Evidence for the third UK Climate Change Risk Assessment (CCRA3)

Summary for England

Author: Sustainability West Midlands
Image: Angel of the North, Gateshead
Summary of climate risks and opportunities for England

The Independent Assessment used to help inform the third UK Climate Change Risk Assessment (CCRA3) assesses 61 risks and opportunities from climate change to England, including to business, infrastructure, housing, the natural environment, our health and risks from the impacts of climate change internationally. Risks categorised as “More action needed” and “Further investigation” are more urgent than “Watching brief” and “Sustain current action.” Of these 61 risks and opportunities, more action is needed in England now to address 34 of them, with sustaining current action only deemed appropriate in four cases. Of the 61, six issues are deemed to be both a risk and opportunity, four of which are associated with the natural environment and each of these require more action or further investigation. There are also eight opportunities that could arise from climate change in England, with half of these also related to the natural environment.

In total, 23 risks from climate change in England have increased in urgency score since the previous CCRA five years ago; these are summarised at the start of each section of this report. Only one risk has decreased in urgency score since the previous CCRA. There are also some new risks that were not covered in CCRA2.

When compared to the other UK nations, there is increasing evidence that risks from extreme heat are greater in England than elsewhere, especially in the south-east, affecting health, infrastructure and the natural environment. The potential for water scarcity and subsidence also appears to be a greater issue here, again with south-east England being at greatest risk. Flooding (coastal and inland), storms, lightning and high winds also play their part in the present and future climate related risks across the whole of England.

In summary, risks in England that have a high future magnitude score and where more action is required now to address them, after considering any existing adaptation responses, include the following:

- The impacts of climate change on the natural environment, including terrestrial, freshwater, coastal and marine species, forests and agriculture.
- An increase in the range, quantities and consequences of pests, pathogens and invasive species, negatively affecting terrestrial, freshwater and marine priority habitats species, forestry and agriculture.
- The risk of climate change impacts, especially more frequent flooding and coastal erosion, causing damage to our infrastructure services, including energy, transport, water and Information and Communication Technologies (ICT).
- A reduction in public water supplies due to increasing periods of water scarcity.
- The impact of extreme temperatures, high winds and lightning on the transport network.
- The impact of increasing high temperatures on people’s health and wellbeing and changes in household energy demand due to seasonal temperature changes.
- Increased severity and frequency of flooding of homes, communities and businesses.
- The viability of coastal communities and the impact on coastal businesses due to sea level rise, coastal flooding and erosion.
- Disruption to the delivery of health and social care services due to a greater frequency of extreme weather.
- Damage to our cultural heritage assets as a result of temperature, precipitation, groundwater and landscape changes.
- Impacts internationally that may affect the UK, such as risks to food availability, safety and security, risks to international law and governance from climate change that will affect the UK, international trade routes, public health and the multiplication of risks across systems and geographies.

The rest of this report outlines what the risks and opportunities are in England associated with climate change, their urgency scores, the evidence for this and the benefits for further adaptation action in the next five years.
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1. Introduction

About

This report is a summary of the implications for England of the evidence for the third and latest UK Climate Change Risk Assessment (CCRA3) Technical Report. The UK Government is required by the Climate Change Act 2008 to conduct such an assessment every five years to inform the National Adaptation Plans for England, Scotland, Wales and Northern Ireland. This is the third such national assessment and the second time the Government has asked its independent advisers, the Climate Change Committee to prepare the initial Independent Assessment. The timescale, process and outputs that form the CCRA3 Technical Report are illustrated on the following page. The process is complex – involving over 450 experts - and has produced a large volume of information which is why a range of materials are provided alongside the CCRA3 Technical Report to summarise the results spatially and thematically. An Advice Report is also provided as part of the Independent Assessment to give the formal advice from the Committee to the Government, which is then required to publish its own assessment (the CCRA3 Government Report) in 2022.

61 specific risks and opportunities were assessed in detail in the Technical Report and each one given an urgency score. As climate risks and adaptation actions vary across the UK, the urgency scores also vary which is why summaries have been produced for England, Scotland, Wales and Northern Ireland to capture the risk scores and highlight the differences accordingly. The summary highlights the most urgent risks, those which require more action taking and/or require more investigation and the less urgent risks where current action is sufficient or where a watching brief is required.

This report does not provide a detailed assessment of policy, and readers wanting further information about this for each risk should consult the relevant technical chapter. This summary provides signposting showing where you can find this information at the end of each risk. These summaries should also be used as a guide to the overall CCRA3 Technical Report findings rather than being seen as ‘the risk assessment’ for each UK nation. They summarise the nature of each risk or opportunity rather than what specific responses should be taken forward.

Audience

The main audience for this summary is the UK Government, its departments and their agencies with responsibilities for England. It may also be of interest to a much wider audience across the public, private and voluntary sectors where the changing climate is likely to affect plans, projects and operations increasingly over time.
Overview of CCRA3 process, timescale and outputs:

**At a glance**

The Third UK Climate Change Risk Assessment 2023

Defra commissions CCC to develop evidence for CCRA3

Research informs Technical Chapters

Translation and communication of CCRA3 Evidence Report

Contractor for national summaries and briefings: SWM project team

Suite of CCRA3 Evidence Report documents published

Sent to UK Government and the three Devolved Administrations

Government reports to Parliament on the latest climate risks to the UK since CCRA2 2017 and the updated plans for managing them
Application

This summary should be used to inform the climate change adaptation plans of the UK Government and be used to help Government understand how the changing climate is likely to impact on its many other programmes and investments so that appropriate adaptation measures can be integrated as required. Local government and other bodies operating at a local level in England may also find this summary helpful in producing or revising their own local climate risk assessments or climate resilience plans.

The context for climate change adaptation in England


The CCRA seeks to answer the question, ‘based on the latest understanding of current, and future, climate risks/opportunities, vulnerability and adaptation, what should the priorities be for the next UK National Adaptation Programme and adaptation programmes of the Devolved Administrations?’

To answer this question, each of the risks is assessed in a three-step urgency scoring process:

- What is the current and future level of risk?
- To what extent is the risk going to be managed?
- Are there benefits of further action in the next five years, over and above what is already planned?

