently in areas susceptible to various types of flooding, and subsidence. The values take into account protection from community defences for

91 Milojevic et al. (2011).
92 Paranjothy et al. (2011).
93 Pitt Review (2008a).
94 Milojevic et al. (2011).

river and coastal flooding. No other resilience measures are assumed as this information is not available.

Notably, emergency services stations are at proportionally greater susceptibility to river and coastal flooding than other types of assets; 10 – 14% of assets are at some degree of exposure.

Understanding the resilience of the supporting infrastructure is as important as measuring the exposure of the asset itself. In September 2012, for example, the Filton blood bank was inundated by surface water flooding, in part caused by a damaged drainage culvert at the back of the building which was not owned by the site. The blood bank was built in 2008 and is responsible for 50% of manufacturing capabilities of the NHS Blood and Transplant Authority (NHSBT). As per business continuity plans, blood and organ donation services were immediately diverted to other sites, and the facility was able to re-open within eight days after extensive cleaning and sterilisation. A review of the incident recommended the creation of a whole-site approach to contingency planning.[95]

NHS asset managers have been asked to report on asset resilience under the National Adaptation Programme in 2015, but there is no action for local authorities to do so.

The Department of Health produces extensive guidance for asset managers on planning, procurement, operation and maintenance of healthcare facilities, to promote resilience to a range of hazards including those associated with climate change. The guidance promotes the inclusion of flood risk, snow and heatwaves in site-specific risk assessments and suggests thinking beyond the site itself to other critical infrastructure. The NHS also has a premises assurance model (PAM) which aims to provide information on the resilience of healthcare estate premises. The National Adaptation Programmes states that PAM should be used to assess flood and extreme temperature resilience in NHS assets, and best practice should be routinely reviewed.

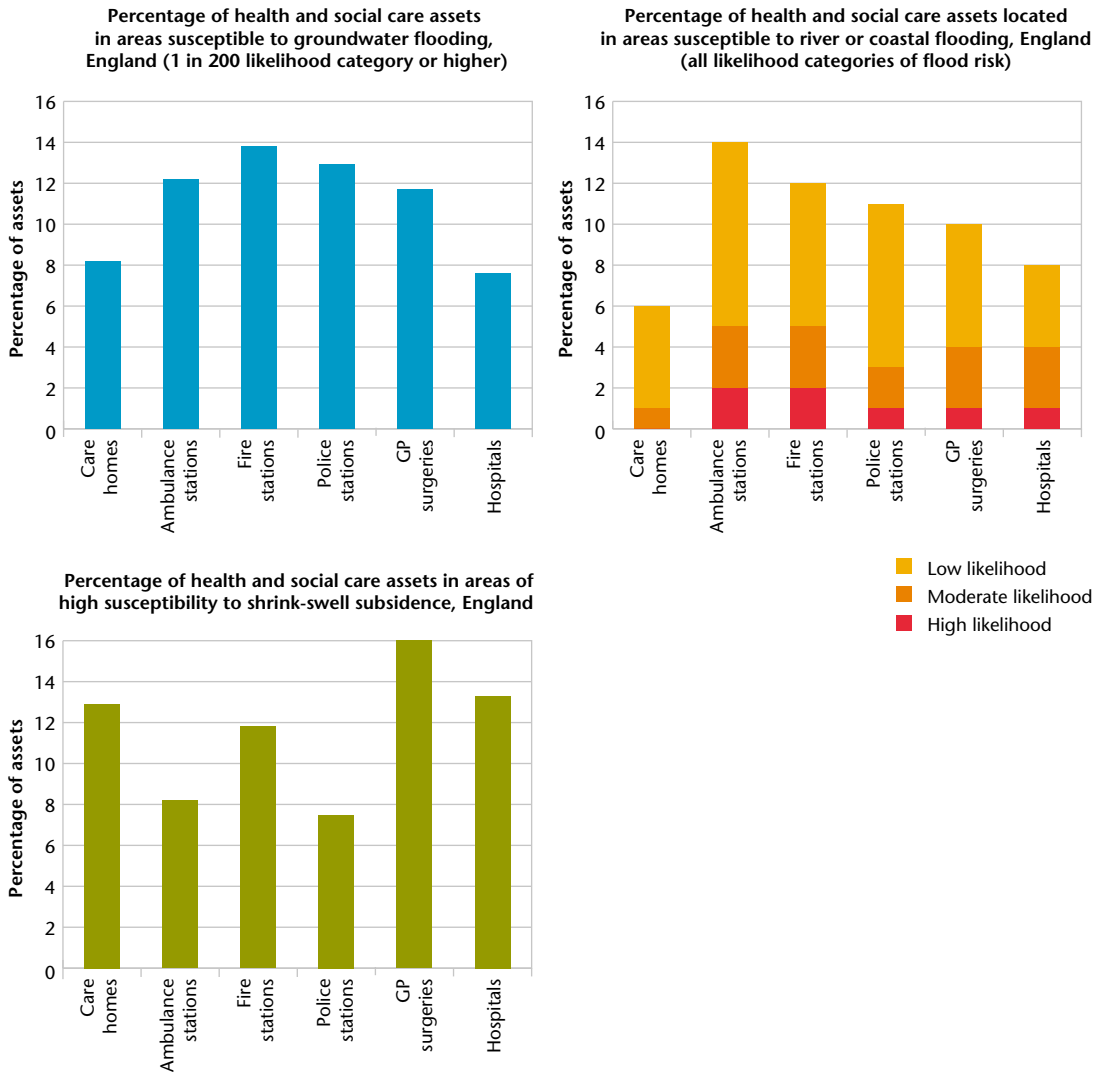
Health and social care providers are also able to assess their exposure to different weather hazards such as flooding using the SHAPE tool; this allows for a consistent approach across England.

Under the NHS standard contract, service providers have to undertake a series of actions related to emergency preparedness and resilience, detailed in a set of core standards. These include maintaining a business continuity plan, ensuring that all reasonable efforts to maintain care are employed in the event of an emergency, and ensuring that staff are adequately trained. NHS funded providers are required to provide assurance to CCGs and NHS England that these standards are complied with.

Although there are processes in place to ensure that resilience is considered and planned for, there is currently no national register of resilience measures of individual health and social care assets. This is needed in order to assess effectively how standards are being implemented, the current level of exposure of health and social care assets, and how this might be changing. Some data on plans for flooding is collected through the Premises

95 Landeg and Lawson (2014).

Figure 5.7: Percentage of health, emergency service and social care assets in England located in areas susceptible to flooding and subsidence



Source: HR Wallingford (2014c) for the ASC.
Notes: Categories of risk shown for the different hazards are based on the data that is available: Groundwater flooding: 1 in 200 year likelihood or higher. River and coastal flooding: assets are divided into those at high, moderate and low likelihood of flooding taking into account community level defences. Shrink-swell subsidence: high susceptibility category. Total numbers of assets in England are: care homes = 17,398; ambulance stations = 795; fire stations = 1,330; police stations = 426; GP surgeries = 7,997; hospitals = 1,386.

Assurance Model and the Cabinet Office's national capabilities survey. This information is reviewed by the Department of Health and NHS England, but the results are not published.

NHS Estates (part of the Department of Health) have an action to report on the uptake of resilience measures under the National Adaptation Programme. Such reporting should include information on coping limits, i.e. the point at which an event becomes too severe for the asset to maintain its ability to function.

The actions under the NAP do not extend to requesting local authorities to report on the uptake of resilience measures for public health and social care assets. This is a substantial gap, particularly in relation to flood and overheating risk in care homes. Directors of Public

Health should take steps to ensure that data on the uptake of resilience measures are collected for their local authority. Health and Wellbeing Boards should also consider the degree of resilience and redundancy across all health and social care assets as a whole. This information could then be shared through Sustainable Development Management Plans with the Sustainable Development Unit, for example.

The degree of resilience of the surrounding infrastructure on which health and social care assets rely is equally important as the buildings themselves. Chapter 3 presents our latest understanding of the exposure and action underway to protect national infrastructure from weather hazards. It is crucial that as well as assessing direct risks to their assets, health and social care asset managers need to consider surrounding infrastructure, in particular the risks to power supplies, water supply, and transport links. Further risks are inherent in the supply chains of businesses and other organisations supplying health and social care facilities with equipment and medicines. Weather-related risks to supply chains are considered further in Chapter 4.

5.7 Conclusions and policy advice

Our analysis has reviewed and summarised the evidence on the scale of risk to health from climate change. From this, we have identified where action is most urgently needed or where further data and evidence are required to better understand the current level of preparedness for climate change.

- Vulnerability and exposure to extreme heat are increasing, whilst exposure to cold in the built environment is expected to diminish if current policies are effective. On the basis of the available evidence, the uptake of cooling measures in homes, health and social care facilities does not appear to be in line with current needs nor the increasing risk from climate change.
- Data exists on exposure levels of health and social care infrastructure to weather-related hazards, and standards exist on how to factor these risks into business continuity plans. However, we were unable to find evidence of the levels of uptake of site-level resilience measures across health and social care assets.
- There are large uncertainties associated with the contribution from climate change to health risks associated with UV radiation, ground level ozone, and new or emerging pathogens. Risks to mental health from flooding are starting to be quantified, but are difficult to assess and monitor over time. More research is needed urgently in these areas in order to assess preparedness.

Further incentives are needed to encourage the uptake of low-regret passive cooling measures in existing homes. This needs to include better information for householders on the benefits of passive cooling, which could be included in the Heatwave Plan, for example.

- Air conditioning, even if generated by renewable energy, is likely to be a costly solution to overheating in homes. Waste heat from air conditioning units heat up the surrounding environment, and air conditioning may be too expensive for lower income households. Previous ASC analysis showed that measures such as reducing internal heat gains from pipes and appliances, shutting curtains during the day, applying tinted window film, painting roofs white, and installing solar shading in new builds are all cost-beneficial in terms of avoided air conditioning costs.
- The uptake of passive cooling measures appears to be very low in existing homes. This could be due to a perceived low level of current risk. It could also be due to a lack of awareness of overheating risk or a lack of information and advice on how to implement cooling measures for householders. The actions being undertaken under the National Adaptation Programme and Heatwave Plan may help to increase awareness of the options for fitting passive cooling measures. We will evaluate evidence of their impact in our first statutory report to Parliament in 2015.

A new standard or other requirement is needed to ensure that passive cooling measures are built in to new homes at the design stage. Voluntary measures are unlikely to be taken up by house builders because the benefits will accrue to the householder rather than the developer.

- Around 20% of the homes present in 2050 have yet to be built, so design of new homes is an important part of improving the resilience of England's housing stock. Measures to retrofit cooling measures in dwellings will be much more expensive than building in resilience at the design stage.
- A barrier to assessing policy options for reducing overheating in new homes in the past has been a lack of evidence on the costs and benefits of passive cooling measures for health. This evidence is now emerging; for example a modelling study for the 2050s show that reducing internal temperatures by 1 – 2°C could reduce heat-related mortality by 30 – 70%. The Government should review the evidence and evaluate options in this area.

Independent evaluations of the Heatwave Plan should be undertaken, with a particular focus on the uptake of measures in health and social care facilities. The Care Quality Commission should consider setting maximum temperature thresholds for hospitals, and monitor the extent to which staff have the ability to control internal temperatures.

- Up to 90% of hospital wards could be at risk of overheating based on their type; further evidence is required to assess the actual level of overheating. Previous evaluations of the Heatwave Plan have showed that awareness is generally good at the managerial level, but that action to put in place cooling measures and contact vulnerable people is variable. An independent review of the Heatwave Plan also found that staff had limited means to control temperatures in hospitals.

NHS Trusts should report on the scale of site-level asset resilience measures (for example site-level flood protection measures) under the National Adaptation Programme, returns to Sustainable Development Management Plans, or under the Adaptation Reporting Power. Local authorities should also collect information, for example through Health and Well-being Boards.

- Some information on exposure of health and social care infrastructure assets is available for flooding, subsidence and landslides. However, the level of risk overall cannot currently be calculated as we do not have data on the uptake of site-level resilience measures. The NHS has a number of routes through which this information could be recorded, whereas there are fewer avenues for reporting on social care assets. Health and Well-being Boards should consider how this information could be collected.

Public Health England should consider how to further prioritise surveillance efforts on pathogens which could become a greater risk from climate change.

- There are a variety of pathogens that could become more prevalent, or be introduced in England due to climate change. A prioritisation exercise would focus collaborations with other bodies (both inside and outside the UK), provide the best chance of early detection, and provide a structure for evaluating spend on surveillance.

Annex 5.1: Priorities for action in relation to the key risks and opportunities in the 2012 UK Climate Change Risk Assessment for health and well-being

Key opportunities (green) and threats (red) identified in the 2012 UK Climate Change Risk Assessment	Is climate change likely to change risk (including when coupled with socio-economic change)?	Are decisions likely to have long-lasting, irreversible or knock-on effects?	Covered in ASC analysis/ indicator framework?
Mortality/morbidity from cold	Yes. Current vulnerability is high; between 35,500 and 49,400 (central estimate 41,000) deaths each year. Warming is likely to reduce deaths in the medium to long-term but mortality is still estimated to be high in the future and action to reduce deaths is required in the short-term.	Yes. Increasing the air tightness of dwellings in order to reduce cold-related mortality could exacerbate overheating in summer if ventilation is not adequate. The benefits of warmer winters through reduced mortality are likely to be realised without Government intervention, but action will help to reduce the risk much further.	Yes.
Mortality/ morbidity from heat	Yes. Current vulnerability is high; around 2,000 deaths brought forward each year.[96] Warming – particularly increased extremes and variability in temperature – is likely to increase excess deaths in the absence of adaptation.	Yes. Passive cooling measures built into homes, health and social care facilities etc. have long lifetimes. Uptake of air conditioning as an adaptation would have negative trade-offs.	Yes.
Mortality/ morbidity from ground level ozone (air pollution)	Yes. Current vulnerability is high; between 240 – 11,900 deaths depending on assumptions about mortality threshold and 30,000 hospital admissions each year (assuming no threshold).[97] However, future increase in risk from climate change is low compared to other drivers of change such as emissions of pollutants.	Yes. Measures to reduce air pollution have multiple benefits and long lasting effects. Measures to improve the air tightness of dwellings to reduce cold-related mortality are likely to increase indoor air pollution without adequate ventilation.	Yes.

Annex 5.1: Priorities for action in relation to the key risks and opportunities in the 2012 UK Climate Change Risk Assessment for health and well-being

Key opportunities (green) and threats (red) identified in the 2012 UK Climate Change Risk Assessment	Is climate change likely to change risk (including when coupled with socio-economic change)?	Are decisions likely to have long-lasting, irreversible or knock-on effects?	Covered in ASC analysis/ indicator framework?
Mortality/morbidity from UVR exposure.	Yes. Current vulnerability is high; around 2,000 deaths from skin cancer each year.[98] Future estimates of mortality and morbidity are highly uncertain and cannot be quantified reliably.	Possibly. Behavioural changes to reduce exposure of skin to UV radiation can take time to become the norm, though in themselves do not have long lead times.	Yes.
Pathogens and diseases	Uncertain. Some pathogens could become more common (Lyme Disease, Vibrio, Salmonellosis and norovirus) or be introduced (malaria, tick-borne encephalitis, dengue fever, Chikungunya virus, Crimean-Congo Haemorrhagic Fever (CCHF)).[99] Future risk is highly uncertain but the overall threat from these pathogens and diseases is likely to increase as temperatures warm.	Yes. Once diseases become endemic they can be very difficult to control.	Yes.
Impacts of flooding and storms on morbidity/ well-being.	Likely, but difficult to quantify. Best estimates suggest that 3,500-4,500 people per year suffer mental health problems from flooding. CCRA suggested that up to 11,050 people per year could suffer mental health problems from flooding by 2050.	Yes. Measures to improve flood protection, improve emergency response capability and recovery have long lead times and lifetimes.	Yes.
Risks to health and social care infrastructure and service provision from flooding, subsidence, coastal erosion or overheating.	Yes. Exposure to flooding, high temperatures and possibly subsidence are likely to increase.	Yes. Choices on siting and building resilience into buildings and infrastructure can have long lead times and lifetimes.	Yes.