The analysis for each risk or opportunity is based on the evidence available to the team of authors that worked on each [technical chapter](https://environment比较多的 lie.gov.uk/business-government/business/transport-and-energy/environmental-statistics-and-reports/technical-chapters) and supplemented by additional [research projects](https://environment比较多的 lie.gov.uk/business-government/business/transport-and-energy/environmental-statistics-and-reports/research-projects) commissioned specifically for the CCRA3 Technical Report. Authors of the Technical Report have been supported to do this through a series of consultations and workshops on risks, and reviewing the draft technical chapters and factsheets with officials and organisations in England. Chapter authors have also been supported to reflect the specific contexts in each devolved administration through research and expert judgement commissioned through the Climate Change Committee.
Based on the evidence available, supplemented by expert judgement where necessary, each risk has been assigned one of four urgency categories as follows (see ‘Method’ technical chapter for more information):

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
</table>
| More action needed      | New, stronger or different Government action, whether policies, implementation activities or enabling environment for adaptation, over and above those already planned, are beneficial in the next five years to reduce climate risks or take advantage of opportunities. This will include different responses according to the nature of the risks and the type of adaptation:  
  - Addressing current and near-term risks or opportunities with low and no-regret options (implementing activities or building capacity).  
  - Integrating climate change in near-term decisions with a long life-time or lock-in.  
  - Early adaptation for decisions with long lead-times or where early planning is needed as part of adaptive management. |
| Further investigation   | On the basis of available information, it is not known if more action is needed or not. More evidence is urgently needed to fill significant gaps or reduce the uncertainty in the current level of understanding in order to assess the need for additional action. **Note:** The category of ‘Research Priority’ in CCRA2 has been replaced with ‘Further investigation’ in CCRA3. This is because of some confusion following CCRA2 that ‘Research Priority’ only denoted that more research was needed, when in fact the urgency is to establish the extent to which further adaptation is required. |
| Sustain current action  | Current or planned levels of activity are appropriate, but continued implementation of these policies or plans is needed to ensure that the risk or opportunity continues to be managed in the future. |
| Watching brief          | The evidence in these areas should be kept under review, with continuous monitoring of risk levels and adaptation activity (or the potential for opportunities and adaptation) so that further action can be taken if necessary. |
The methodology and process of the CCRA3 Technical Report risk assessment process is as follows:

1. What is the current and future level of risk/opportunity?

   - High, medium or unknown

2. Is the risk/opportunity going to be being managed, taking into account government commitments and non-governmental adaptation?

   - Significant adaptation shortfall (barriers / failures)

3. Are there benefits to further action in the next five years, over and above what is already planned?

   - Yes: More action needed, Further investigation
     - More urgent
   - No: Sustain current action, Watching brief
     - Less urgent

Supported by capacity building
2. Climate change in England

How is the climate in England already changing?

<table>
<thead>
<tr>
<th>Variable</th>
<th>Observed change in England</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average annual temperature</td>
<td>Increase of 0.9°C from mid-1970s to mid-2010s</td>
</tr>
<tr>
<td>Annual mean rainfall</td>
<td>Increase of 4.5% from mid-1970s to mid-2010s</td>
</tr>
<tr>
<td>Sunshine</td>
<td>Increase of 9.2% from mid-1970s to mid-2010s</td>
</tr>
<tr>
<td>Weather extremes</td>
<td>UK-wide increase in extreme heat events</td>
</tr>
<tr>
<td></td>
<td>Little evidence yet on changes in extreme rainfall</td>
</tr>
<tr>
<td>Sea level rise</td>
<td>UK-wide increase of ~1.4mm per year since 1901 (16cm to date)</td>
</tr>
</tbody>
</table>

**Temperature**

Across England, average annual land temperature in the decade 2010-2019 was 0.9°C warmer than in the period of mid 1970s to mid-2010s, up to 9.5°C from 8.6°C. Based on the Central England Temperature record, the 21st century has so far been warmer overall than any of the previous three centuries, reinforcing the attribution of UK warming to increasing greenhouse gases (GHGs). Most notable is the greater incidence of hot summer maximum temperatures in England. In July 2019, the UK recorded its highest daily maximum temperature to date which occurred in Cambridge, when the temperature peaked at 38.7°C.

**Rainfall**

There has been a small observed increase in annual mean rainfall in recent decades. Between the period of mid 1970s to mid-2010s and 2010-2019 there was an increase of 4.5%, from an average of 827mm to 864mm. The increases, while modest, still need to be taken seriously given that the National Flood and Coastal Erosion Risk Management Strategy for England, published in 2020, states that 5.2 million homes and businesses are at risk from flooding.

**Sunshine hours**

A clear trend is emerging for increasing sunshine hours for all parts of the UK including England, where there was a 9.2% increase in average sunshine hours from the period of mid 1970s to mid-2010s to 2010-2019. Spring 2020 was the sunniest on record for all UK countries in a series stretching back to 1929.

**Weather extremes**

The latest climate science suggests that the effects of climate change on daily extreme rainfall events are only just beginning to emerge. However, the evidence of extreme maximum summer temperatures is becoming clearer, as
reflected by how many of the UK’s record extreme monthly temperatures have been set in the most recent decade along with a tendency for more heatwaves in London in recent years.

**Sea level rise**

Observed sea level rise is also difficult to determine for each country as a whole. A UK-wide sea level index suggests that sea level has risen by between 1.2 and 1.6mm per year since 1901. National variations are projected in future as outlined in the following section.

**How could the climate change in future?**

The changes in climate that we are already experiencing are projected to continue and intensify. In the second half of the century, the amount of change that occurs will depend strongly on how successful we are in reducing greenhouse gas emissions globally.