Annex 5.1: Priorities for action in relation to the key risks and opportunities in the 2012 UK Climate Change Risk Assessment for health and well-being

Key opportunities (green) and threats (red) identified in the 2012 UK Climate Change Risk Assessment	Is climate change likely to change risk (including when coupled with socio-economic change)?	Are decisions likely to have long-lasting, irreversible or knock-on effects?	Covered in ASC analysis/ indicator framework?
Impacts of flooding and storms on mortality.	No. Currently only around 10-20 deaths per year due to flooding or storms (high confidence). Injuries are poorly quantified. Numbers of deaths are not projected to increase significantly with climate change.	Yes. Measures to improve flood protection, improve emergency response capability and recovery have long lead times and lifetimes.	No.
Risks from climate change to indoor air pollution.	Uncertain. Some risk of increased mould/damp due to flooding of homes, but this has not been quantified.	Yes. Measures to improve flood protection, improve emergency response capability and recovery have long lead times and lifetimes.	No.
Risks to health from increases in aeroallergens as a result of climate change.	Uncertain. Aeroallergen levels are linked to hay fever, allergic rhinitis and potentially asthma, but the risks associated with climate change are not quantified at present. Indicator analysis suggests no convergence in the timing of flowering of allergenic plants at present, though trends in duration of flowering season are unknown.[100]	Unclear what adaptations are available beyond dealing with symptoms of allergic reactions and asthma.	Not in report, but there is an indicator on convergence of timing of flowering of allergenic plants.

Source: Hames and Vardoulakis (2012) unless otherwise stated.

96 Hajat et al. (2014)
97 HPA (2012).
98 Office for National Statistics (2012).
99 HPA (2012).
100 HR Wallingford (2014b) for the ASC.

Chapter 6

6.1 Context
6.2 Future risks from extreme weather
6.3 Trends in exposure and vulnerability to extreme weather
6.4 Assessing the current emergency planning system
6.5 Conclusions and policy advice

Chapter 6:
Emergency planning

Key messages

Emergency response and recovery are needed when preventative measures alone do not provide complete protection against an extreme weather event. Organisations involved in emergency response will need to be able to cope with the increasing frequency and intensity of severe weather expected with climate change.

- Climate change is likely to lead to increased river, coastal and surface water flooding in England. A current 1-in-250 year coastal flood could become more than twice as frequent by 2050. A heatwave on the scale of the 2003 event is likely to become a 1-in-2 year event by the 2040s. There could also be increases in droughts, strong winds and wildfires, though the ability to project these changes is fairly limited at present. There is some evidence that changes in extreme weather attributable to climate change are already occurring, particularly in relation to temperature.
- Although the frequency and intensity of cold snaps and snowfall is likely to decline, episodes of very cold weather will still occur and we may be less prepared for them as they become rarer.

Exposure and vulnerability to extreme weather impacts is increasing, due to a growing and ageing population, flood protection measures not keeping pace with the rising risk of flooding, and the building stock not designed to cope with extreme heat.

- The number of people aged over 75 years – who are generally more vulnerable in weather-related emergencies – has increased by 0.8 million to 4.1 million over the last 20 years. The total population in England is projected to increase from 53 million to 62 million by 2035, mostly in London and the South East.
- More homes and other buildings will be needed to support a larger population. Approximately 22,000 new properties were built in the river and coastal floodplain per year over the decade to 2011. Many of these will be protected to a degree by existing flood defences. However, current spending plans are not set to keep pace with the rising risk (Chapter 2).
- The building stock, including homes and hospitals, is not designed with current or future high temperatures in mind (Chapter 5).

In recent years there have been notable successes in developing plans for, and responding to extreme weather events.

- The 2004 Civil Contingencies Act put in place the first mandatory emergency planning system for England. The National Risk Assessment considers how to plan for major risks to the country over the next five years. The current system is tested through its response to actual events, as well as national and local exercises. Lessons learned from previous emergencies, such as the 2007 floods, have led to widespread improvements in the way the current system responds to extreme weather.
- The Government's Heatwave and Cold Weather Plans for England are now in place and updated annually. They provide information on the actions needed to protect vulnerable people before and during hot and cold periods.
- The number of people signed up to the Environment Agency's flood warning scheme has increased to over 50% of all households at risk, in part due to the introduction of a new 'opt-out' service.
- The impact on people and homes of the December 2013 east coast tidal surge was an order of magnitude lower than the 1953 event, despite the two events being very similar in terms of tide height.

Key messages

Our analysis has identified four areas where the Government should consider whether the current emergency response system needs to be strengthened to be better prepared for current and future extreme weather.

- **In order to fully assess preparedness, more information is needed on the local actions being taken in response to extreme weather.** In a survey of Local Resilience Forums, a lack of knowledge of the risks to infrastructure assets was cited as a barrier to effective planning in 4 out of 13 of cases. Evaluations of the Heatwave and Cold Weather plans undertaken by Public Health England show that the level of action underway in care homes and by GP surgeries is variable, and the outcomes associated with these actions are unknown (Chapter 5). An independent evaluation suggested that awareness and ability to implement the Heatwave Plan in hospitals is lacking. A single body, with cross-departmental representation, could be given responsibility for collecting and analysing data, and providing advice back to Government on evidence gaps.
- **In specific cases there is a lack of clarity on capabilities and responsibilities for flooding.** For example, there appears to be continuing confusion at the local level over the role of local councils in providing sandbags. It is also unclear what bilateral arrangements for mutual aid exist between Local Resilience Forums, and what the required and actual level of capability is for flood rescues. The Government should review where understanding of capabilities and responsibilities is still unclear.
- **The cumulative impact of declining resources on the overall capacity of the emergency response system has not been assessed.** Staff numbers have declined in key bodies such as the Fire and Rescue Service, the Police, the Environment Agency, and local authorities. While the number of incident response staff may be sufficient for single events, the cumulative impact of these cuts should be assessed against level of capability required to cope with severe and widespread weather events.
- **Local plans may not be giving sufficient weight to all risks outlined in the National Risk Assessment.** Only 26% of Local Resilience Forums currently consider drought as a high or very high risk in their community risk registers even though 74% are located in regions that were declared to be in drought in 2012. Local Resilience Forums regularly review and update their plans with support from central Government, but there appears to be an absence of independent scrutiny to check the capability and coverage of plans against the risks they should plan for. This could form part of the Government's annual resilience review.

6.1 Context

Emergency planning and response to extreme weather events involves many sectors. It extends into the "respond and recover" rather than just the "prepare" aspects of climate change adaptation.

Emergency planning to extreme weather has implications for many sectors. This includes health and well-being but also local government, infrastructure, the built environment and the wider economy.

Emergency planning and response is a different type of adaptation to the other issues considered in this and previous ASC progress reports. It extends into the "respond and recover" as opposed to just the "prepare" category of resilience set out by the Intergovernmental Panel on Climate Change.[1] For example, adequate preparation is critical to avoid the worst impacts from heatwaves, whilst the recovery phase following a flood event is important in minimising the risk to well-being. Protecting people fully from all potential weather-related impacts is unrealistic and it would be prohibitively expensive to do so. There is a balance to be struck between prevention and response to the impacts.

1 IPCC (2012).

Emergency services provide a multi-purpose capacity to respond to unexpected crises. Given the uncertainties around future climate change, in particular around extreme events, a flexible response capability is a good way of building societal resilience.

In many respects, the emergency services are a relatively adaptable capability. If necessary, capacity can be built up, year-on-year, in response to the climate changes that materialise. However, some aspects of capacity building will have long lead-times. Climatic change may be having an effect on the likelihood of severe weather even if extreme events do not occur for a few years. It is important therefore that emergency planning capability is anticipated, developed and maintained in a systematic way.

Although the number of deaths from extreme weather in the UK is low compared to other weather-related health impacts, the impacts on the economy and well-being are large.

Flooding and storms currently account for between 10 and 20 deaths per year (Chapter 5). There are large economic impacts from extreme weather on infrastructure (Chapter 3) and business (Chapter 4). Annual insurance claims for weather-related damage in the UK are approximately £735 million per year.[2] The winter storms of 2013/14 cost an estimated £1.1 billion in insured damages.[3]

The social impacts of flooding on well-being are potentially very high, though the evidence for these impacts is sparse and difficult to collect (Chapter 5).

Responding to weather-related emergencies places extra demands on the emergency services.

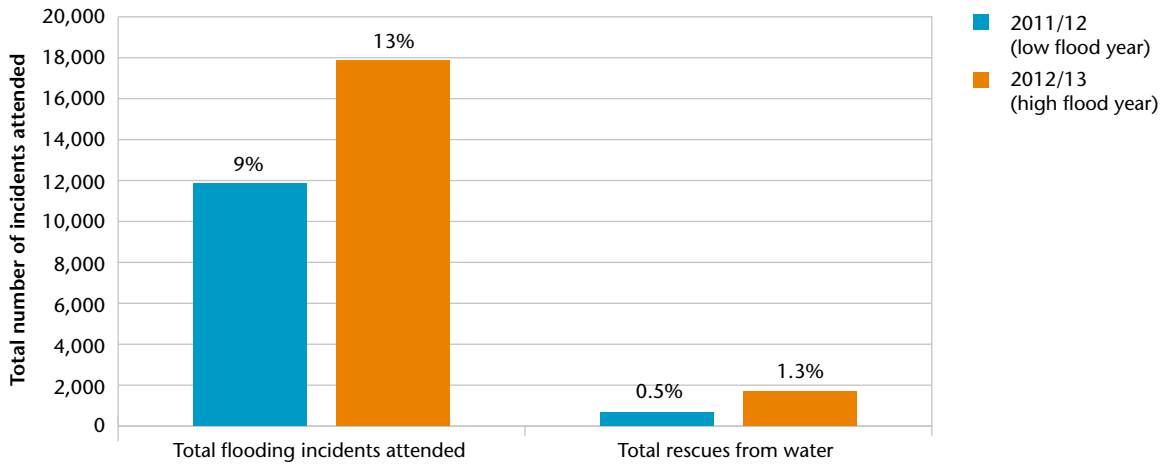
In the 2012/13 financial year, widespread flooding led to 6,000 more flood-related fire service call outs than in 2011/12, an increase of 4% in all non-fire call outs (Figure 6.1).

During hot and cold weather, the number of ambulance call outs increases (Figure 6.2). Analysis of the relationship between extreme weather and ambulance call outs in London shows that:

- for every 1°C increase in temperature over 20°C, the percentage of ambulances meeting an 8 minute response time decreases by 1%.
- for every 1°C decrease in temperature below 2°C, the percentage of ambulances meeting an 8 minute response time decreases by 1.5%.

2 Ramsbottom et al. (2012).
3 https://www.abi.org.uk/News/News-releases/2014/03/6-7-million-a-day-in-insurance-claims-from-customers-hit-by-the-recent-flooding

Figure 6.1: Number of fire service call outs related to flooding and rescues from water (England)



Source: HR Wallingford (2014b) for the ASC.
Notes: Percentages shown are in relation to the total number of non-fire related incidents that the fire services attended in each year.

The 2004 Civil Contingencies Act put in place the first mandatory emergency planning system for England. The current system involves multiple partner organisations working together.

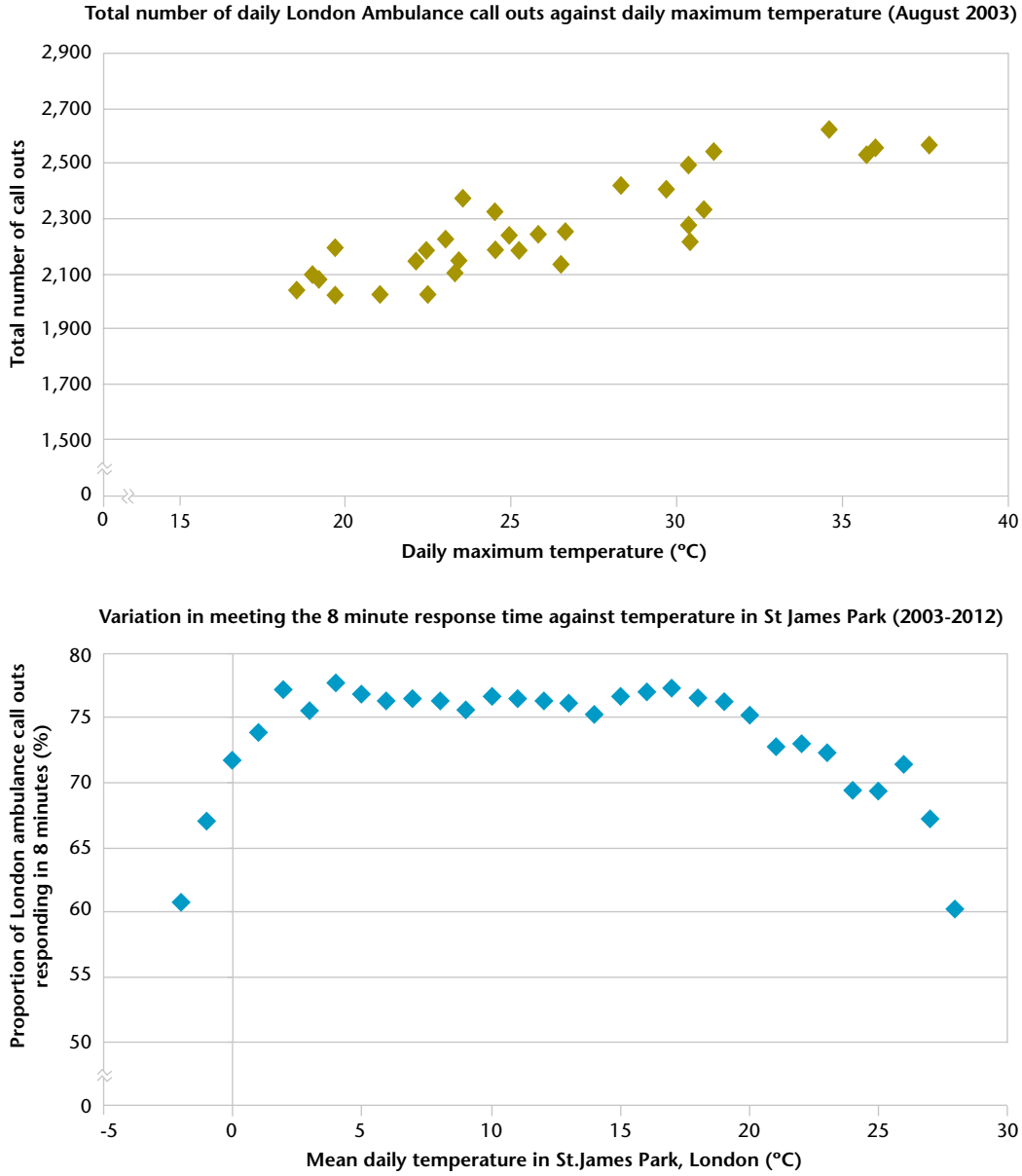
At the highest level, the National Security Strategy (NSS) sets out tier 1 and tier 2 priority risks. Major coastal flooding is included as a tier 1 risk. The National Resilience Strategy (NRS) forms part of the NSS, and the Cabinet Office produces the National Risk Assessment (NRA) on a two-yearly basis. The NRA identifies, assesses and prioritises risks – both hazards and threats – to the UK over a 5 year period.[4] The assessment covers major coastal or river flooding, droughts, heatwaves, cold spells, wildfire, and animal or human disease outbreaks. It also includes other risks such as a terrorist attack or major industrial accident. The analysis within the NRA is classified, but a summary version called the National Risk Register (NRR) is publicly available. There is also a National Security Risk Assessment (NSRA). It is a 5 to 20 year framework with an international focus and informs the National Security Strategy. Flooding is also included within this strategy.

Individual departments or agencies have responsibility for advising and preparing for events that fall within their remit. For example, Defra leads on flooding and drought, the Department for Communities and Local Government (DCLG) on wildfire, and the Met Office on heatwaves and cold weather.

There are numerous bodies involved in planning, response and coordination for natural hazards within the emergency planning system (Figure 6.3). At the local level, emergency response is led by category 1 and category 2 responders designated in the Act. In each part of the country they work together as Local Resilience Forums (LRFs), of which there are 38 in England. LRFs are supported in almost all cases by non-statutory community resilience networks, such as flood wardens, who volunteer in supporting local communities.[5] The LRFs are supported within central Government by the Resilience and Emergencies Division in the Department for Communities and Local Government (DCLG),

4 "Threats" refer to malicious attacks, whereas "hazards" refer to other kinds of risk including extreme weather.
5 Survey of Local Resilience Forums by the ASC (2014) – unpublished.

Figure 6.2: Relationship between temperature, ambulance call outs, and achievement of 8 minute response times in London

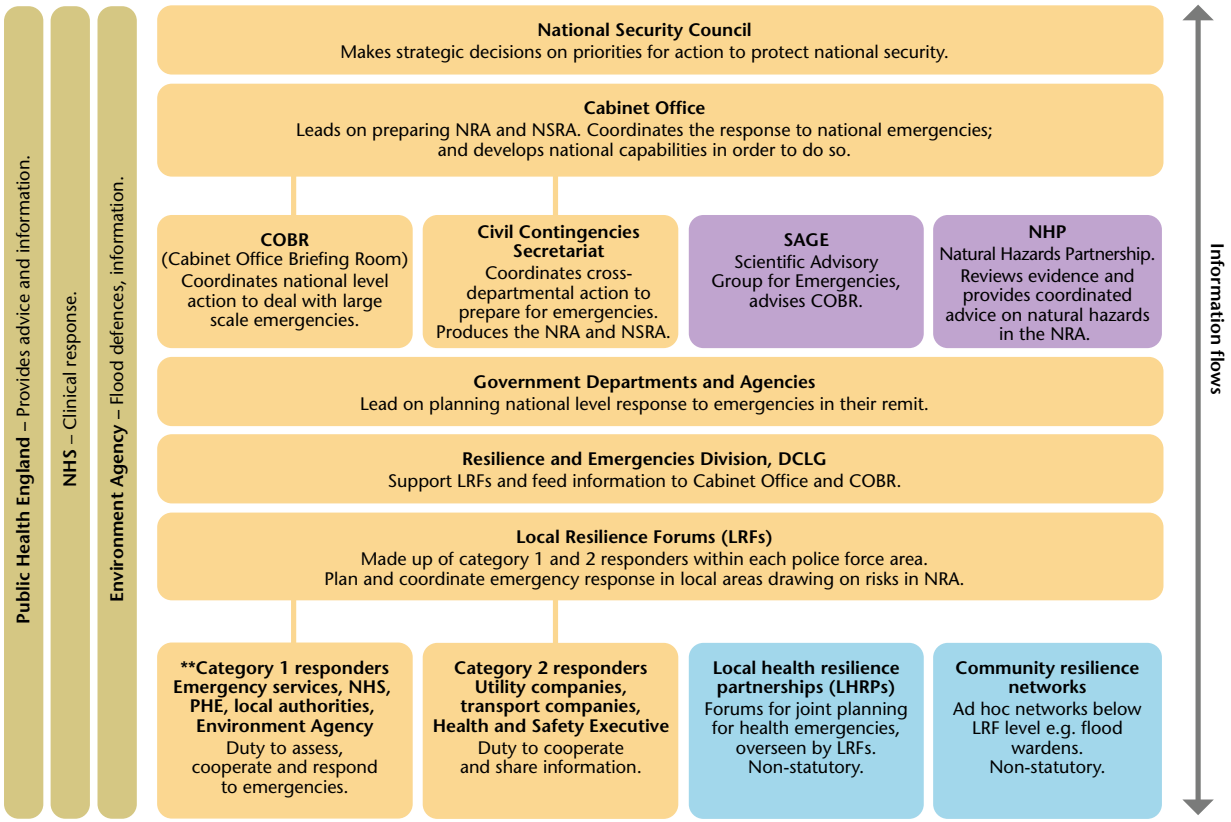


Source: Thornes (2014).

which also assists the response of LRFs when an event spans more than one LRF boundary, or where the severity of the event causes central Government to lead the response through the ministerial emergency committee COBR. The Scientific Advisory Group for Emergencies (SAGE) and Natural Hazards Partnership (NHP) provide scientific evidence and coordinated advice to the Cabinet Office.

The effectiveness of plans and responses to emergencies is reviewed through the National Resilience Capabilities Programme, test exercises, and both internal and independent reviews.

Figure 6.3: Structure of the emergency planning system in England related to natural hazards



Source: Adaptation Sub-Committee, based on various publications
Notes: Yellow boxes: bodies or groups with a statutory role under the Civil Contingencies Act. **Green boxes:** bodies or groups that operate at all levels across the emergency response system. **Purple boxes:** groups that provide scientific advice. **Blue boxes:** bodies or groups that feed in to Local Resilience Forums. **Within the emergency services (category 1 responder), a hierarchical framework exists of gold, silver and bronze command structures. NRA = National Risk Assessment. NSRA = National Security Risk Assessment.

The National Resilience Capabilities Programme (NCRP) aims to increase the national capability to respond to civil emergencies. Its associated National Resilience Capabilities Programme Board (NRCPB) oversees the assessment of capabilities at the national level. To feed into this programme, the Government produces a set of National Resilience Planning Assumptions (NRPAs) to set a benchmark for planning. The assumptions consider high level consequences across all risks and what is needed to deal with these, including if two or more events occur together. The Cabinet Office carries out a capabilities survey of category 1 and 2 responders every two years to inform a national picture of capability and drive work across central Government. The NRPAs and responses to the capabilities survey are classified and not published.

Individual government departments and category 1 responders have a responsibility to review the level of preparedness for emergencies they lead on, including through test events. Recent examples include Exercise Watermark in 2011, the review of the Heatwave and Cold Weather Plans by Public Health England (Chapter 5), and Exercise Cygnus taking place throughout 2014 to test the national and local response to a flu pandemic. In general, test exercises are carried out by lead departments or agencies, and are not overseen by an independent evaluator.

Local Resilience Forums produce debriefs from events, collating information across partner organisations. In some cases local authorities have also produced lessons learned documents following extreme weather in their area. Newcastle City Council produced a report evaluating the response to a serious culvert collapse and widespread flooding in 2012 for example.[6]

The National Adaptation Programme focuses on strengthening community resilience to climate change through Local Resilience Forums and other local-level bodies as set out in Box 6.1**.**

Box 6.1: National Adaptation Programme: emergency services, local responders and community resilience (healthy and resilient communities chapter)

The National Adaptation Programme's emergency services, local responders and community resilience (i.e. emergency planning) section of the healthy and resilient communities chapter contains a list of actions aimed at increasing national and local resilience to climate related risks. These actions highlight the role of local responders, LRFs, communities and civil society in building resilience, and set the Government community resilience programme the following tasks:

- Maintain the community resilience knowledge hub, and signpost materials for communities and LRFs to draw from.
- Promote climate resilience and adaptation within the Ambulance Service, including collation of information on the extent of adaptation coverage within sustainable development management plans.
- The Chief Fire Officers' Association to report on a voluntary basis under the Adaptation Reporting Power, and review their capability for responding to severe wildfires.

Source: HM Government (2013).

6.2 Future risks from extreme weather

Climate change is likely to alter the pattern and severity of extreme weather that the emergency response system will have to deal with.

It is well understood that a warmer atmosphere contains more energy and water vapour, which tends to result in greater intensity of extreme weather events such as heavy rain and strong winds. Globally, we expect the general prevalence of extreme weather to increase in the future.[7]

Changes to the atmospheric circulation around the UK will also lead to changes in the location of storm tracks and high/low pressure systems. These are much more difficult to predict. The weather over the UK is strongly influenced by the position of the jet stream that brings weather systems across the Atlantic to Europe. Shifts in sea surface temperatures, arctic sea ice and upper atmospheric processes could change the behaviour of the jet stream in future, leading to greater or smaller numbers of storms, cold snaps, flooding or heatwaves (Chapter 1).

Table 6.1 summarises the evidence set out in the UK Climate Projections on how climate change might alter key weather variables for the UK.[8]

6 Newcastle City Council (2013).
7 IPCC (2014a).
8 Murphy et al. (2009).

Table 6.1: Evidence from the UK Climate Projections (2009) on changes in key climate variables

Climate variable	Projections (30-year average changes for 2040-2069 – note that individual years would show a much greater range)	Degree of confidence (ASC view)
Mean temperature	Regional changes for winter are +0.5 – +3.5 °C, for summer +0.9 – +4.6 °C compared to the 1961-90 baseline.	High. UKCP09 projects warming in all scenarios and time periods.
Sea level rise	Regional changes vary between +11 and +26cm compared to a 1990 baseline.	High. Processes determining mean sea level are well understood and modelled.
Mean precipitation	Annual changes vary by about -5 and +5%, but strong seasonal variation exists with regional changes in winter between 0 to +40% and in summer between +10 to -50% compared to 1961-90 baseline.	Medium. Uncertainty in seasonal precipitation is large for the UK as the interactions between atmospheric circulation, storm tracks and cloud formation are difficult to model.
Hottest day of the summer	Regional changes for summer are between -2°C to +10°C compared to the 1961-90 baseline.	Medium. More likely to be an increase than a decrease in the temperature on the hottest day in summer.
Wettest day of the season	Regional changes in wettest day of winter are between -10% to +50%, in summer between -30% to +40% compared to the 1961-90 baseline.	Low, especially for summer. Extreme precipitation is difficult to predict due to the influence of blocking episodes, storm tracks and circulation patterns, which are not represented well in current models.
Storm surge	Very small projected change in surge height across the UK, within the bounds of natural variability.	Low. Surge frequency and intensity will be strongly tied to future position of storm tracks over the UK.
Storms and high winds	Small changes for average wind speed, and no projections for extreme winds. Little change in storm frequency over the UK in winter, despite a projected southward shift in the North Atlantic storm track. Also little change in the intensity of storms.	Low. Storm and wind intensity, and direction, will be strongly tied to future position of storm tracks over the UK.
Drought	Using soil moisture levels, models represented in UKCP09 show small decreases to large increases. The return period for a 1976-level drought is projected to change from 1-in-50 year present day to between 1–in-10 and 1-in-1 year by the 2080s.	Low. There has been no observable global or UK trend in droughts to date. Future drought frequency and intensity will be strongly tied to the prevalence of future blocking episodes over the UK.
Fog	Reductions in fog of at least 50% projected for all regions except southern Britain in winter, where increases of up to 30% are projected.	Low. Projections are also based on the Met Office HadRM3 model only.
Lightning	Increases in all regions and seasons.	Low. Projections are also based on the Met Office HadRM3 model only.
Near-term changes (2020s and 2030s)	Projecting the effects of climate change in the near-term is made difficult due to the strong influence of natural variability. The underlying climate change signal will become clearer as the effects from emissions start to dominate from about 2050. Models are less-skilled at projecting future changes in year-to-year variability than a 30-year average. In addition, changes in the extent of Arctic sea ice may have a strong influence on the UK climate in the near-term.	
Blocking episodes	Atmospheric blocking causes weather systems to get stuck over the UK, creating prolonged cold spells and heatwaves for example. The climate models used in UKCP09 have difficulty in projecting the frequency of future blocking episodes, but newer models such as HadGEM3 are proving more skilful.	

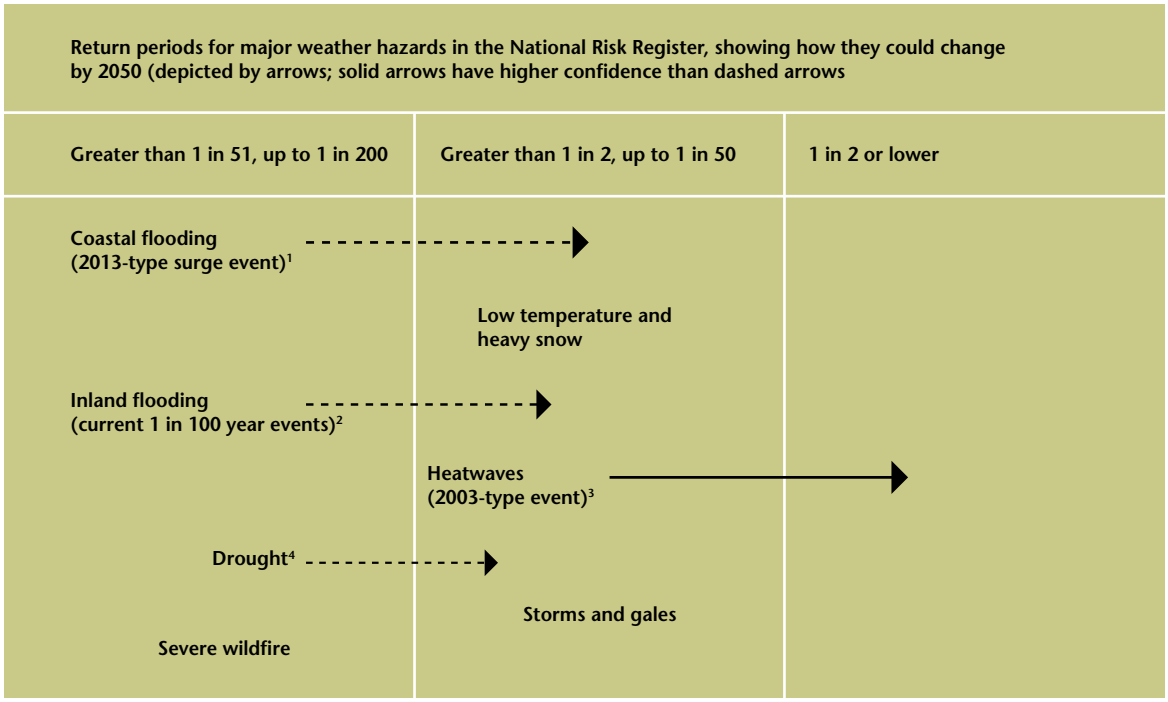
Source: UK Climate Projections (2009), UK Climate Change Risk Assessment Evidence Report 2012 (annex A).
Notes: Reported ranges are for a low emissions p10 to high emissions p90 scenario.

Future patterns of extreme weather in the UK due to climate change are uncertain. This makes it difficult to assess whether the emergency planning system is sufficiently prepared for the future climate. Before we assess future preparedness, we need to understand current capability. Therefore, we have focussed in this chapter on assessing the current capacity in the system to respond to current weather extremes.

As shown above, the level of confidence in projecting future changes to extreme weather events is generally low. Figure 6.4 illustrates how the frequency of some extreme events in the National Risk Register could change by 2050 using results from published research papers, but uncertainties in these estimates are high. There is also a question over whether new weather-related risks might need to be included in the National Risk Assessment and National Risk Register at some point in the future. For example, the effects of severe weather on global human migration are very uncertain, but could become a more significant issue for emergency planners in the future.

The remainder of this chapter aims to assess the current level of exposure and vulnerability to extreme weather in England, and the ability of the emergency planning system to deal with current weather-related risks.

Figure 6.4: How the return periods of weather hazards in the National Risk Register could change by 2050



Source: Various, see below.
Notes: Evidence sources are as follows:
[1]Ramsbottom et al. (2012). Table A7.4 in this report shows that for the East of England, a current 1-in-250 year event could become a 1-in-100 year event by the 2050s (medium emissions p50).
[2]Ramsbottom et al. (2012). Table A7.3 in this report shows that for the Humber, a current 1-in-100 year event could become a 1-in-35 year event under a medium emissions p50 scenario.
[3]Charpentier (2011) on changing return periods of the 2003 heatwave. Met Office analysis has similarly projected a 2003 summer becoming a normal (1-in-2 year) event by the 2040s and cool (less than 1-in-2 year) by the 2060s. This arrow has a higher confidence rating as there are a greater number of references.
[4]Climate Change Risk Assessment Evidence report (annex A). Drought analysis uses soil moisture as the metric and projects the return period for a 1976 drought changing from a current 1-in-50 year event to 1-in-10 year event by the end of the century. We could not find information on how the return periods might change for low temperatures and heavy snow, storms and gales, or severe wildfire.

6.3 Trends in exposure and vulnerability to extreme weather

Trends in exposure to extreme weather

Historic trends in extreme weather events and the attribution of these trends to climate change are difficult to determine, but the evidence is improving.