The latest set of projected changes in climate for England come from the 2018 UK Climate Projections as shown in the table below

<table>
<thead>
<tr>
<th></th>
<th>2050s RCP2.6 (50th percentile)</th>
<th>2050s RCP6.0 (50th percentile)</th>
<th>2080s RCP2.6 (50th percentile)</th>
<th>2080s RCP6.0 (50th percentile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Temperature</td>
<td>+1.3°C</td>
<td>+1.2°C</td>
<td>+1.4°C</td>
<td>+2.4°C</td>
</tr>
<tr>
<td>Summer Rainfall</td>
<td>-15%</td>
<td>-14%</td>
<td>-15%</td>
<td>-22%</td>
</tr>
<tr>
<td>Winter Rainfall</td>
<td>+6%</td>
<td>+6%</td>
<td>+8%</td>
<td>+13%</td>
</tr>
<tr>
<td>Sea level rise (London)</td>
<td>+23cm</td>
<td>+29cm*</td>
<td>+45cm</td>
<td>+78cm*</td>
</tr>
</tbody>
</table>

**Temperature**

Annual temperatures in England are expected to rise between approximately 1.3°C by the 2050s and between 1.4 and 2.4°C by the 2080s from a 1981-2000 baseline, based on the methodology set out above and depending on global efforts to reduce greenhouse gas emissions between now and then. Risks associated with rising temperatures, such as

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1 These values are taken from the UKCP18 probabilistic projections and represent a central (median) estimate of 30-year average change in each variable from a 1981-2000 baseline. Two emissions scenarios are used; RCP2.6 (roughly equivalent to a global warming +2°C above preindustrial scenario by 2100) and RCP6.0 (roughly equivalent to a global warming +4°C above preindustrial levels by 2100). *The exception is Sea Level Rise, where the RCP8.5 scenario is used, as for marine projections this is closer to a +4°C global warming scenario. The full likely range of change (i.e. 10 - 90th percentile) in each average variable is not shown here but is available from the full UKCP18 database. It is important to note that because these projections show average changes for a 30-year period and only the central estimate, changes in individual years would show a much greater range of change and could be significantly higher (or lower).
more extreme heatwave events causing impacts on people’s health and wellbeing, are likely become more prevalent as a result of these projections, with their magnitude depending on the degree of change that is experienced.

**Rainfall**

There is a difference in expected rainfall trends in future in England, depending on the season. In winter, rainfall is expected to increase by approximately 6% by the 2050s and by between 8% to 13% by the 2080s from a 1981-2000 baseline, depending on global efforts to reduce greenhouse gas emissions. This is projected to lead to an increase in the likelihood of flooding of infrastructure, businesses and homes. Conversely, summer rainfall is expected to decrease by approximately 15% by the 2050s and by between 15% to 22% by the 2080s. Periods of water scarcity are projected to become more prevalent under these scenarios, leading to possible implications for agriculture and industry, for example.

**Weather extremes**

The frequency and intensity of extreme temperature and rainfall events is also likely to increase in future, with the extent of change depending on global efforts to reduce greenhouse gas emissions. By 2100, many areas in the north could exceed 30°C at least once per decade. In the south-east, temperatures above 35°C become increasingly common, and temperatures exceeding 40°C also become more likely. Summers that experience days above 40°C somewhere in the UK have a return time of 100-300 years at present, but in a high climate change scenario this could increase to once every 3.5 years by 2100.

As well as winters becoming wetter overall, the intensity of rainfall is also projected to increase by as much as 25%, particularly in the south-east. The same analysis for summer shows that, despite overall summer drying with wet days projected to become less frequent, when it does rain, the rainfall will be more intense.

**Sea level rise**

As indicated in the table, using scenarios for London, sea level is expected to rise by between approximately 23 and 29cm by the 2050s and by approximately 45 to 78cm by the 2080s, compared to a 1981-2000 baseline and depending on global efforts to reduce greenhouse gas emissions. In general, sea level rise is expected to be greater in the south of England than in other parts of the UK. Such rises could lead to an increase in likelihood of associated risks, such as saltwater intrusion of agricultural land and flooding of coastal communities.

The risks associated with these projected changes in England are outlined overleaf and are summarised throughout the rest of this document.
### 3. Summary of the risks and opportunities in England

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Risk number and Receptor</th>
<th>Nature of risk/opportunity</th>
<th>Urgency Score</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RISKS</strong></td>
<td>N1. Terrestrial species and habitats</td>
<td>Changing climatic conditions and extreme events, including temperature change, water scarcity, wildfire, flooding, wind, and altered hydrology (including water scarcity, flooding and saline intrusion)</td>
<td>More action needed</td>
</tr>
<tr>
<td><strong>RISKS</strong></td>
<td>N2. Terrestrial species and habitats</td>
<td>Pests, pathogens and invasive species</td>
<td>More action needed</td>
</tr>
<tr>
<td><strong>RISKS</strong></td>
<td>N4. Soils</td>
<td>Changing climatic conditions, including seasonal aridity and wetness</td>
<td>More action needed</td>
</tr>
<tr>
<td><strong>RISKS</strong></td>
<td>N7. Agriculture</td>
<td>Pests, pathogens and invasive species</td>
<td>More action needed</td>
</tr>
<tr>
<td><strong>RISKS</strong></td>
<td>N8. Forestry</td>
<td>Pests, pathogens and invasive species</td>
<td>More action needed</td>
</tr>
<tr>
<td><strong>RISKS</strong></td>
<td>N10. Aquifers and agricultural land</td>
<td>Sea level rise, saltwater intrusion</td>
<td>Further investigation</td>
</tr>
<tr>
<td><strong>RISKS</strong></td>
<td>N11. Freshwater species and habitats</td>
<td>Changing climatic conditions and extreme events, including higher water temperatures, flooding, water scarcity and phenological shifts</td>
<td>More action needed</td>
</tr>
<tr>
<td><strong>RISKS</strong></td>
<td>N12. Freshwater species and habitats</td>
<td>Pests, pathogens and invasive species</td>
<td>More action needed</td>
</tr>
<tr>
<td><strong>RISKS</strong></td>
<td>N14. Marine species, habitats and fisheries</td>
<td>Changing climatic conditions, including ocean acidification and higher water temperatures</td>
<td>More action needed</td>
</tr>
<tr>
<td><strong>RISKS</strong></td>
<td>N16. Marine species and habitats</td>
<td>Pests, pathogens and invasive species</td>
<td>More action needed</td>
</tr>
<tr>
<td><strong>RISKS &amp; OPPORTUNITIES</strong></td>
<td>N5. Natural carbon stores, carbon sequestration and GHG emissions</td>
<td>Changing climatic conditions, including temperature change and water scarcity</td>
<td>More action needed</td>
</tr>
<tr>
<td><strong>RISKS &amp; OPPORTUNITIES</strong></td>
<td>N6. Agricultural and forestry productivity</td>
<td>Extreme events and changing climatic conditions (including temperature change, water scarcity, wildfire, flooding, coastal erosion, wind)</td>
<td>More action needed</td>
</tr>
<tr>
<td><strong>RISKS &amp; OPPORTUNITIES</strong></td>
<td>N17. Coastal species and habitats</td>
<td>Coastal flooding, erosion and climate factors</td>
<td>More action needed</td>
</tr>
<tr>
<td><strong>RISKS &amp; OPPORTUNITIES</strong></td>
<td>N18. Landscape character</td>
<td>Climate change</td>
<td>Further investigation</td>
</tr>
<tr>
<td><strong>OPPORTUNITIES</strong></td>
<td>N3. Terrestrial species and habitats</td>
<td>New species colonisations</td>
<td>Further investigation</td>
</tr>
<tr>
<td><strong>OPPORTUNITIES</strong></td>
<td>N9. Agricultural and forestry productivity</td>
<td>New/alternative species becoming suitable</td>
<td>Further investigation</td>
</tr>
<tr>
<td><strong>OPPORTUNITIES</strong></td>
<td>N13. Freshwater species and habitats</td>
<td>New species colonisations</td>
<td>Sustain current action</td>
</tr>
<tr>
<td><strong>OPPORTUNITIES</strong></td>
<td>N15. Marine species, habitats and fisheries</td>
<td>Changing climatic conditions</td>
<td>Further investigation</td>
</tr>
</tbody>
</table>
## Infrastructure