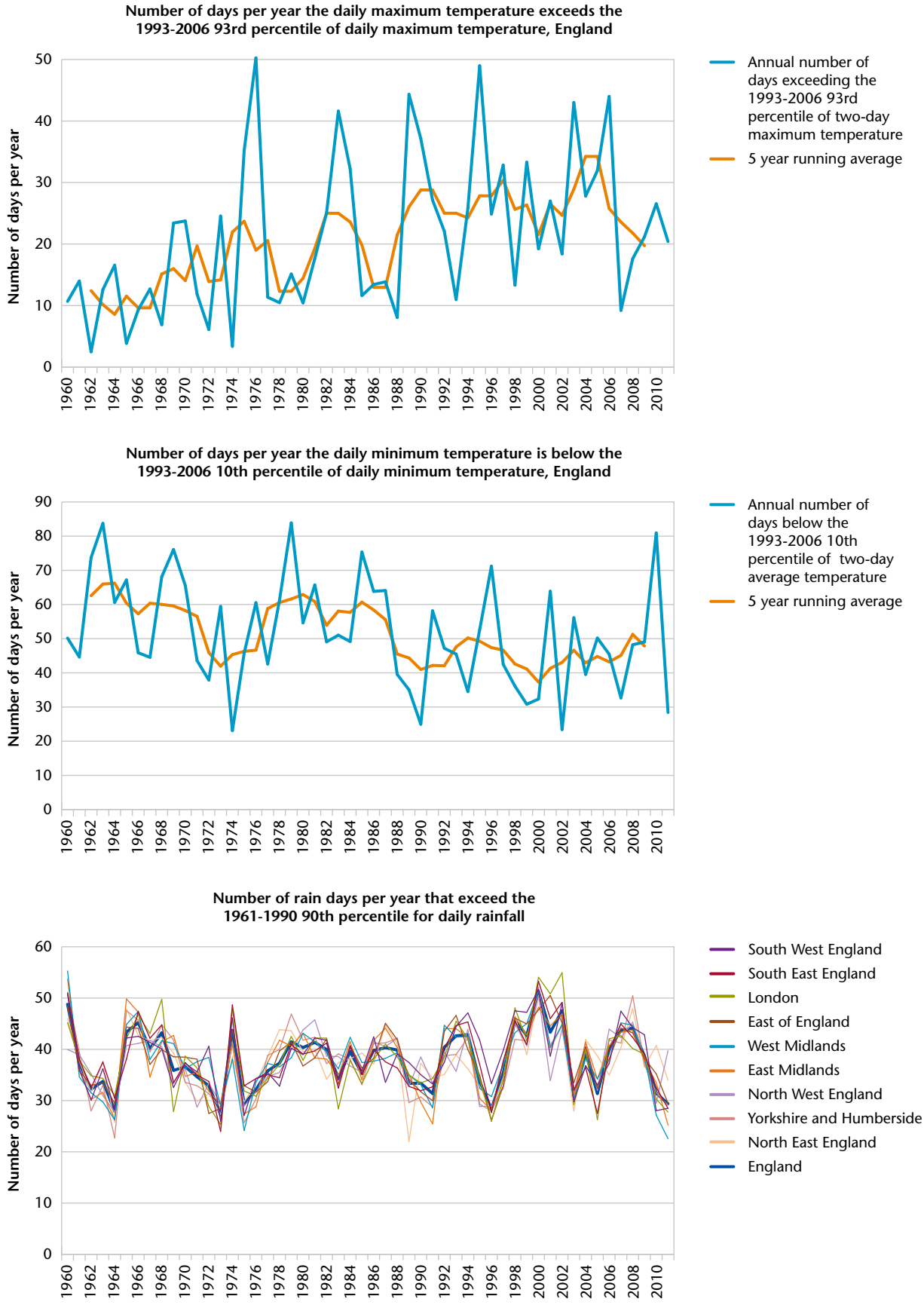
Because extreme events are by their nature rare occurrences, it can be difficult to distinguish between the year-to-year natural variability in the climate and a change in the frequency or intensity of an event caused by climate change. Attribution studies for extreme weather are computationally very difficult as they require large amounts of processing to compare the effects of many different processes. However, such studies are becoming more sophisticated and the number of published attribution studies is increasing.

In England, there have been attributable changes in mean temperature and sea level. There has been some change to high river flows but these cannot be attributed to climate change at present. There is some evidence that the pattern of extreme rainfall has already changed. There is no discernable trend in the occurrence of high tides at present despite rises in mean sea level.

- Mean temperatures for England increased by 1.0°C between 1970 and 2008.[9] Between 2009 and 2013 the rate of increase slowed, but temperatures remain higher than the 1961-1990 average.[10] Mean sea levels rose around England by about 13 – 15 centimetres during the 20th century. Both temperature and sea level trends are very likely to have been caused primarily by greenhouse gas emissions from human activity.[11]
- The number of cold days per year has declined while the number of hot days has increased in England since 1960, though it is difficult to ascertain if this has also led to an increase in heatwaves (consecutive days with hot temperatures). (Figure 6.5).
- The number of days with heavy rain does not appear to have increased when considering England only (Figure 6.5).[12] Met Office analysis suggests that the amount of rain falling in heavy bursts has increased for the UK as a whole.[13] Rainfall over Scotland may therefore dominate the trend in wet days at the UK level.[14]
- There is also some evidence of an increase in high river flows in northern and western parts of England, though not in other parts of the country. Trends in fluvial flood impacts can be assessed, but these are complicated by development and insurance coverage as well as any changes in river flows.[15]

9 Jenkins et al. (2008).
10 http://www.metoffice.gov.uk/hadobs/hadcet/
11 Jenkins et al. (2008). Sea level around the UK rose by about 1mm/year during the 20th century, while the rate of increase since 1990 has been higher than this (between 2 – 3mm/year).
12 HR Wallingford (2014b) for the ASC.
13 Met Office (2014b).
14 HR Wallingford (2014b) for the ASC.
15 Watts et al. (2013).

Figure 6.5: Trends in temperature and rainfall extremes for England



Source: HR Wallingford (2014b) for the ASC.
Notes: These metrics have been population weighted to show the trends over centres of population. Removing population weightings does not alter the overall trends.

- There has been no observed trend in the occurrence of extreme high tides for England since 1990, though the time series available may be too short to determine a trend, if one exists.[16]
- There has been no clear pattern in the frequency of droughts in England.[17] At the global level, there is low confidence in the impact of climate change on drought frequency to date, though some regional changes can be detected.[18]

Trends in socio-economic vulnerability

Changes to the population and to the built environment are increasing both vulnerability and exposure to extreme weather.

- **The population is growing and ageing.** The total population of England increased from 47 to 53 million between 1991 and 2011. By 2035, the total population is expected to rise further to 62 million.[19] Obviously, this will increase the total number of people that will be exposed to extreme weather. The population is also ageing, with 4.1 million people now over the age of 75 compared to 3.3 million in 1991. People over 75 are more vulnerable to heat and cold extremes, and may need more assistance during a flood or other extreme weather event. Coastal areas in particular have larger proportions of local populations consisting of people aged over 75.[20] This may present additional challenges to Local Resilience Forums in these areas.
- **Land use planning choices are increasing overall exposure to flooding.** Annual growth in the rate of development in the floodplain between 2001 and 2011 was between 0.8 – 1.2%, compared to 0.6% elsewhere. Much of this new development will be protected to a degree by existing flood defences.[21] However, if these defences fail or are overtopped the resulting impact will be larger. The area of urban greenspace has also declined by 74,000 hectares (7%) between 2001 and 2011, which could increase the population's vulnerability to the impacts of heatwaves (Chapter 5) and flooding in urban areas (Chapter 2).

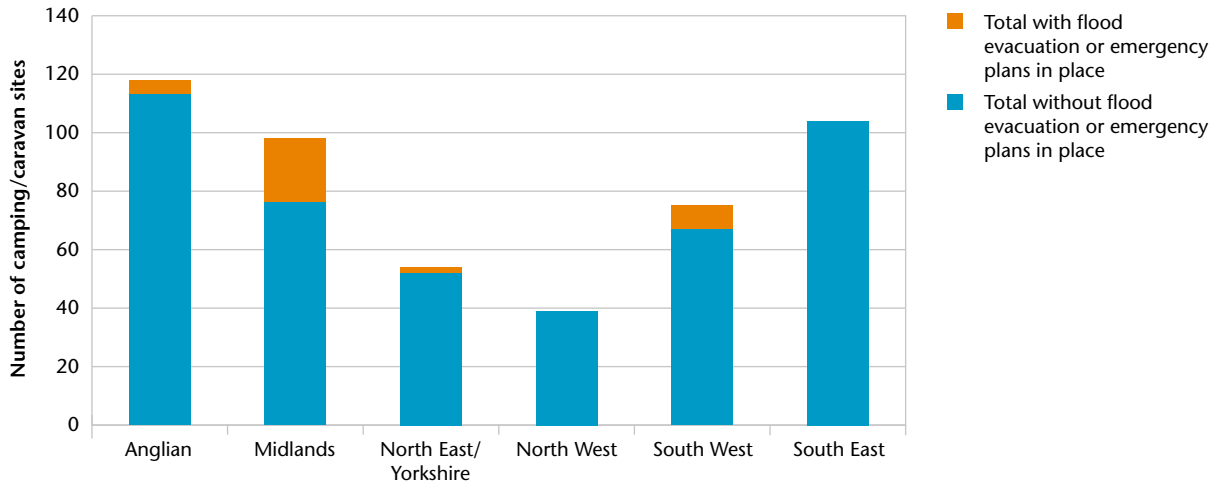
As covered in Chapter 2**, more homes, businesses and other important buildings are likely to become at risk from flooding in the coming decades. This together with a low level of public awareness of flood risk is likely to place more pressure on emergency responders when flooding occurs.**

Chapter 2 describes current investment and other spending plans for flood and coastal erosion risk management. Even if current and future plans are able to keep pace with climate change, more pressure will be placed on the emergency response system when flooding occurs if defences are overtopped. Low awareness amongst people living in flood risk areas is also likely to increase the burden on the emergency services, as people may not take precautionary measures and heed flood warnings when issued (Figure 2.2).

16 HR Wallingford (2014b) for the ASC.
17 Watts et al. (2013).
18 IPCC (2013b).
19 Office for National Statistics (2014b).
20 HR Wallingford (2014b) for the ASC.
21 ASC (2012).

In addition, Defra analysis has found that only 8% of camping and caravan sites situated in areas of significant flood risk from rivers or the sea have flood evacuation or emergency plans in place, suggesting that awareness is also low amongst this sector (Figure 6.6).[22] A large number of the fatalities recorded in the 1953 flood were people living on permanent caravan sites.[23]

Figure 6.6: Number of camping and caravan sites at significant flood risk in England with flood evacuation or emergency plans in place (2010)



Source: Defra (2012b).
Notes: These sites include caravan parks used as permanent residences, as well as caravan and campsites used by holiday makers.

6.4 Assessing the current emergency planning system

Examples of successful planning and action

The Civil Contingencies Act provides a strong framework for emergency preparedness. There have been some notable successes in recent years in predicting and raising awareness of flooding and storms in England.

The existence of the Civil Contingencies Act provides the UK with a strong basis for emergency planning. A review of the UK under the Hyogo Framework for Action praised its use of science, attention to business continuity plans, the professional and dedicated staff working in the field of disaster risk reduction, and the national commitment to pushing further implementation.[24]

22 Significant risk in this report was defined as a 1-in-75 year chance of flooding.
23 Baxter (2005).
24 UNISDR, EC, OECD (2013).

Following on from the 2007 floods and subsequent Pitt Review (2008) there have been notable improvements in the way flood and other early warnings are given, as well as the provision of scientific advice:

- The Met Office and Environment Agency jointly operate the National Flood Forecasting Centre, allowing prior warnings of flood risk up to 5 days in advance. The Met Office severe weather warning service also provides this capability for other types of severe weather (Box 6.2).
- The Natural Hazards Partnership (NHP) was set up in 2010 to provide consistent expert advice to Government on the types and severity of extreme weather event to be included in the National Risk Assessment. The partnership currently consists of 17 organisations and provides a coordinated daily hazard assessment to all category 1 and 2 responders.
- The Heatwave Plan and Cold Weather Plan have created a strong link between the severe weather forecasting ability in the Met Office, and the planning and advice capability within Public Health England.
- The Environment Agency published updated flood maps for river, coastal, and reservoir flooding in December 2013. For the first time, surface water flood maps were also included (Chapter 2).
- The number of people signed up to the Environment Agency's flood warning scheme has also increased to over 50% of all at risk households, in part due to the introduction of an 'opt-out' service.[25]

Box 6.2: Examples of early warnings for extreme weather in 2013

In 2013, the emergency planning system was tested several times as the UK was hit by periods of extremely wet and windy weather.

- **28th October 2013 – St Jude's Day storm.** Preparations were put in place to reduce exposure through five-day advance warnings from the Met Office. Train companies closed routes in advance and cleared away over 100 fallen trees blocking the lines before they were re-opened. The number of commuters exposed to risk dropped dramatically given line closures, and many people were told to work from home by their employers. Tragically, four people died from tree falls. Many more injuries and fatalities were probably prevented as a result of the early warnings given.
- **5th December 2013 – east coast tidal surge.** Compared to the 1953 surge, the impact of this surge was an order of magnitude lower despite the two events being very similar in terms of the height of the tides. It is likely that the improvement in flood defences along the east coast over recent decades and the advanced warning system played a major role in protecting people. The Environment Agency reported that 800,000 homes were in areas protected by defences against the tides. The presence of a sophisticated forecasting and early warning system managed by the Met Office and Environment Agency meant that the event was predicted several days in advance, giving people time to prepare. The Environment Agency issued 160,000 flood warnings, and an estimated 18,000 people were evacuated from homes in coastal areas. The differences in impact between the 1953 and 2013 surge events are illustrated in Figure 6.7.

Source: Met Office, Environment Agency, Baxter (2005).

25 HR Wallingford (2014b) for the ASC.

Figure 6.7: Comparison of the 1953 and 2013 tidal surges

	31 January 1953 coastal flood	5 December 2013 coastal flood
Presence of early warning system?	No (no forecasting of event, rudimentary media, no centralised planning)	Yes (3-day warning from Met Office/ Environment Agency flood forecasting centre, 160,000 flood warnings issued)
Number of people evacuated prior to event	0	18,000
Change in sea level	Greater than 2 metres south of the Humber	5.2 metres OD at Immingham
Return Period for surge recorded	1-in-200 years at Lowestoft	Varied by location, but of the order of 1-in-200 to 1-in-400 years
Number of properties flooded	24,000	1,400
Number of deaths	307	0

Source: Met Office, Environment Agency, Baxter (2005), National Tide and Sea Level Facility (NTSLF) tide gauges.
Notes: OD = Ordnance datum, the reference level above which changes in sea level are measured.

- **The Government is providing support and funding for local resilience forums (LRFs) and other local groups to boost community-level resilience and plan for climate change.**
- The Government has been working to boost dialogue on climate change issues in LRFs, including through awarding grants to nine LRFs to fund projects related to strengthening community resilience. Projects have included the creation of web portals for information sharing and development of a series of children's books.[26]
- In North Somerset over 20 separate communities are working to increase their resilience to climate change. A website acts as a focal point, providing awareness, information and resources for local responders and the public. Teams of volunteers have been trained and equipped to implement their own flood response plans.
- Both Surrey and London LRFs are actively looking at the impacts of climate change as a risk for their area. Surrey has a climate change working group specifically considering flooding in relation to climate change.
- In Liverpool, a project is focussing on adapting properties in an inner city area, alongside tree planting to reduce the risk of surface water flooding. Local residents act as community champions and undertake projects to engage young people through schools and youth clubs.

26 HM Government (2013).

- The Defra Flood Community Resilience Pathfinder has been set up to support local communities to identify what works in preparing for flooding. Defra is investing over £4 million in 13 demonstration schemes over two years. One of the interim outputs has been the creation or reinvigoration of 37 community flood groups. A framework for evaluating the success of the pathfinders has been published and evaluation will take place in 2015.

Climate change is being factored into national guidance on emergency planning.

The Department of Health issues guidance for emergency planning, resilience and response for NHS funded providers. The most recent guidance document contains a section on emergency planning with respect to climate change.

The Cabinet Office is considering the extent to which climate change should be taken into account in the National Risk Assessment.

The importance of planning for climate change is also acknowledged in the national Heatwave and Cold Weather Plans, which have been published annually since 2004 and 2011 respectively. The plans aim to raise public awareness of the need to act in preparation for and response to hot and cold weather. Heatwave and cold weather alerts are triggered by the Met Office severe weather warning service. In turn these should trigger action within the NHS and other health and social care organisations to protect vulnerable people.

Monitoring the national capability to respond

The National Resilience Capabilities Programme assesses high level capabilities across the UK, including through a national capabilities survey of category 1 and 2 responders.