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Risk number and Receptor</th>
<th>Nature of risk/opportunity</th>
<th>Urgency Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISKS</td>
<td>I1. Infrastructure networks (water, energy, transport, ICT)</td>
<td>Cascading failures</td>
<td>More action needed</td>
</tr>
<tr>
<td>RISKS</td>
<td>I2. Infrastructure services</td>
<td>River, surface water and groundwater flooding</td>
<td>More action needed</td>
</tr>
<tr>
<td>RISKS</td>
<td>I3. Infrastructure services</td>
<td>Coastal flooding and erosion</td>
<td>Further investigation</td>
</tr>
<tr>
<td>RISKS</td>
<td>I4. Bridges and pipelines</td>
<td>Flooding and erosion</td>
<td>Further investigation</td>
</tr>
<tr>
<td>RISKS</td>
<td>I5. Transport networks</td>
<td>Slope and embankment failure</td>
<td>More action needed</td>
</tr>
<tr>
<td>RISKS</td>
<td>I6. Hydroelectric generation</td>
<td>Low or high river flows</td>
<td>Further investigation</td>
</tr>
<tr>
<td>RISKS</td>
<td>I7. Subterranean and surface infrastructure</td>
<td>Subsidence</td>
<td>Further investigation</td>
</tr>
<tr>
<td>RISKS</td>
<td>I8. Public water supplies</td>
<td>Reduced water availability</td>
<td>More action needed</td>
</tr>
<tr>
<td>RISKS</td>
<td>I9. Energy generation</td>
<td>High and low temperatures, high winds, lightning</td>
<td>Further investigation</td>
</tr>
<tr>
<td>RISKS</td>
<td>I10. Energy</td>
<td>Reduced water availability</td>
<td>Further investigation</td>
</tr>
<tr>
<td>RISKS</td>
<td>I11. Offshore infrastructure</td>
<td>Storms and high waves</td>
<td>Sustain current action</td>
</tr>
<tr>
<td>RISKS</td>
<td>I12. Transport</td>
<td>High and low temperatures, high winds, lightning</td>
<td>More action needed</td>
</tr>
<tr>
<td>RISKS</td>
<td>I13. Digital</td>
<td>High and low temperatures, high winds, lightning</td>
<td>Further investigation</td>
</tr>
</tbody>
</table>

## Health, Communities and the Built Environment

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Risk number and Receptor</th>
<th>Nature of risk/opportunity</th>
<th>Urgency Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISKS</td>
<td>H1. Health and wellbeing</td>
<td>High temperatures</td>
<td>More action needed</td>
</tr>
<tr>
<td>RISKS</td>
<td>H3. People, communities and buildings</td>
<td>Flooding</td>
<td>More action needed</td>
</tr>
<tr>
<td>RISKS</td>
<td>H4. Viability of coastal communities</td>
<td>Sea level rise</td>
<td>More action needed</td>
</tr>
<tr>
<td>RISKS</td>
<td>H5. Building fabric</td>
<td>Moisture, wind and driving rain</td>
<td>Further investigation</td>
</tr>
<tr>
<td>RISKS</td>
<td>H7. Health and wellbeing</td>
<td>Changes in indoor and outdoor air quality</td>
<td>Further investigation</td>
</tr>
<tr>
<td>RISKS</td>
<td>H8. Health</td>
<td>Vector-borne disease</td>
<td>More action needed</td>
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<tr>
<td>RISKS</td>
<td>H9. Food safety and food security</td>
<td>Higher temperatures (food safety) and extreme weather (food security)</td>
<td>Further investigation</td>
</tr>
<tr>
<td>RISKS</td>
<td>H10. Health</td>
<td>Poor water quality and household water supply interruptions</td>
<td>Further investigation</td>
</tr>
<tr>
<td>RISKS</td>
<td>H11. Cultural heritage</td>
<td>Changes in temperature, precipitation, groundwater, land, ocean and coastal change</td>
<td>More action needed</td>
</tr>
<tr>
<td>RISKS</td>
<td>H12. Health and social care delivery</td>
<td>Extreme weather</td>
<td>More action needed</td>
</tr>
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<td>RISKS</td>
<td>H13. Delivery of Education and prison services</td>
<td>Extreme weather</td>
<td>More action needed</td>
</tr>
<tr>
<td>RISKS &amp; OPPORTUNITIES</td>
<td>H6. Household energy demand</td>
<td>Summer and winter temperature changes</td>
<td>More action needed</td>
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<tr>
<td>OPPORTUNITIES</td>
<td>H2. Health and wellbeing</td>
<td>High temperatures</td>
<td>Further investigation</td>
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### Business and Industry

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Risk number and Receptor</th>
<th>Nature of risk/opportunity</th>
<th>Urgency Score</th>
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</thead>
<tbody>
<tr>
<td>RISKS</td>
<td>B1. Flooding of business sites</td>
<td>Increase in flood risk</td>
<td>More action needed</td>
</tr>
<tr>
<td>RISKS</td>
<td>B2. Coastal business locations and infrastructure</td>
<td>Coastal flooding, extreme weather, erosion and sea level rise</td>
<td>More action needed</td>
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<tr>
<td>RISKS</td>
<td>B3. Business production processes</td>
<td>Water scarcity</td>
<td>Further investigation</td>
</tr>
<tr>
<td>RISKS</td>
<td>B4. Business access to finance, investment and insurance</td>
<td>Extreme weather</td>
<td>Sustain current action</td>
</tr>
<tr>
<td>RISKS</td>
<td>B5. Reduced employee productivity in businesses</td>
<td>Infrastructure disruption and higher temperatures in working environments</td>
<td>Further investigation</td>
</tr>
<tr>
<td>RISKS</td>
<td>B6. Disruption to business supply chains and distribution networks</td>
<td>Extreme weather</td>
<td>More action needed</td>
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<tr>
<td>OPPORTUNITIES</td>
<td>B7. Changes in demand for goods and services</td>
<td>Long-term climate change</td>
<td>Further investigation</td>
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### International Dimensions

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Risk number and Receptor</th>
<th>Nature of risk/opportunity</th>
<th>Urgency Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISKS</td>
<td>ID1. Food availability, safety, and quality</td>
<td>Decreasing yields from rising temperatures, water scarcity and ocean changes globally</td>
<td>More action needed</td>
</tr>
<tr>
<td>RISKS &amp; OPPORTUNITIES</td>
<td>ID3. Migration to the UK and effects on the UK’s interests overseas</td>
<td>Climate-related international human mobility</td>
<td>Watching brief</td>
</tr>
<tr>
<td>RISKS</td>
<td>ID4. The UK’s international interests and responsibilities</td>
<td>International violent conflict resulting from climate change overseas</td>
<td>More action needed</td>
</tr>
<tr>
<td>RISKS</td>
<td>ID5. Changes to international governance affecting the UK</td>
<td>Reduced international collective governance due to climate change and responses to it</td>
<td>More action needed</td>
</tr>
<tr>
<td>RISKS</td>
<td>ID7. International trade routes</td>
<td>Climate hazards affecting supply chains</td>
<td>More action needed</td>
</tr>
<tr>
<td>RISKS</td>
<td>ID8. Economic loss to the UK</td>
<td>Climate driven resource governance pressures and financial exposure</td>
<td>Sustain current action</td>
</tr>
<tr>
<td>RISKS</td>
<td>ID9. UK public health</td>
<td>Increase in vector borne diseases due to climate change</td>
<td>More action needed</td>
</tr>
<tr>
<td>RISKS</td>
<td>ID10. Risk multiplication to the UK</td>
<td>Interactions and cascades of named risks across systems and geographies</td>
<td>More action needed</td>
</tr>
<tr>
<td>OPPORTUNITIES</td>
<td>ID2. UK food availability and exports</td>
<td>Increases in productivity and areas suitable for agriculture overseas</td>
<td>Watching brief</td>
</tr>
<tr>
<td>OPPORTUNITIES</td>
<td>ID6. Increased trade for the UK</td>
<td>Arctic ice melt opening up new trading routes</td>
<td>Watching brief</td>
</tr>
</tbody>
</table>
The following sections of this report elaborate on this list of identified climate risks and opportunities to England’s natural environment, infrastructure, population health and businesses mirroring the CCRA3 Technical Report. All information included in this document comes from the chapters that make up the Technical Report, unless specified otherwise. There is also a section dedicated to the potential risks and opportunities to the UK posed by expected climate change internationally. Under each risk heading there is a definition and description of the risk and then a summary of the actions that would be beneficial over the next five years.

Links are provided for readers wanting to find more detail of the assessment findings and the adaptation action that would be beneficial to be taken by the Government and their arm’s length bodies and partners over the next five years to improve the country’s resilience, knowledge and understanding. This will be useful for departmental and agency officials needing to work out the details of how to make changes in practice, and to universities and other research bodies wanting to offer their expertise in filling the identified research gaps.
4. Natural Environment and Natural Assets

This section examines the evidence regarding the key risks and opportunities from climate change in England for terrestrial, freshwater, coastal and marine natural environments, as well as for agriculture and forestry, landscape and ecosystem services. It recognises the key principles of the ecosystem approach, including the benefits of the natural environment for human wellbeing.

Climate change continues to affect the natural environment across England. A different framing and a larger number of risks have been included in the CCRA3 Technical Report than in the previous assessment. There is also a limited amount of new evidence for some risks making it difficult to assess their magnitude in many cases, especially across the different UK countries.
Most of the risk and opportunity urgency scores related to the natural environment have remained the same as in the CCRA2 Technical Report, but in some cases they have increased, as shown in the table below.

<table>
<thead>
<tr>
<th>Risk, Opportunity or Risk and Opportunity</th>
<th>Urgency Score CCRA2</th>
<th>Urgency Score CCRA3</th>
</tr>
</thead>
<tbody>
<tr>
<td>N2. Risks to terrestrial species and habitats from pests and pathogens and invasive species</td>
<td>Sustain current action</td>
<td>More action needed</td>
</tr>
<tr>
<td>N7. Risks to agriculture and forestry from pests and pathogens and invasive species</td>
<td>Sustain current action</td>
<td>More action needed</td>
</tr>
<tr>
<td>N14. Risks to marine species, habitats and fisheries from changing climatic conditions</td>
<td>Research priority</td>
<td>More action needed</td>
</tr>
<tr>
<td>N16. Risks to marine species and habitats from pests, pathogens and invasive species</td>
<td>Sustain current action</td>
<td>More action needed</td>
</tr>
<tr>
<td>N18. Risks and opportunities from climate change to natural heritage and landscape character</td>
<td>Watching brief</td>
<td>Further investigation</td>
</tr>
</tbody>
</table>

There follows a summary of all climate risks and opportunities in England related to the natural environment.
N1. Terrestrial species and habitats

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>England Urgency Score</th>
<th>Risk Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISK</td>
<td>N1. Terrestrial species and habitats</td>
<td>Changing climatic conditions and extreme weather events, including temperature change, water scarcity, wildfire, flooding, wind, and altered hydrology (including water scarcity, flooding and saline intrusion)</td>
<td>More action needed</td>
<td>Defra</td>
</tr>
</tbody>
</table>