The capabilities survey includes questions on a range of risks, including extreme weather. The survey is voluntary, and the results of the capability survey are not published. It is therefore not possible for the ASC to use this evidence to comment publicly on the overall level of capability in place to respond to extreme weather incidents.

At present, individual bodies collect some non-classified information on the level of resource available for dealing with weather-related emergencies, such as the number of flood rescue boats available.

A national asset register for flood rescue boats is held by the Fire and Rescue Service National Coordination Centre. The register includes details of organisations that have declared that their flood rescue assets may be made available during an emergency, though availability cannot be guaranteed at the time of need. The register does not include those boats owned by fire and rescue services which have not been declared. The Chief Fire Officers' Association (CFOA) is currently undertaking an audit to improve the accuracy of the register.

Evaluation exercises provide some information on current capability levels. Public Health England undertake reviews of the Heatwave Plan and Cold Weather Plan

annually (Chapter 5)**. Action appears to be variable and information on levels of resilience is difficult to collect.**

Despite the review process, it is difficult to determine what the actual level of action has been at the local level in response to the Heatwave Plan and Cold Weather Plans. The information that is available suggests that action is variable. An independent case study review found, for example, that while hospital managers were aware of the plan, frontline nursing staff were not. It also found that measures to control internal temperatures in hospitals were limited due to an absence of appropriate equipment and thermostat controls.[27] One study has suggested that up to 90% of hospital wards are of a type that could be at risk of overheating (Chapter 5).[28]

The Pitt Review recommended that category 2 responders should have a strengthened duty to share information on risks to their infrastructure, to enable more effective emergency planning within Local Resilience Forums. Our analysis suggests that a lack of understanding of infrastructure resilience remains an issue.

Analysis in Chapter 3 showed that while risks are assessed, acted upon and progress transparently reported by electricity transmission and distribution operators, some of these steps are not followed by rail, water companies, roads, ports, airports and ICT providers. Out of 13 Local Resilience Forums who completed an ASC survey, four stated that they lacked knowledge about the risks to infrastructure in their areas.[29]

Responses to a separate ASC survey of the Core Cities Group also suggested that the removal of regional Government offices has reduced the ability of LRFs to coordinate multi-agency activity, including between category 1 and 2 responders.[30]

Roles and responsibilities

Roles and responsibilities during weather-related emergencies are not always clear.

The 2008 Pitt Review identified several examples of a lack of clarity on roles and responsibilities in relation to flood emergencies. For example, the Fire and Rescue Service is not legally required to rescue people during a flood. The Government considered this situation as recommended by the Pitt Review and following Exercise Watermark, but decided that a statutory duty was not needed. There remains a gap in knowledge as to what the total capability for flood rescues should be, including what the presumed and actual level of mutual aid is between Local Resilience Forums. Defra and DCLG are intending to undertake a study that assesses overall capability for flooding.

During the winter floods of 2013/14 in England, confusion was reported over the benefits and provision of sandbags. Oral evidence to the Environment, Food and Rural Affairs committee from MPs and Ministers in January 2014 implied that district councils are always responsible for providing sandbags, and media reports during the floods suggested that

27 Boyson et al. (2014).
28 Follow on study to be published from Short et al. (2012).
29 ASC survey of Local Resilience Forums (unpublished).
30 ASC survey of the Core Cities Group (unpublished).

residents assumed they could request sandbags from their local council.[31] [32] Environment Agency guidance states that sandbag provision is at the discretion of local authorities and it is not clear what the level of resource is in different councils. In any case, sandbags are not as effective for holding back flood water as other measures such as products designed to block doorways.

The peer review of the UK under the Hyogo Framework for Action noted that while command and control mechanisms appear efficient for emergencies in one area or under the remit of one department, they may be less effective for major or more complex events.[33]

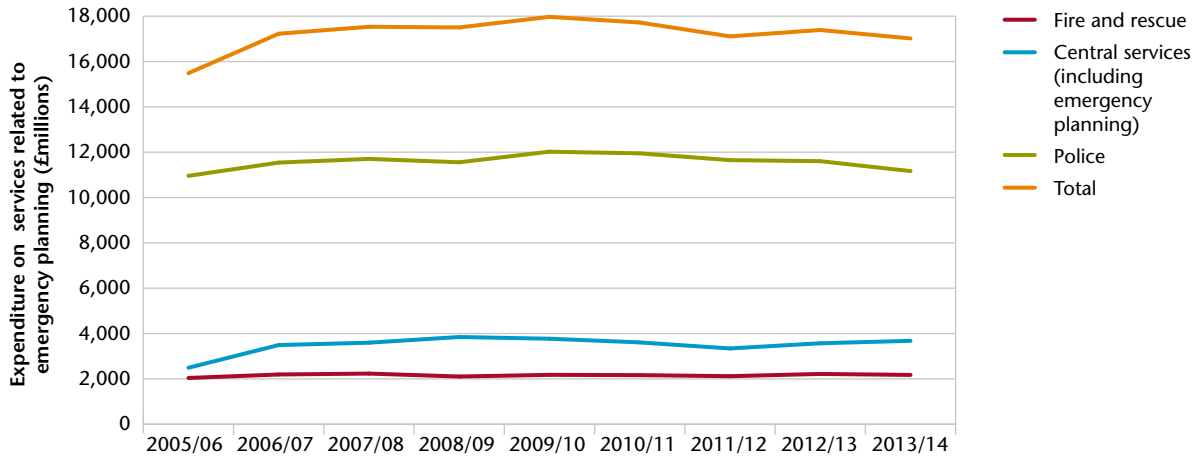
Resources in key responding organisations

Spending cuts in recent years have reduced the total number of people working in some category 1 and 2 organisations. Pressures will continue to grow on local authority budgets in the future. The cumulative impacts of these cuts has not been assessed.

In 2013/14, local authorities in England spent around £17 billion on services related to emergency planning and response.

- **Expenditure levels on emergency planning services have remained fairly static since 2005** (Figure 6.8)**. However, over the same time period, total numbers of police and fire officers have declined by 2,000 (4%) for fire officers and 13,000 (8%) for police officers** (Figure 6.9)**.** These reductions in staffing may be driven by a reducing need in general. For example, the number of fires has declined by 55% since 2002, suggesting fewer staff may now be needed for controlling fires.[34] However, we could not find evidence of how these cuts relate to the level of emergency capability needed within these organisations.

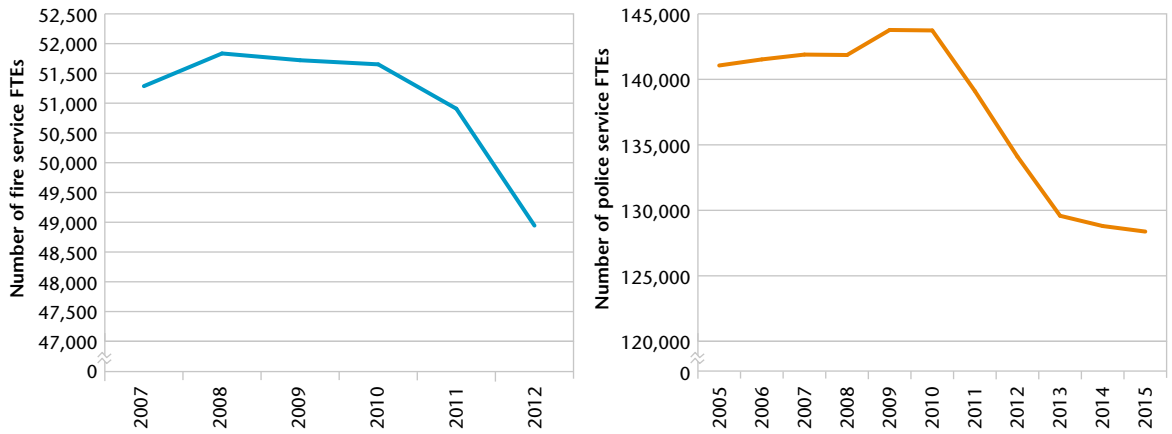
Figure 6.8: Local authority expenditure on services related to emergency planning (2005-2014)



Source: Government local authority revenue expenditure and financing statistics.

31 E.g. http://www.bbc.co.uk/news/uk-england-surrey-26151714
32 EFRA committee oral briefing session, 22 January 2014, and Environment Agency (2009) – Sandbags.
33 UNISDR, EC, OECD (2013).
34 DCLG (2013).

Figure 6.9: Numbers of fire and police officers (2005-2015)



Source: DCLG operational fire statistics bulletin (2014), House of Commons – police service strength (2013).

- **Funding for local government emergency planning functions may decline significantly by 2020.** Central Government funding for local authorities declined by £6 billion (19.6%) between 2010 and 2014, although spending on core functions including emergency planning appears to have been protected to date (Figure 6.8). Local authority expenditure on employees fell from £21.1 billion in 2010/11 to £18.4 billion in 2012/13. Around one third of councils are considered by the Audit Commission to be at risk of not delivering their financial plans in the future.[35] The Local Government Association suggests that funding for services other than public health, social care and waste management will decline by 46% to 14.3 billion by 2020 compared to 2010.[36]
- **The Environment Agency now has 800 fewer flood risk management posts than in September 2010** (Figure 2.5, Chapter 2). Within this, the number of office-based flood incident management posts has decreased by 20%. Half the total, four hundred posts, have been lost from asset management teams, primarily office-based roles and in project management (a 15% reduction on the 2010 staffing level). The Environment Agency states that field-based operational roles were unaffected by the staff reductions, and that despite the recent headline staff losses they have been able to maintain, at around 400, the number of staff they have on standby at any one time to help manage incidents. During the 2013/14 winter storms they called upon around 5,000 employees to staff their emergency rotas and help in the flood response on the ground. With additional funding provided by the Government following the winter flooding in 2013/14, future reductions in staff across the agency will not be as high as previously planned. By October 2014 it is likely that the number of staff across the EA will fall to around 10,250, from 11,000 in 2013/14. By April 2014 staffing levels had already fallen to around 10,600.[37]

35 Audit Commission (2013).
36 Local Government Association (2013). This assumes that councils make efficiency savings of between 1 – 2% per year.
37 Numbers provided by the Environment Agency.

Coverage and content of local emergency response plans

Responses to an ASC survey of Local Resilience Forums suggested that past experience is an important driver of prioritisation of emergency response planning at the local level.

For example, local authorities have improved their response to snow in the last five years due to having experienced several cold winters. Prior to this there were ten years of mild winters with very little snow, when most councils reduced their capabilities and funding, and have since had to reappraise.[38]

The prioritisation of more "visible risks" in community risk registers is also evident in the amount of action and information available on flooding, but less so for drought.

The 2011-2012 drought was nearly declared as a national emergency following two dry winters. This was avoided by the high level of rainfall in the early summer and throughout the autumn of 2012 (which in turn led to widespread flooding).

Both drought and animal disease risks have the same risk rating in the National Risk Register, and would therefore be expected to have similar levels of coverage and importance across local community risk registers. However, while animal diseases are mentioned in 97% of English risk registers, drought is mentioned in 73%.

This could be due to drought being a more regionally-focussed risk, in which case it would be expected that more of the plans that mention it would give it a high or very high rating. This is also not the case; 26% of plans that mention drought give it a high or very high rating, whereas 65% of plans that mention animal disease give it a high or very high rating.

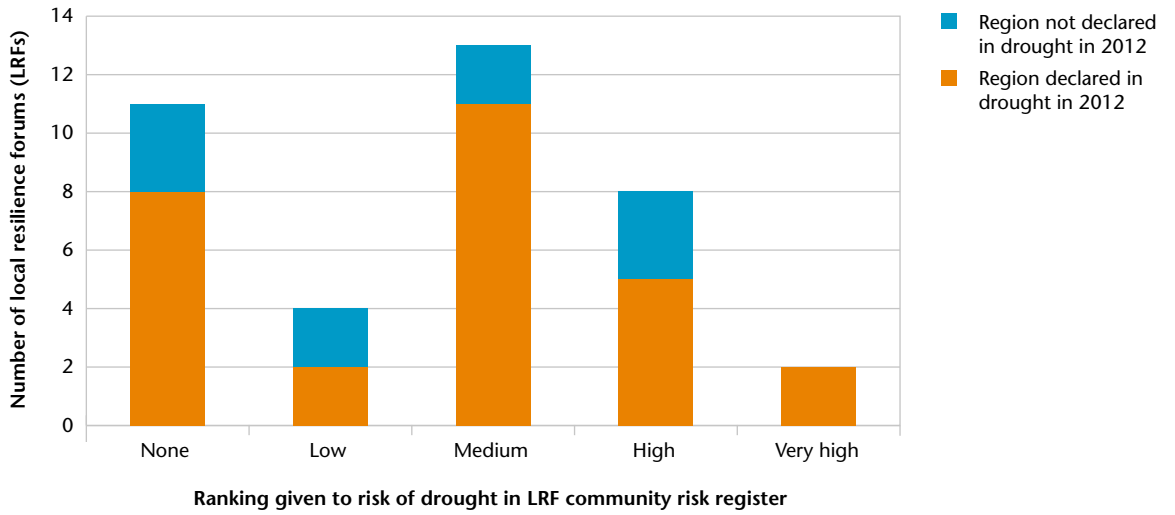
There is also no relationship between those Local Resilience Forums that mention drought as a risk in their risk registers to those in areas that were declared to be in drought by the Environment Agency in 2012 (Figure 6.10). Ten Local Resilience Forums that were in areas declared to be in drought in 2012 either do not include drought, or give it a low score in their risk registers.

Community risk registers produced by LRFs are not independently scrutinised. There is no independent verification of the priorities or resource assigned to different risks by local responders.

Central Government through DCLG's Resilience and Emergencies Division provides advice and guidance on preparing community risk registers. However, neither DCLG nor Cabinet Office have a remit to scrutinise local plans. Local authorities review their own plans, but an independent challenge function does not currently exist.

38 Survey responses from Local Resilience Forums and the Core Cities Group for the ASC (unpublished).

Figure 6.10: Comparison of English local resilience forum regions declared to be in drought in 2012, against those that currently include drought in community risk registers



Source: Community risk registers (2014), Environment Agency drought timeline for 2012.
Notes: This graph shows the relationship between those LRFs that were declared in drought in 2012 and the ranking given to drought in their community risk registers. For example, 8 local resilience forums that do not include drought as a risk were declared to be in drought by the Environment Agency in 2012. This assessment has been conducted on 38 community risk registers covering England only.

6.5 Conclusions and policy advice

Our analysis suggests that the burden on the emergency planning system is likely to increase in the future due to socio-economic change alone. Climate change is likely to bring further stress to the system by increasing the frequency and severity of weather extremes.

The emergency planning system has to respond to whatever impact occurs when the limits of preventative measures are exceeded. As such, decisions on preparatory issues such as flood defence spending or resilience to heat in buildings have knock-on impacts for emergency response organisations. A growing and ageing population is placing more people and assets at risk over time. Current measures to prevent flooding and reduce the health risks from overheating do not appear to be keeping pace with the growing risks from climate change.

The Government needs to consider the combined effects of socio-economic change, policy choices and climate change on the current and required capacity of the emergency planning system.

In response to the storms and flooding in winter 2013/2014, the Government announced a new annual review of resilience to consider the local, regional and national response to extreme weather and make recommendations for the Government's short and long-term strategies.[39]

This review should consider whether the balance of decisions being made across Government are addressing or increasing the level of risk from weather hazards.

39 https://www.gov.uk/government/news/first-meeting-of-new-cabinet-committee-on-flooding

In particular, population growth and development without adequate resilience would increase the overall exposure and impact from extreme weather, even before climate change is considered.

The Government also needs to keep abreast of latest scientific developments on understanding the frequency and intensity of future extreme weather events. The Cabinet Office is planning to consider how the risks from climate change might alter the way the National Risk Assessment (5-year forward look) and National Security Risk Assessment (20 year forward look) are developed.

Our analysis also highlights four areas where Government and the relevant authorities should consider whether the current emergency planning system needs strengthening in order to cope with current risks. This would help to ensure the system is in a stronger position to respond to the additional risks resulting from climate and socio-economic change.

1. **The Government should consider whether a single body, with cross-departmental representation, should be given overall responsibility for collecting and analysing all required data related to emergency capability. It could in turn provide advice back to Government on gaps in awareness or action.**

Data sharing was highlighted as an issue following the 2007 floods, and remains an issue, particularly for infrastructure-related risks. Some Local Resilience Forums have highlighted a lack of understanding of infrastructure resilience as an ongoing problem. In addition, evaluations of the Heatwave and Cold Weather Plans have shown that collecting data on the uptake of resilience measures is challenging, but information on whether or not organisations are acting is easier to collect (and shows in the case of the Heatwave Plan that action is variable).