Summary of risk definition and description

There is considerable evidence of the current and potential future effects of climate change and associated drivers on land dwelling plants and animals in England. This includes impacts on individual species, their population abundance and distribution, as well as the composition of habitats. Expected climate changes, including increasing temperatures, changes in rainfall and wildfire, the latter of which is a higher risk in England, can lead to losses or gains of species in a community or geographic area, while changes in distribution can represent opportunities for the receiving area. For example, climate modelling and analysis of 402 species in England found that 36% were at risk of range loss and 41% may expand their range in future (see N3). An analysis of the risks and opportunities showed considerable variation between groups, with many insects, for example, ants and wasps, showing high levels of projected opportunity, whilst bryophytes and vascular plants had more species at risk (figure 1).
Another study assessed the risks climate change poses to National Nature Reserves in England, and it found that most of the biodiversity features (species, habitats and assemblages) for which the sites were designated were at a medium or high vulnerability to projected changes against different climatic variables. The greatest levels of vulnerability were associated with projected changes in extreme events and the combined impacts of climate change, but with variations in habitat types. The same study showed that Nature Reserve staff recognise the risk of climate change and were taking actions to build resilience, but there was less progress with accommodating change which cannot be prevented.

It is hard to assess the balance of risk versus the benefit for terrestrial species as the change will vary so much depending on the species or group being considered, and changes in species distributions will also be affected strongly by other factors like land use change. But the potential for local or more widespread extinctions and losses means the current and future risk are both considered to be high for particular species groups.

There are many relevant policies on environmental protection in England that could help to reduce the risks to terrestrial species if they result in improvements in habitat condition, extent and connectivity, such as the 25 Year Environment Plan (and sitting underneath this, specific strategies and measures like the Nature Recovery Network or anticipated England Peat Strategy). Natural England have also published an updated Adaptation Manual to support conservation managers. In addition to enhancing ecological resilience, it recognises the need to prepare for and accommodate inevitable change.

**Benefits of further adaptation action in the next five years**

The CCRA2 evidence review said that further action is needed now and into the future to increase current efforts to reduce existing human pressures on biodiversity, improve the ecological condition of protected wildlife sites and restore degraded ecosystems, such as peatlands, wetlands and native woodlands. Ecological restoration can take many decades for some habitats, meaning that it can take a long time for adaptation actions to be realised. The assessment undertaken for the CCRA3 evidence review emphasises that this has not changed and it can still be beneficial to take more flexible and integrated approaches to managing natural capital, alongside protecting specific species including further realignment of the coast, catchment-scale management strategies and landscape-scale initiatives to increase habitat extent and improve habitat condition and connectivity.

It would be beneficial for climate change to be more explicitly accounted for in conservation planning at site level and more widely. This may include modifying conservation objectives and planning for and anticipating necessary changes in spatial distribution, for example by identifying more resilient species that could thrive in particularly challenging environments. Site level conservation objectives and plans could be reviewed to assess whether management is appropriate for new or potential species to thrive. It is important that planning begins in time for action to be effective.

The Environmental Land Management scheme in England ought to increase the engagement of landowners in conservation activities, some of which could enhance species resilience and adaptation potential for climate change, for example by restoring or creating new habitats, such as hedges. Meanwhile, the UK’s Net Zero carbon target offers the potential to greatly increase resilience and build climate change adaptation into land management. It is, however, essential to ensure that nature-based solutions are at the heart of Net Zero actions and that other actions that may contribute to our Net Zero carbon target, such as an increasing use of biofuels, do not present an even greater risk of habitat loss or damage.
N2. Terrestrial species and habitats

<table>
<thead>
<tr>
<th>Natural Environment and Assets</th>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>England Urgency Score</th>
<th>Risk Owner</th>
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</thead>
<tbody>
<tr>
<td>RISK</td>
<td>N2. Terrestrial species and habitats</td>
<td>Pests, pathogens and invasive species</td>
<td>More action needed</td>
<td>Defra</td>
<td></td>
</tr>
</tbody>
</table>

Summary of risk definition and description

Pests, pathogens and invasive, non-native species (INNS) have the potential to disrupt key ecosystem functions and cause significant economic damage. They threaten individual species or whole habitats and can severely impact a range of ecosystem services, e.g. carbon storage and biodiversity and cultural heritage, e.g. parks, gardens and designed landscapes. Evidence of recent increases in the number and severity of outbreaks of native pest and pathogen species, and establishment of INNS, indicate that risks to terrestrial species and habitats have continued to increase since CCRA2 (figure 2). Their relationship with climate depends on the individual pest/pathogen but maximum and minimum temperature, precipitation, humidity and potentially wind direction, and overall warming is likely to increase the chance of establishment of INNS.

Figure 2: Number of invasive non-native species established across or along 10% or more of the land area or coastline of Great Britain, 1960 to 2018. Note that the last time period is shorter than the other bars (from 2010 to 2018) (taken from ‘Natural Environment and Assets’ technical chapter).
New and emerging pests, diseases and INNS have been identified as important risks due to their negative effect on biodiversity, as well as agriculture and forestry (see \textit{N7} and \textit{N8}). Warmer winters have already had a clear influence on outbreaks of some pests and pathogens. Terrestrial environments in the UK have seen the highest number of recorded INNS compared to freshwater or marine environments between 2010 and 2018, with 58 in total. Recent analysis also shows that INNS are one of the top five threats to England’s natural environment with estimates of the economic cost of INNS being in the region of £1.3 billion per year. While the risk is assessed as having a medium magnitude in the current climate, it is assessed as high in a future climate in England for all future climate scenarios.

The \textit{25 Year Environment Plan} has a goal of enhanced biosecurity and includes details on the management and reduction of the impacts of existing plant and animal diseases, reducing the risk of new ones and tackling INNS. Such action will contribute to addressing this risk.

**Benefits of further adaptation action in the next five years**

- Enhanced monitoring and surveillance of pests, pathogens and INNS would be beneficial.
- Greater collaboration between UK-wide, European and international pest risk and surveillance organisations would be helpful, especially because of potential changes to England’s international trade portfolio.
- Early responses to pests, pathogens and INNS to prevent them becoming established would be beneficial, as economic and environmental management costs are higher once they are established.
- Further research on the likely responses and resilience of native species and habitats to high risk pest and pathogens resulting from climate change and trade and adaptation options to manage these risks would also help.
- More integrated cross-sector policy initiatives, for example across agriculture, forestry, natural environment and human health, can also help to implement good practice and share tools and resources.
N3. Terrestrial species and habitats

<table>
<thead>
<tr>
<th>Natural Environment and Assets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk or Opportunity</td>
</tr>
<tr>
<td>OPPORTUNITY</td>
</tr>
</tbody>
</table>

Summary of risk definition and description

As species respond to climate change by moving and/or expanding their ranges northwards, they could colonise new areas including England. If these species interact negatively with native species, or alter habitat condition, then they may be considered an INNS (see N2). However, in some cases they could also enhance species richness and contribute to community adaptation to climate change. In addition to new species arriving, other species that are already in England may increase in population due to warmer winters. There is a fair amount of evidence for bird and insect species showing northwards range shifts, but less research is available for other species groups.

As with risk N1 Terrestrial species and habitats, identifying the precise changes in species distributions that will happen in the future is difficult due to so many driving factors apart from climate change. The current and future opportunity associated with new species colonisation is assessed as medium in England (in a +4°C at 2100 scenario) partly because there is a lack of evidence of the long-term effects of such movement, particularly for species that are not as visible as birds, for example. More information is needed to facilitate species movement and to consider how to integrate them into conservation planning.

Benefits of further adaptation action in the next five years

Land management policies such as the forthcoming Environmental Land Management scheme and the Nature Recovery Network have the potential to be beneficial in terms of helping existing species in England adapt to climate change through enhanced connectivity, as well as the potential to support for species arriving in the UK. However at present, it is not possible to assess the extent of the impact that these initiatives are likely to have on this opportunity. Other positive impacts would occur through afforestation and peatland restoration measures and the changes in agriculture practices in support of implementing the UK’s Net Zero targets. For tree planting, this would depend on the species, their location and how it is carried out. Carbon offsetting and Government funding for implementing these measures, such as the Nature for Climate fund, would provide additional support.

Developing new approaches to establishing species in new locations and adapting objective setting and condition assessments to reflect changing distributions, for which there are no plans or funding at present, are also likely to be beneficial.
N4. Soils

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>England Urgency Score</th>
<th>Risk Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISK</td>
<td>N4. Soils</td>
<td>Changing climatic conditions, including seasonal aridity and wetness</td>
<td>More action needed</td>
<td>Defra</td>
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</tbody>
</table>

Summary of risk definition and description

As with the CCRA2 review, risks to soils are identified as requiring more action in England. The magnitude of risk increases from medium at present to high in future, and, although awareness of this threat has improved, the necessary adaptation responses are not yet commensurate with this level of risk.

Climate is one of the key factors influencing soil formation, processes and properties, therefore changes in climate can be expected to have a significant impact on soils and their key functions. Temperature, precipitation, evapotranspiration and wind can all impact on soil productivity. For example, observed increases in rainfall intensity imply increased soil erosion and soil losses to water erosion, as shown by analysis of recent data for south-east England. Soils are, however, extremely complex and can vary even at field level, with over 700 soil types present in the UK, adding to uncertainties around the scale and specifics of the change that is likely to be seen.

However, Technical Chapter three states that soils in England are already under pressure from both climatic and non-climatic factors. For example, a recent study estimates soil loss in England and Wales in the order of 2.9 million tonnes per year with associated productivity losses estimated at £40 million per year, and total costs from decreased soil and water quality at £150 million per year. In addition, an estimated 3.9 million hectares of agricultural land has been identified at risk of compaction in England and Wales, with the risk highest on clay soils during wet periods. Severe degradation of soil quality would be very likely to have long-term, potentially irreversible, implications particularly given the critical importance of soil in underpinning biodiversity, providing high-quality farmland and a range of ecosystem services. There is the potential for major threshold effects at higher levels of warming (i.e. 4°C global warming at 2100).

Policies can help to fill existing adaptation deficits. The 25 Year Environment Plan has an aspiration to bring all soils into sustainable condition by 2030, with further actions in the second National Adaptation Programme focussed on research and monitoring. The proposed Environmental Land Management scheme could be a primary driver of greater actions by landowners to support soil health, but at the time of writing it is not yet clear how this will be implemented on the ground.
Benefits of further adaptation action in the next five years

Given the core importance of soil for underpinning and maintaining biodiversity, regulating water flows and quality, recycling nutrients, carbon storage, landscape character, cultural value and provision for ecosystem services, there are significant benefits to ensuring good health of English soils in future.

Analysis of agricultural locations that have been associated with severe soil erosion in south-east England indicated that most farmers would change land use or management to avert the erosion risk. However, Technical Chapter three states that current trends in soil degradation are not currently being reversed.

As such, an integrated land use policy linking agricultural and forestry productivity with measures that improve soil health and resilience based upon good knowledge of the potential of different soil types and their key functions would be beneficial. This would also need to include further integration of adaptation and mitigation strategies based upon long-term planning, including for ambitious land use policies such as woodland expansion and new bioenergy crops. Improved support for land managers would also be beneficial, in terms of access to benchmarking data and advice how to improve soil health outcomes consistent with improved use of public payments to soil health tracking and outcomes. With greater technical support to improve soil health, benefits would also be through improved connection of land managers back to their soil and therefore encourage more bottom-up adaptation initiatives based on different local contexts. The basis for an integrated policy that achieves this is starting to emerge through the 25 Year Environment Plan, but implementation of actions that reduce pressures on soils and evidence that soil health is increasing as a result will be key to showing that the relevant strategies are working.
N5. Natural carbon stores, carbon sequestration and GHG emissions

Summary of risk definition and description

This topic presents both risks and opportunities that occur from the effects of a changing climate on carbon stores and GHG emissions, and therefore on the UK commitment to reduce GHG emissions through climate change mitigation. Important stores of carbon that are considered in the CCRA analysis includes coastal and marine habitats including saltmarsh and kelp forests (‘blue carbon’), soils and peatlands, vegetation and trees, as well emissions from agriculture.

Analysis for the CCRA3 Technical Report updates evidence that peatland degradation and carbon losses will be exacerbated by runoff during intense rainfall events, in addition to increased oxidation from warmer and sometimes drier conditions. There are likely to be threshold effects for carbon gains and losses from soils and peatlands, but the evidence remains uncertain, especially when coupled with the uncertainty over the effects of changes in CO₂ emissions. Wildfire also poses a significant risk to loss of carbon stores and wildfires are projected to increase in frequency and severity in England in future. There is also projected to be a much greater risk of loss of coastal and marine carbon sequestration at higher magnitudes of climate change, associated with both warmer temperatures and acidification risks for marine organisms.