Such an organisation should have the means to call upon classified data to support its analysis.

2. **The Government should review the level of clarity within and between different responders on responsibilities and capabilities for extreme weather events. In particular, it should review the required level of capability for flooding and whether further clarification to householders is needed in relation to responsibilities for providing temporary flood protection measures.**

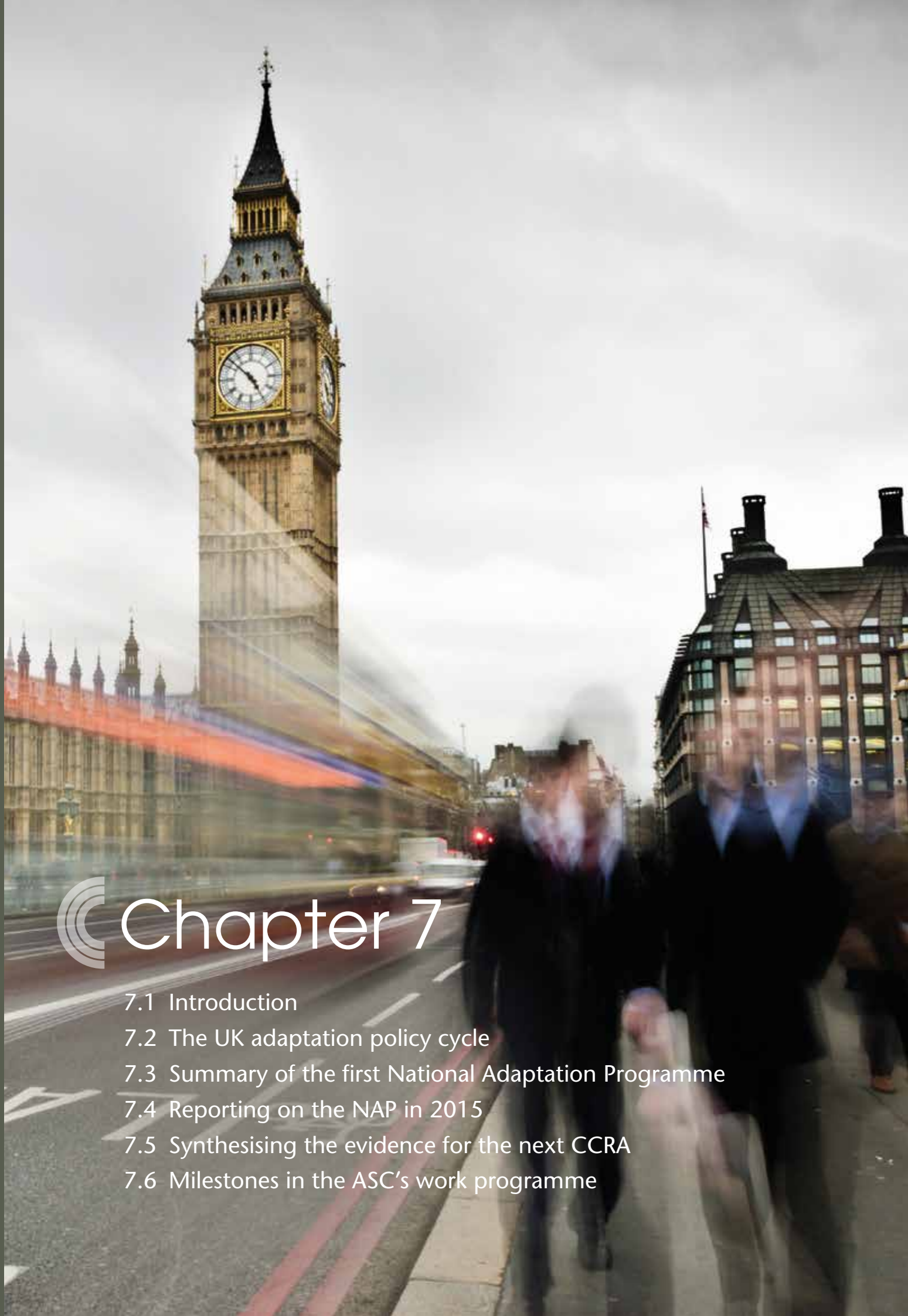
Confusion over roles and capabilities for responding to flooding was highlighted in the 2008 Pitt Review. The winter 2013/14 floods have demonstrated that some confusion still exists at the local level over the benefits and provision of sandbags, for example. The Government has decided not to place a statutory duty on the Fire and Rescue Service to undertake flood rescues, and it is still unclear what the required level of capability for flood rescues needs to be now and under different future scenarios.

3. **Resourcing levels should be reviewed across the board to ensure there are sufficient trained personnel, and assets, available to respond in an emergency (once capabilities are clarified). This could form part of the Government's annual review of resilience or be considered by the National Resilience Capabilities Programme Board (NRCPB).**

While there may be justifiable reasons for reducing overall resource levels across responder organisations, the impact on emergency capability from staff cuts as a whole has not been assessed. This is potentially concerning in part because mutual aid is essential in some cases, and may be less forthcoming in the future if resources are stretched. The Government should review and compare the detailed level of capability required to respond to different events against current resourcing levels.

4. **Independent scrutiny of local plans is needed to consider the balance and coverage of risks nationwide, and consistency with the National Risk Assessment.**

Our analysis suggests that drought may not be covered sufficiently in community risk registers. Independent scrutiny of priorities and resources would be helpful to provide additional challenge and confidence in the risks being planned for at the local level. The process by which local plans are deployed could also be reviewed. This could form part of the Government's annual resilience review.



Chapter 7

7.1 Introduction
7.2 The UK adaptation policy cycle
7.3 Summary of the first National Adaptation Programme
7.4 Reporting on the NAP in 2015
7.5 Synthesising the evidence for the next CCRA
7.6 Milestones in the ASC's work programme

Chapter 7:
Next steps

7.1 Introduction

Building on our previous studies, this report completes the ASC's first cycle of analysis of the major threats and opportunities identified within the 2012 UK Climate Change Risk Assessment. This final chapter sets out the next steps in delivering our statutory roles under the 2008 Climate Change Act between now and 2017.

7.2 The UK adaptation policy cycle

The UK is one of the first countries to have established a legal framework for adapting to climate change.

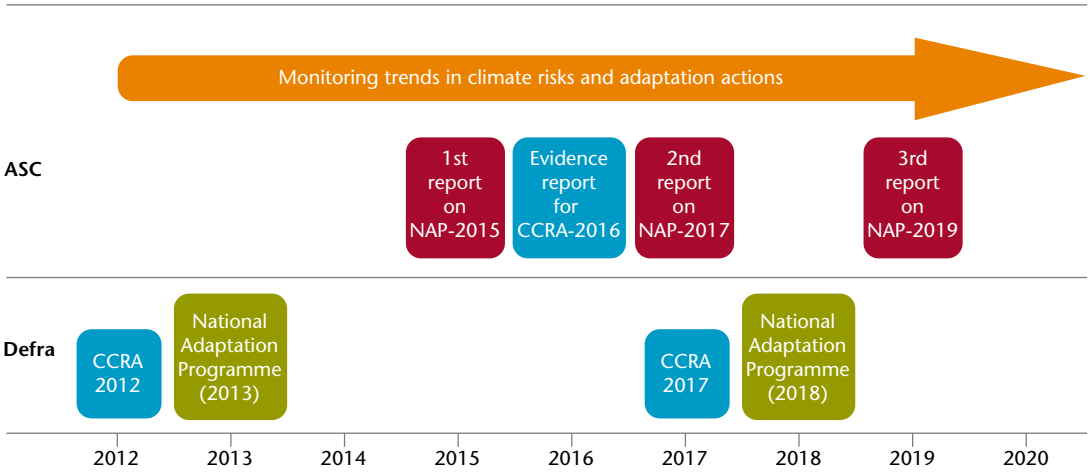
The Climate Change Act was ground-breaking in creating a framework for both mitigating and adapting to climate change. The Act established legally binding carbon budgets to put the UK on a trajectory to meet the target of an 80% reduction in greenhouse gas emissions by 2050 compared to 1990.

The Act also put in place an adaptation policy cycle where the Government first assesses the risks and opportunities facing the UK from climate change, and then produces a policy programme to address those risks. The first UK Climate Change Risk Assessment was published in January 2012, and the first National Adaptation Programme in July 2013. This process will be repeated every five years, with the next CCRA due in 2017 and the second NAP in 2018.

Recognising that adaptation to climate change is a long-term process, the Act also requires regular, independent scrutiny of the Government's programme. The ASC was created by the Act with responsibility to report to Parliament every two years with an assessment of progress with the NAP and to advise Government on the risks from climate change every five years.

This cyclical process of assessment, planning and reporting is an iterative approach to managing the risks associated with a changing climate. Each cycle should build on the previous one. So the next CCRA, due in 2017, should take account of the extent to which the actions set out in the 2013 NAP are influencing the overall level of climate risk. No other country has yet established an equivalent legal framework for adaptation that includes independent scrutiny of progress. Figure 7.1 summarises the adaptation policy cycle.

Figure 7.1: Adaptation policy cycle created by UK Climate Change Act



Source: ASC.

7.3 Summary of the first National Adaptation Programme

The National Adaptation Programme set out for the first time the Government's objectives in preparing for climate change. It describes the range of actions that will be taken to address the risks whilst exploiting the opportunities identified in the 2012 Climate Change Risk Assessment.

The NAP is primarily for England but also covers reserved and non-devolved matters.[1] Statutory adaptation programmes were published in 2014 for Northern Ireland[2] and Scotland.[3] In Wales a non-statutory Climate Change Strategy was published in 2011.[4]

The programme is guided by the Government's overarching vision of a climate-ready society *"which makes timely, far-sighted and well-informed decisions to address the risks and opportunities posed by a changing climate".*

It is recognised that although in some cases well-informed decisions will be made naturally by individuals and organisations in response to a changing climate, there are barriers to adaptation in many cases that require government intervention. The programme is underpinned by evidence that identified barriers across different sectors, and the role of government in overcoming them.[5]

The NAP has six chapters that broadly follow the themes in the CCRA:

- built environment,
- infrastructure,
- healthy and resilient communities,

1 For example, the provision of some types of national infrastructure like the rail network and electricity transmission networks.
2 DOENI (2014). This was a statutory requirement of the 2008 Climate Change Act.
3 Scottish Government (2014). This was a statutory requirement of the Climate Change Act (Scotland) 2009.
4 Welsh Government (2011). The 2008 Climate Change Act does not require the Welsh Government to produce an adaptation programme, although Welsh Ministers have to report to the Welsh Assembly on the action the Welsh Government is taking on adapting to climate change.
5 Defra (2013d).

- agriculture and forestry,
- natural environment, and
- business.

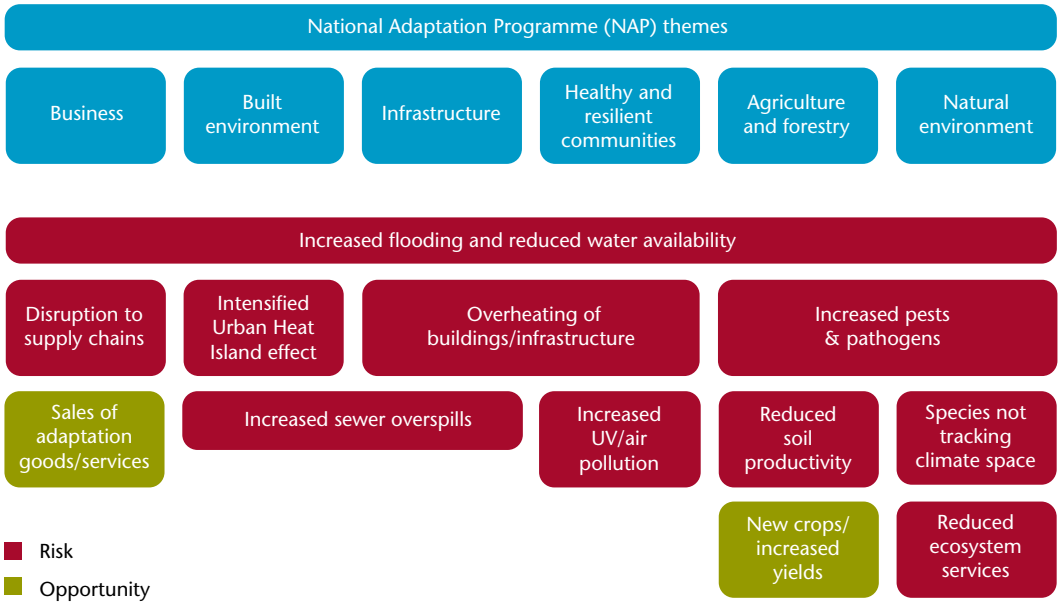
In addition, a seventh chapter describes the role of local government in delivering adaptation across all sectors of society.

Each of the NAP chapters set out objectives and specific actions that will be taken to address the priority climate risks and opportunities in the CCRA that, in the Government's view, require the most urgent attention.

In identifying the priority risks, the Government was guided by the magnitude, confidence and urgency scores assigned in the CCRA. This highlighted those risks needing urgent attention due to confidence in the potential for high magnitude impacts, or where there are long planning horizons. Two cross-cutting risks (flooding and reduced water availability) dominate the list of the highest priorities and are important to each NAP chapter. Other climate risks and opportunities are directly relevant to one or more NAP chapters (Figure 7.2).

Objectives have been developed for each NAP chapter to address the greatest risks and opportunities. These objectives aim to increase awareness, increase resilience to current weather extremes, take timely action and address major evidence gaps. There are 31 separate objectives across the seven chapters. The chapters describe the most significant actions that will be taken to deliver the objectives. An annex to the NAP contains a more detailed register with over 370 specific actions, together with owners and timings.

Figure 7.2: Aggregated priority CCRA risks and opportunities for each of the six thematic NAP themes



Source: ASC based on the National Adaptation Programme.
Note: We have aggregated the detailed (Tier 2) CCRA risks and opportunities that are listed in each of the NAP themes.

The actions in the NAP are primarily for central government departments and their agencies, although other bodies also made commitments including local government, infrastructure providers, research councils, industry bodies and non-governmental organisations.

7.4 Reporting on the NAP in 2015

Our 2015 report will assess the progress made to date with the implementation of the NAP and the extent to which it is addressing the priority climate risks and opportunities identified in the CCRA. To do this, we have developed a set of indicators to provide evidence of the progress being made.

Since 2012 we have been developing an indicator set through a series of annual progress reports. We have primarily identified indicators that tell us whether actions on the ground are either increasing or reducing risk. These are known as 'outcome' indicators and provide a strong foundation for assessing overall progress.

For example, our 2012 report assessed progress with managing flood risk in a changing climate. We used outcome indicators to assess the number of households that had benefited from the construction of new defences since 2008. We then assessed whether additional protection would be needed, given the projected increase in the number of households at high risk due to climate change by the 2030s.

Together with the analysis presented in this report, we now have a draft set of indicators for each of the priority risks and opportunities highlighted in Figure 7.2. We have found, however, that identifying outcome indicators can be challenging as they are heavily reliant on national-level spatial datasets being available. As such, there are a number of gaps where we have not been able to find data. There are also several risks; particularly those related to the marine environment, where more work is required to identify indicators.

We will be publishing a consultation and call for evidence on our draft indicators shortly. This will gather feedback on their appropriateness and seek additional datasets that we could use.

We will review delivery of the NAP actions to date to assess the progress being made with implementing the NAP objectives.

The actions in the NAP set out the measures that key actors, such as central and local government, infrastructure operators, public health bodies and businesses, are taking to prepare for climate change. We will review the progress being made in each case and assess the extent to which key decision-makers are taking up low-regret adaptation measures and embedding climate change into their long-term planning.

Reviewing delivery of the NAP actions will require those organisations with actions assigned to them to provide evidence of whether they are complete, what has been achieved to date, and any further steps planned. These updates will provide process-based indicators of whether planned policies and milestones have been, or are on course to be, delivered. This will complement the evidence provided by our outcome indicators.

Later in 2014, we will formally request Government Departments to co-ordinate the collation of updates for those actions they and their Arms Length Bodies lead on across for each of the NAP chapters. At the same time, we will request other organisations that are responsible for NAP actions but not part of central government to provide updates. This will include organisations that represent local government (such as the Local Government Association) and private companies (for example, Water UK on behalf of the water companies).

Early in 2015, we will follow up with individual departments and organisations where further evidence is thought necessary to assess the delivery of actions and their impact in addressing risks identified in the CCRA.

The final step of our approach will be to evaluate the extent to which implementation of the NAP is addressing the priority climate risks identified in the CCRA and making a difference to vulnerability in the near term.

We will interpret the trends from our indicators and the updates we receive on the implementation of the NAP actions to evaluate:

- whether progress is being made in addressing the priority risks identified in the CCRA; and
- the extent to which implementation of the NAP is contributing towards addressing the priority climate risks identified in the CCRA.

Based on this evaluation, we will comment on progress for each of the priority risks and make recommendations to Government on where further action may be necessary or justified.

Our 2015 report will provide advice on how to further strengthen adaptation policy and be the one of the first examples in the world of an independent national-level assessment of progress with adaptation.

We expect that our assessment will provide the Government with a number of recommendations and advice on how the NAP can be strengthened in coming years. As the report is required by law, the Government has to provide Parliament with a formal response.

A number of countries in Europe and other parts of the world are following our work and learning from our approach in preparing similar national-level assessments of progress with adaptation. We will also be undertaking an independent assessment of the Scottish Climate Change Adaptation Programme in 2016 at the request of Scottish Ministers.

7.5 Synthesising the evidence for the next CCRA

The ASC is required under the Climate Change Act to provide advice to the UK Government on the Climate Change Risk Assessment.

For the first CCRA (published in 2012), the Government asked the ASC to review the underlying methodology, its application and results, while the work to create the evidence report was undertaken by a consortium of contractors led by HR Wallingford.

For the 2017 risk assessment, the Government has requested that the ASC produce the independent evidence report that will be used to inform the Government's report to Parliament. The evidence report must be completed by July 2016.

Our CCRA evidence report will update the key risks and opportunities identified within the first CCRA, and seek to improve our understanding in areas where the first study was limited.

This next CCRA is planned to be a smaller, more focussed study than the first assessment in 2012.[6] It will focus on the following aspects:

- updating our understanding of risks and opportunities where new evidence has emerged;
- assessing how climate and socio-economic change interact, including how current adaptation plans affect the level of risk;
- the effects of climate change overseas on the UK; and
- the net impact of risks and opportunities when considered together.

We will make use of the extensive expertise available in the UK to undertake the evidence review.

We will call upon a selection of experts from academic institutions, Government departments and agencies, NGOs and consultancies to help us to undertake the assessment. The assessment will be based on the following themes:

- the latest climate science and understanding of risk;
- the rural economy and natural environment;
- infrastructure;
- people and the built environment;
- business;
- global security; and
- cross-cutting issues.

We issued a call for evidence earlier in 2014 to encourage organisations to submit evidence that they felt would be important for the new assessment. We had responses from over 50 organisations containing more than 200 papers. This evidence will form the basis of the

6 Defra intend to undertake another large review in future years.

report, which will be drafted by the ASC in partnership with nine lead contributors selected from a wide range of academic institutions and consultancies.

We will also use our indicator set to ensure that the baseline for the risk assessment is well grounded in evidence of current risks and climate impacts, and also incorporates the beneficial effects of the adaptation actions that we are monitoring.

Throughout summer and autumn 2014, the ASC will work up a detailed methodology and produce chapter narratives for each of the themes. Writing will take place for 12 months between winter 2014 and winter 2015. The final report will then be independently peer reviewed and published in July 2016.

7.6 Milestones in the ASC's work programme

The ASC will be working towards a number of key deliverables in 2015, 2016 and 2017 in order to meet our statutory duties. These are summarised in Table 7.1.

Table 7.1: Key milestones in the delivery of the ASC's statutory duties

Deliverable	Due
Consultation and call for evidence on the indicator set to be used to inform the ASC's assessment of the National Adaptation Programme.	July – September 2014
Request to Government Departments and other NAP action owners to provide the ASC with updates on the implementation of actions.	September – December 2014
Drafting of CCRA evidence report begins.	Winter 2014
Evaluation of the progress being made in addressing the priority risks and extent to which NAP actions are contributing to risk reduction.	January – March 2015
Follow up with NAP action owners and finalising statutory report.	April – June 2015
Statutory report to UK Parliament: First independent assessment of National Adaptation Programme.	July 2015
Draft CCRA evidence report provided to UK Government and devolved administrations for comments, plus peer review.	December 2015
Statutory advice to UK Government and devolved administrations: Final CCRA 2017 Evidence Report published.	July 2016
Statutory report to Scottish Parliament: Independent assessment of Scottish Climate Change Adaptation Programme.	September 2016
Statutory report to UK Parliament: Second independent assessment of National Adaptation Programme.	July 2017

References

Research commissioned by the Adaptation Sub-Committee

Amec (2014) for the Adaptation Sub-Committee. *Survey of a sample of development applications within flood risk areas*.

BRE (2014) for the Adaptation Sub-Committee. *The risks to housing from overheating.*

HR Wallingford (2014a) for the Adaptation Sub-Committee. *Preliminary Expected Annual Households Flooded (EAHF) analysis based on 2013 NaFRA household counts.*

HR Wallingford (2014b) for the Adaptation Sub-Committee. *Indicators to assess the resilience of health and emergency planning in England to the projected impacts of climate change.*

HR Wallingford (2014c) for the Adaptation Sub-Committee. *Indicators to assess the exposure of critical infrastructure in England to current and projected climate hazards.*

HR Wallingford (2014d) for the Adaptation Sub-Committee. *Approaches to account for current and future climate hazards. An assessment of applications for Nationally Important Infrastructure.*

Jenco Consultancy Ltd and Climate Resilience Ltd (2014) for the Adaptation Sub-Committee. *Research to ascertain the proportion of block paving sales in England that are permeable.*

University of Leeds (2014) for the Adaptation Sub-Committee. *Estimating global value chain impacts associated with UK consumption patterns*.

WRc (2014) for the Adaptation Sub-Committee. *Research to produce indicators to assess current and future risk to the chemicals, paper and mining and quarrying industries from reduced water availability, and potential for uptake of water management measures in these industries.*

These references are all available on the Committee on Climate Change Website:
http://www.theccc.org.uk/publications

General references

Achilles (2013). *Supply Chain Mapping.*

AEA (2010) for Defra. *Adapting the ICT Sector to the Impacts of Climate Change.*

AECOM (2012). *Investigation into overheating in homes: literature review.*

AEP, Association of Electricity Producers (2011). *Climate change risks and adaptation responses for UK electricity generation – a sector overview*, EnvC 162/11.

ASC, Adaptation Sub-Committee (2010). *How well prepared is the UK for climate change?*

ASC, Adaptation Sub-Committee (2011). *Adapting to climate change in the UK: measuring progress.*

ASC, Adaptation Sub-Committee (2012). *Climate Change: is the UK preparing for flooding and water scarcity?*

ASC, Adaptation Sub-Committee (2013a). *Managing the land in a changing climate.*

ASC, Adaptation Sub-Committee (2013b). *Advice on designing flood insurance proposals to encourage flood risk reduction. Letter to the Secretary of State for the Environment, Food and Rural Affairs.*

ASC, Adaptation Sub-Committee (2013c). *Policy note: The Government should use full flexibility under the CAP to maintain the current pace of habitat restoration.*

ASC, Adaptation Sub-Committee (2014a). *Policy note: flood and coastal erosion risk management spending.*

ASC, Adaptation Sub-Committee (2014b). *A sustainable, long – term plan for the Somerset Levels and Moors. Letter to the Secretary of State for the Environment, Food and Rural Affairs.*

ASC, Adaptation Sub-Committee (2014c). *Consultation on water abstraction reforms – the case for Water Shares. Letter to the Parliamentary Under-Secretary of State for the Environment, Food and Rural Affairs.*

Asda (2014). *The Challenge of a Changing Climate.*

Atkins (2013) for the Highways Agency. *Economics of Climate Change Adaptation and Risks, Final report.*

Audit Commission (2013). *Tough Times. Councils' responses to financial challenges from 2010/11 to 2013/14.*

Baglee, A; Haworth, A; Anastasi, S. (2012). *Climate Change Risk Assessment for the Business, Industry and Services sector.*

Baxter (2005). *The east coast big flood, 31st January – 1st February 1953: a summary of the human disaster.* Philosophical Transaction of the Royal Society, 363.

Beizaee, A; Lomas, K; Firth, S. (2013). *National survey of summertime temperatures and overheating risk in English homes.* Building and Environment 65: 1-17.

Birmigham Airport (2011). *Climate Change Adaptation Reporting Power report.*

BIS, Department for Business, Innovation & Skills (2011). *Business Population Estimates 2011.*

BIS, Department for Business, Innovation & Skills (2013). *Business population estimates for the UK and regions 2013: dataset.*

Bloom, D; Canning, D. (2008). *Population health and economic growth.* Commission on growth and development working paper no.24

Bowler, D; Buyung-Ali, L; Knight, T; Pullin, A. (2010). *Urban greening to cool towns and cities: A systematic review of the empirical evidence.* Landscape and Urban Planning 97, 147–155.

Boyson, C; Taylor, S; Page, L. (2014). *The National Heatwave Plan – A Brief Evaluation of Issues for Frontline Health Staff.* PLOS Currents Disasters, 2014 Jan 13, Edition 1.

Braga, A; Zanobetti, A; Schwartz, J. (2001). *The time course of weather-related deaths.* Epidemiology, 12:662–667.

BRE, Building Research Establishment (2012). *The Government's standard assessment procedure for energy rating of dwellings.*

British Geological Survey (2014). *Shrink-swell, Geosure: National Ground Stability Data.*

BSI Group (2014). *Adapting to climate change using your business continuity management system.*

Business Continuity Institute (2013). *Supply Chain Resilience 2013.*

Byers, E; Hall, J; Amezaga, J. (2014). *Electricity generation and cooling water use: UK pathways to 2050.* Global Environmental Change 2014, 25, 16-30.

Cabinet Office (2010). *Strategic Framework and Policy Statement on Improving the Resilience of Critical Infrastructure to Disruption from Natural Hazards.*

Cabinet Office (2011). *Keeping the Country Running: A Guide to improving the resilience of critical infrastructure and essential services.*

Carbon Dioxide Information Analysis Center (2010). *Global Fossil-Fuel CO_2 Emissions.* Oak Ridge National Laboratory, U.S. Department of Energy.

Carbon Dioxide Information Analysis Center (2013). *Global Carbon Budget 2013.* Oak Ridge National Laboratory, U.S. Department of Energy.

Carbon Disclosure Project (2013). *Water Project.*

KPMG (2013) for the Confederation of British Industry. *Connect More, CBI/KPMG Infrastructure survey.*

CCC, Committee on Climate Change (2013a). *Fourth Carbon Budget Review – part 1: assessment of climate risk and the international response.*

CCC, Committee on Climate Change (2013b). *Meeting carbon budgets: 2013 progress report to Parliament.*

CCC, Committee on Climate Change (2014). *Meeting carbon budgets: 2014 progress report to Parliament.*

Chartered Institute of Purchasing and Supply (2014). *CIPS Risk Index.*

Chartered Management Institute (2013). *Weathering the Storm. The 2013 Business Continuity Management Survey.*

Chini, N; Stansbya, P; Leakea, J; Wolfa, J; Roberts-Jonesa, J; Lowea, J. (2010). *The impact of sea level rise and climate change on inshore wave climate: A case study for East Anglia (UK),* Coastal Engineering Volume 57, Issues 11–12

Climate Change Vulnerability Index (2011). *Quantifying Vulnerability to Climate Change: Implications for Adaptation Assistance.*

CIBSE (2013). *TM52 – The Limits of Thermal Comfort: Avoiding Overheating in European Buildings.*

ClimateNexus (2013). *Jet streams + climate change: a science backgrounder.*

DARA (2012). *Climate Vulnerability Monitor.*

DCLG, Department for Communities and Local Government (2012). *National Planning Policy Framework.*

DCLG, Department for Communities and Local Government (2013). *Fire statistics monitor: England, April to September 2013.*

DECC, Department for Energy and Climate Change (2012). *Final stage impact assessment for the Green Deal and Energy Company Obligation.*

Defra, Department for Environment, Food and Rural Affairs (2008). *Comprehensive spending review (CSR) 2007 – flood and coastal erosion risk management allocations.*

Defra, Department for Environment, Food and Rural Affairs (2010). *Future funding for flood and coastal erosion risk management – consultation document.*

Defra, Department for Environment, Food and Rural Affairs (2011a). *Policy statement: flood and coastal resilience partnership funding.*

Defra, Department for Environment, Food and Rural Affairs (2011b). *Future flood and water management legislation: Government response to the Committee's First Report of Session 2010-11 – Environment, Food and Rural Affairs Committee.*

Defra, Department for Environment, Food and Rural Affairs (2011c). *Synthesis of the independent studies commissioned by the Government's Infrastructure & Adaptation Project.*

Defra, Department for Environment, Food and Rural Affairs (2012a). *UK Climate Change Risk Assessment: Government report.*

Defra,Department for Environment, Food and Rural Affairs (2012b). *Developing a joint approach to improving flood awareness and safety at caravan and camping sites in England and Wales.*

Defra, Department for Environment, Food and Rural Affairs (2013a). *Securing the future availability and affordability of home insurance in areas of flood risk.*

Defra, Department for Environment, Food and Rural Affairs (2013b). *Common Agricultural Policy reform: implementation in England.*

Defra, Department for Environment, Food and Rural Affairs (2013c). *Making the Most of Every Drop: Consultation on Reforming the Water Abstraction Management System.*

Defra, Department for Environment, Food and Rural Affairs (2013d). *Economics of Climate Resilience.*

Defra, Department for Environment, Food and Rural Affairs (2013e). *Programme on Adaptation Preparedness and Risk (PREPARE).*

Defra, Department for Environment, Food and Rural Affairs (2013f). *Water quality and abstraction statistics.*

Defra, Department for Environment, Food and Rural Affairs (2014a). *Funding flood and coastal erosion risk management in England.*

Defra, Department for Environment, Food and Rural Affairs (2014b). *Flood and Coastal Erosion Resilience Partnership Funding Evaluation – Final report.*

Defra, Department for Environment, Food and Rural Affairs (2014c). *Briefing note: Water Bill Sustainable Development and Resilience Duties.*

Department of Health (2012). *An Outcomes Strategy for Chronic Obstructive Pulmonary Disease (COPD) and Asthma in England.*

Detica and BAE Systems (2013) for Ofcom. *Security and Resilience Vulnerabilities in the UK's Telecoms Networks.*

Diacon, S. (2013) for Defra. *Independent Review of Flood Insurance Analysis.*

DOENI, Department of the Environment, Northern Ireland (2014). *Northern Ireland Climate Change Adaptation Programme.*

Eddington, R. (2006). *The Eddington Transport Study, The case for action: Sir Rod Eddington's advice to Government,* HM Treasury.

Electronic Communications-Resilience and Response Group (2014). *Climate Change Adaptation Report for Telecoms Infrastructure.*

Element Energy and Imperial College London (2013) for the Committee on Climate Change. *Infrastructure in a low-carbon energy system to 2030.*

ENA, Energy Networks Association (2006). *Engineering Technical Note 132. Improving network performance under abnormal weather conditions by use of a risk based approach to vegetation management near electric overhead lines.*

ENA, Energy Networks Association (2009). *Engineering Technical Note 138. Resilience to flooding of Grid and Primary Substations.*

ENA, Energy Networks Association (2011). *Engineering Report 1. Electricity networks climate change adaptation report.*

Environment Agency (2008). *Environment Agency Flood and coastal erosion risk management appraisal guidance (FCERM-AG).*

Environment Agency (2009). *Investing for the future. Flood and coastal risk management in England – a long-term investment strategy.*

Environment Agency (2010). *The costs of the summer 2007 floods in England.*

Environment Agency (2013a). *Current and future water availability – addendum. A refresh of the Case for Change analysis.*

Environment Agency (2013b). *Assessing and managing climate change risks in supply chains.*

Environment Agency (2013c). *How to Prepare a Climate Change Action Plan – Food and Drink Sector Guidance.*

Environment Agency (2013d). *Managing flood and coastal erosion risks in England: 1 April 2012 to 31 March 2013.*

Environment Agency (2013e). *What's in your backyard?*

Environment Agency (2014a). *Programme of flood and coastal erosion risk management schemes.*

Environment Agency (2014b). *Corporate Scorecard 2013-14 Appendix One, Quarter Four, January – March 2014.*

Environment, Food and Rural Affairs Committee (2014). *Oral evidence: Winter Floods.*

Environmental Change Institute, University of Oxford (2014). *Global warming makes very wet winters 'more likely'.*

European Commission (2012). *Mandate M/515 for amending existing Eurocodes and extending the scope of structural Eurocodes.*

Fowler, T; Southgate, R; Waite, T; Harrell, R; Kovats, S; Bone, A; Doyle, Y; Murray, V. (2014). *Excess winter deaths in Europe: a multi-country descriptive analysis.* European Journal of Public Health.

GAIN index (2012). *Notre Dame Global Adaptation Index (ND-GAIN).*

Gatwick Airport Limited (2011). *Climate Change Adaptation Reporting Power report.*

Gatwick Airport Media Centre (2014). *London Gatwick sets aside £30 million as a resilience fund following recommendations of review into Christmas Eve flooding,* press release on 26 February 2014.

GHK (2010) for Defra. *Opportunities for UK business from climate change adaptation.*

Gill, S; Handley, J; Ennos, A; Pauleit, S. (2007). *Adapting Cities for Climate Change: The Role of the Green Infrastructure.* Built Environment 33 (1).

Good Homes Alliance (2014). *Preventing overheating: Investigating and reporting on the scale of overheating in England, including common causes and an overview of remediation techniques.*

Government Office for Science (2011). *International dimensions of climate change.*

Grainger, A; Achutan, K. (2014). *Port resilience: a primer.*

Grantham Research Institute at the London School of Economics (Forthcoming a). *Reflections on the current understanding of multi-national corporations and climate adaptation.*

Grantham Research Institute at the London School of Economics (Forthcoming b). *Invention and international diffusion of water conservation and availability technologies: evidence from patent data.*

Hajat, S; Armstrong, B; Gouveia, N; Wilkinson, P. (2005). *Mortality displacement of heat-related deaths: a comparison of Delhi, São Paulo, and London.* Epidemiology 16(5),613-20.

Hajat, S; Vardoulakis, S; Heaviside, C; Eggen, B (2013). *Climate change effects on human health: projections on temperature-related mortality for the UK during the 2020s, 2050s and 2080s.* J Epidemiol Community Health, 0:1-8.

Halcrow (2008) for Ofwat. *Asset Resilience to Flood Hazards: Development of an analytical framework.*

Hames, D; Vardoulakis, S. (2012). *Climate Change Risk Assessment for the health sector (UK Climate Change Risk Assessment).*

Health Protection Agency (2007). *Evaluation of the Department of Health National Heatwave Plan.*

Health Protection Agency (2012). *Health effects of climate change in the UK.* Sotiris Vardoulakis and Clare Heaviside (editors).

Healy, J. (2003) *Excess winter mortality in Europe: a cross-country analysis identifying key risk factors.* Journal of Epidemiology and Community Health,57:784–789.

Heathrow Airport Limited (2010). *Towards a sustainable Heathrow, 2010 Sustainability action plan summary.*

Heathrow Airport Limited (2011). *Climate Change Adaptation Reporting Power report.*

Heathrow Airport Limited (2013). *Heathrow Strategic Capital Business Plan 2013.*

Highways Agency (2011). *Climate Change Risk Assessment.*

HM Government (2011). *Climate-resilient infrastructure: Preparing for a changing climate.*

HM Government (2013). *The National Adaptation Programme: Making the country resilient to a changing climate.*

HM Treasury (2010). *National Infrastructure Plan.*

HM Treasury (2013a). *National Infrastructure Plan.*

HM Treasury (2013b). *Investing in Britain's Future.*

HM Treasury (2014). *National Infrastructure Plan: finance update.*

HS2 (2013). *London- West Midlands Environmental Statement. Volume 3 Route-wide effects.*

ICE (2009). *The State of the Nation: Low-Carbon infrastructure.*

IPCC, United Nations Intergovernmental Panel on Climate Change (2012). *Summary for Policymakers. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation.*

IPCC, United Nations Intergovernmental Panel on Climate Change (2013a). *Summary for Policymakers: The Physical Science Basis. Contribution of Working Group I to the IPCC Fifth Assessment Report.*

IPCC, United Nations Intergovernmental Panel on Climate Change (2013b).*Technical Summary: The Physical Science Basis. Contribution of Working Group I to the IPCC Fifth Assessment Report.*

IPCC, United Nations Intergovernmental Panel on Climate Change (2014a). *Summary for Policymakers: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the IPCC Fifth Assessment Report.*

IPCC, United Nations Intergovernmental Panel on Climate Change (2014b). *Summary for Policymakers: Mitigation of Climate Change. Contribution of Working Group III to the IPCC Fifth Assessment Report.*

IPCC, United Nations Intergovernmental Panel on Climate Change (2014c). *Chapter 7. Food Security and Food Production Systems.*

Jacob, D; Petersen, J; Bastian, E; Alias, A; Christensen, O; Bouwer, L; Braun, A; Colette, A; Deque, M; Georgievski, G; Georgopoulou, E; Gobiet, A; Menut, L; Nikulin, G; Haensler, A; Hempelmann, N; Jones, C; Keuler, K; Kovats, RS; Kroner, N; Kotlarski, S; Kriegsmann, A; Martin, E; Van Meijgaard, E; Moseley, C; Pfeifer, S; Preuschmann, S; Radermacher, C; Radtke, K; Rechid, D; Rounsevell, M; Samuelsson, M; Somot, S; Soussana, J; Teichmann, C; Valentini, R; Vautard, R; Weber, B; Yiou, P. (2014). *Euro-Cordex: new high-resolution climate change projections for European impact research.* Regional Environmental Change (2014) 14:563–578

Jenkins, G; Perry, M; and Prior, M. (2008). *The climate of the United Kingdom and recent trends.* Met Office Hadley Centre, Exeter, UK.

Jenkins, K; Hall, J; Vassilis, G; Kilsby, C; McCarthy, M; Goodess, C; Smith, D; Malleson, N; and Birkin, M. (2014). *Probabilistic spatial risk assessment of heat impacts and adaptations for London.* Climatic Change.

Jude, S; Weatherhead, K; Wherry, M; Farewell, T. (2013). *OpenReach Climate Change Summary.*

Kay, A; Crooks, S; Pall, P; and Stone, D. (2011). *Attribution of Autumn/Winter 2000 flood risk in England to anthropogenic climate change: A catchment-based study.*

King's Fund (2013). *Transforming our health care system: ten priorities for commissioners.*

K-Matrix (2012) for BIS. *Adaptation and resilience to climate change (ARCC): Report for 2010/11.*

K-Matrix (2013) for BIS. *Adaptation and resilience to climate change (ARCC): Report for 2011/12.*

Kovats, R and Hajat, S. (2008). *Heat stress and public health: a critical review.* Annual Review of Public Health, 29:9.1–9.15.

Kovats, R; Hajat, S; Wilkinson, P. (2004). *Contrasting patterns of mortality and hospital admissions during hot weather and heat waves in Greater London, UK*. Occupational and Environmental Medicine, 61:893–898.

Landeg, O. and Lawson, J. (2014). *Effective flood resilience in health providers: Flooding at a major NHS Blood and Transplant facility.*

Local Government Association (2012). *Flood risk management survey 2012.*

Local Government Association (2013). *Future funding outlook for councils from 2010/11 to 2019/20.*

London Luton Airport (2011). *Climate Change Adaptation Reporting Power report.*

London Stansted Airport (2011). *Climate Change Adaptation Reporting Power report.*

Manchester Airport Group (2011). *Climate Change Adaptation Reporting Power report for East Midlands Airport and Manchester Airport.*

Mavrogianni, A; Wilkinson, P; Davies, M; Biddulph, P; Oikonomou, E. (2012). *Building characteristics as determinants of propensity to high indoor summer temperatures in London dwellings*. Building and Environment 55, 117-130.

McMillan D. (2014). *Disruption at Gatwick Airport – Christmas Eve 2013: Report to the Board of Gatwick Airport Limited.*

Met Office (2012). *Assessing the potential impact of climate change on the UK's electricity network.*

Met Office (2014a). *The Recent Storms and Floods in the UK.*

Met Office (2014b). *Drivers and impacts of the seasonal weather in the UK.*

Milojevic, A; Armstrong, B; Kovats, R; Butler, B; Hayes, E; Leonardi, G; Murray, V; Wilkinson, P. (2011). *Long-term effects of flooding on mortality in England and Wales, 1994-2005: controlled interrupted time-series analysis.* Environmental Health 2011, 10:11.

Mott McDonald (2012) for Ofwat. *Resilience-outcomes focused regulation, Principles for resilience planning.*

Murphy, J; Sexton, D; Jenkins, G; Boorman, P; Booth, B; Brown, C; Clark, R; Collins, M; Harris, G; Kendon, E; Betts, R; Brown, S; Howard, T; Humphrey, K; McCarthy, M; McDonald, R; Stephens, A; Wallace, C; Warren, R; Wilby, R; Wood, R. (2009). *UK Climate Projections Science Report: Climate change projections.* Met Office Hadley Centre, Exeter.

NAO, National Audit Office (2011). *Flood risk management in England.*

NAO, National Audit Office (2013). *Planning for economic infrastructure.*

Nestlé (date unknown). *Nestlé Helps Farmers Prepare for Climate Change.*

Network Rail (2010). *Annual Return for 2010: Moving Ahead. Investing in the Future.*

Network Rail (2011). *Annual Return 2011: Helping Britain Run Better.*

Network Rail (2012). *Annual Return 2012: Driving Economic Growth.*

Network Rail (2013a). *Annual Return 2013: A Technology-Enabled Future.*

Network Rail (2013b). *Strategic Business Plan for England and Wales.*

Network Rail (2014). *Network Rail's Delivery Plan for Control Period 5.*

Newcastle City Council (2013). *The Newburn culvert collapse and citywide flooding; a review of extreme events in Newcastle in 2012.*

NHBC (2012). *Overheating in new homes: a review of the evidence.*

NHBC (2013). *New homes statistics review Q1 2013.*

O'Neill, M; Zanobetti, A; Schwartz, J. (2005). *Disparities by race in heat-related mortality in four US cities: the role of air conditioning prevalence.* Journal of Urban Health 82(2), 191-7.

OECD (2013). *How's life? 2013: Measuring well-being, OECD publishing.*

Ofcom (2010). *Climate Change Adaptation: Impact on our functions, a response to the Secretary of State's Direction of 31 March 2010.*

Ofcom (2013a). *Infrastructure report: 2013 update.*

Ofcom (2013b). *Updating Ofcom's guidance on network security- Call for inputs.*

Office of Science and Technology (2004). *Foresight Future Flooding.*

Ofgem (2012). *Electricity Distribution Annual Report for 2010-11.*

Ofgem (2013). *Electricity Capacity Assessment Report 2013.*

Ofwat (2008). *Setting price limits for 2010-15: Framework and approach.*

Ofwat (2009). *Future water and sewerage charges 2010-15: final determinations.*

Ofwat (2010). *Prevention, protection and preparedness – how should resilient supplies be achieved? Focus report and detailed note.*

Ofwat (2013). *Companies' updated cost and performance (August submission) data.*

ONS, Office for National Statistics (2012). *Deaths registered in England and Wales.*

ONS, Office for National Statistics (2013a). *Expenditure on healthcare in the UK: 2011.*

ONS, Office for National Statistics (2013b). *Blue Book.*

ONS, Office for National Statistics (2014a). *Business Structure Database (BSD).*

ONS, Office for National Statistics (2014b). *National Population Projections, 2012-Based Projections Release.*

ORR, Office for Rail Regulation (2013a). *Maintenance underspends and deferred renewals contributing to delays on the railways, Network Rail Monitor Q2 2013-14 press release.*

ORR, Office for Rail Regulation (2013b). *Periodic Review 2013: Final determination of Network Rail's outputs and funding for 2014-19.*

ORR, Office for Rail Regulation (2014). *Network Rail Monitor. Quarter 3 of Year 5 of Control Period 4.*

Pall, P; Aina, T; Stone, D; Stott, P; Nozawa, T; Hilberts, A; Lohmann, D; Allen, M. (2011). *Anthropogenic greenhouse gas contribution to flood risk in England and Wales in autumn 2000.*

Paranjothy, S; Gallacher, J; Amlôt, R; Rubin, G; Page, L; Baxter, T; Wight, J; Kirrage, D; McNaught, R; Palmer, SR (2011). *Psychosocial impact of the summer 2007 floods in England.* BMC Public Health 2011, 11:145.

Parsons Brinckerhoff (2012) for the Environment Agency. *Water Demand for Carbon Capture and Storage (CCS).*

Pitt Review (2008a). *Learning lessons from the 2007 floods.*

Pitt Review (2008b) *An update of the Foresight Future Flooding 2004 qualitative risk analysis.*

Public Health England (2013a). *Cold weather plan for England; protecting health and reducing harm from cold weather.*

Public Health England (2013b). *Heatwave plan for England; protecting health and reducing harm from severe heat and heatwaves.*

PwC (2008). *From vulnerable to valuable: how integrity can transform a supply chain.*

PwC (2010). *Adapting to climate change in the infrastructure sectors, Maintaining robust and resilient infrastructure systems in the energy, transport, water and ICT sectors.*

PwC (2013a). *International Threats and Opportunities from Climate Change for the UK.*

PwC (2013b). *CDP 2013: are FTSE 350 companies prepared for the impacts of climate change?*

Ramsbottom, D; Sayers, P; Panzeri, M. (2012). *Climate change risk assessment for the flood sector (UK Climate Change Risk Assessment).*

RIBA, Royal Institute of British Architects (date unknown). *Climate change briefing: executive summary.*

Scottish Government (2014). *Scottish Climate Change Adaptation Programme.*

Scripps Institution of Oceanography (2013). *Carbon Dioxide at Mauna Loa Observatory reaches new milestone: Tops 400 ppm.*

Short, C; Lomas, K; Giridharan, R; Fair, A. (2012). *Building resilience to overheating into 1960's UK hospital buildings within the constraint of the national carbon reduction target: Adaptive strategies.* Building and Environment.

Smith, C. and Levermore, G. (2008). *Designing urban spaces and buildings to improve sustainability and quality of life in a warmer world.* Energy Policy 36, 4558–4562.

Stedman, JR (2004). *The predicted number of air pollution related deaths in the UK during the August 2003 heatwave.* Atmospheric Environment 38 (1087-1090).

Taylor, A; Bruine de Bruin, W; Dessai, S (2014). *Climate Change Beliefs and Perceptions of Weather-Related Changes in the United Kingdom.* Risk Analysts.

Thornes JE (2014). *The Impact of Extreme Weather and Climate Change on Ambulance Incidents and Response Times in London, Public Health England Report for the London Ambulance Service.*

Unilever (2010). *Our Water Strategy.*

United Nations International Strategy for Disaster Reduction, European Commission, OECD (2013). *UK peer review-building resilience to disasters: implementation of the Hyogo Framework for Action (2005-2015).*

Volker, S; Baumeister, H; Classen, T; Hornberg, C; Kistemann, T. (2013). *Evidence for the temperature-mitigating capacity of urban blue space – a health geographic perspective.* Erdkunde 67:4 (355-371).

Walker Institute (2010). *London's urban heat island. Research highlights 2010.*

Watts, G; Battarbee, R; Bloomfield, J; Crossman, J; Daccache, A; Durance, I; Elliot, J; Garner, G; Hannaford, J; Hannah, D; Hess, T; Jackson, CR; Kay, A; Kernan, M; Knox, J; Mackay, J; Monteith, D; Ormerod, S; Rance, J; Stuart, M; Wade, A; Wade, S; Weatherhead, E; Whitehead, P; Wilby, R. (2013). *Climate change and water in the UK – past changes and future prospects.*

Welsh Government (2011). *Adaptation Delivery Plan: Climate Change Strategy for Wales.*

World Bank Data Portal (2014). *World and UK GDP Growth.*

World Economic Forum (2013). *Building Resilience in Supply Chains.*

WrC (2014). *Sewerage management and recovery in small communities, Technical note.*

Zurich Insurance (2013). *Strategic risk: do not forget your supply chain!*