Opportunities may also arise due to a changing climate. For example, regarding peatlands, locations at which carbon sequestration rates are highest are typically associated with mild and wet bioclimates, allowing high primary productivity. One example is in Dartmoor where current sequestration rates are higher now than compared to the rest of the current Holocene era. This suggests a high natural resilience against present-day climate change and milder winters. However, higher magnitudes of climate change in future may be less favourable.

Modelling is taking place that demonstrates what could occur in future, and one such example using a combination of analyses suggests a major risk of saltmarsh loss, showing an up to 80% probability of marsh retreat could occur in southern and eastern England by 2040. The risks across England are projected to increase from medium to high in the future in the absence of further adaptation.

Various policies are relevant to this risk including the forthcoming England Peatland Strategy, 25 Year Environment Plan and strategies for tree planting, which need to take account of climatic suitability for different tree species. These policies set out the Government’s aspiration to increase woodland cover in England to 12% of total land area by 2060, from the 10% cover at present, which implies planting rates of at least 5,000 hectares per year. However, adaptation is not yet explicitly included in most of these policies and, therefore, a suggested next step is to consider whether associated actions can also contribute to adaptation.
Benefits of further adaptation action in the next five years

An integrated land use policy and a more spatially-targeted strategy for land use change initiatives would be helpful, together with more integration of the mitigation and adaptation policy agendas, including:

- Stress-testing of proposed measures in Net Zero pathways against the wider range of climate change risks, including the full range of climate projections.
- More targeted actions to restore degraded carbon stores, particularly peatlands. In England, the Nature for Climate Fund aims to restore 35,000 hectares of England’s peatland by 2025, but it is still not yet inclusive of adaptation actions.
- A more strategic approach to land use planning in the context of a spatial strategy to minimise climate risks and maximise opportunities for achieving Net Zero.
- A more strategic approach in planning and decision-making to integrate the use of land, coast and marine effectively, recognising their interdependencies through development of appropriate policy frameworks.
- More research needed to account for climate change risks to carbon stores in UK GHG Inventory projections.
- A better understanding of carbon storage and sequestration potential for blue carbon and the risks to these assets from climate change.
- A systematic programme of soil carbon monitoring for diverse land uses, bioclimatic zones, management interventions etc.
### N6. Agricultural and forestry productivity

<table>
<thead>
<tr>
<th>Natural Environment and Assets</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>England Urgency Score</th>
<th>Risk Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RISK &amp; OPPORTUNITY</strong></td>
<td>N6. Agricultural and forestry productivity</td>
<td>Extreme events and changing climatic conditions (including temperature change, water scarcity, wildfire, flooding, coastal erosion, wind)</td>
<td>More action needed</td>
<td>Defra</td>
</tr>
</tbody>
</table>

#### Summary of risk definition and description

This topic covers the implications of climate change for the productive capacity of agriculture and forestry, notably for crops, livestock, milk, timber and other fibres. This risk increases from medium at present to high in future, with a significant adaptation gap in addressing this risk, especially for agriculture.

Since the CCRA2 evidence review was undertaken, more evidence has become available on this risk and, in combination with that used for the previous assessment, suggests that the urgency rating should now be ‘more action needed’ because of the significant lead time to develop and implement actions in the land use sector. However, important knowledge gaps also remain which highlight the importance of continuing research on adaptation strategies.

Some examples of evidence that outlines the urgency of this risk in England is shown by the following:

- **After the hot, dry summer of 2018, potato yields were down on average by 20% in England and Wales and 2020 UK wheat yields were down by 40% compared to 2019 due to the wet winter.**
- **Water stress is already a significant factor for the main wheat producing areas of southern and eastern England. Because of the concentration of UK wheat production in this area, more than 50% of the total UK wheat production can be affected in a drought year.**
- **Conversely, field inaccessibility due to excess wetness is expected to rise, especially in relation to wheat fields in England in future.**
- **By 2050, increasing temperatures are likely to lead to suboptimal conditions becoming more frequent in south-east England with respect to milk production, and in south-west England where dairy farming is a significant beneficiary for the economy, heat stress could result in an income loss for this region by the end of this century of £13.4 million in average years and £33.8 million in extreme years. All areas of England will, however, be affected by increases in temperature.**
- **Permanent loss of the Best and Most Versatile Land due to future coastal erosion has been projected for England, showing that by the 2050s, between 240 and 320 hectares could be lost, and by 2100, between 545 and 754 hectares could be lost; these estimates could be greater still if erosion and movement of complex cliff landforms are included.**
- **Analysis for England and Wales, using climate projections, also shows reduced areas of excellent and very good quality land (according to the Agricultural Land Classification), downgrading to moderate and poor on a significant scale.**
- **Regarding forestry, although there is evidence of enhanced tree growth from the UK, attribution of this to direct climate factors, notably temperature increase, is not conclusively established. Forestry production may also be exposed to sporadic extreme events, notably from windthrow exposure during severe storms and tree mortality or loss of function due to droughts, but evidence remains limited as to whether these have an influence beyond local-scale effects.**
The **UK Agriculture Act 2020** represents one of the most significant pieces of legislation for farmers in England for several decades. The Act sets out provisions for transition between 2021-2028 away from the former Common Agricultural Policy (CAP) subsidy scheme, replacing direct payments based on land area in agricultural production with a scheme providing payments for ‘public goods.’ However, specific consideration of how Environmental Land Management (ELM) payments will support adaptation to climate change is missing at the time of writing.

The Forestry Commission has produced adaptation guidance for woodland management that includes diversification of species, genetics and stand structure.

**Benefits of further adaptation action in the next five years**

In terms of adaptation planning, it would be beneficial to make decisions that focus on the long-term sustainability of some types and modes of agricultural production in their current locations, and in some cases whether investment should be moved towards new areas that are likely to be more climate resilient in the longer term, especially in the context of water availability. This challenge also emphasises the importance of recognising that agriculture and forestry enterprises are businesses.

Opportunities can arise through the development of an effective strategy to address the historical productivity gap in agriculture in England, including skills, training and knowledge exchange, rural infrastructure and connectivity and delivering R&D at farm level. A major impetus for this strategy would be to better link adaptation and mitigation across the land use sector, including a combined pathway to the 2050 Net Zero carbon target outcome. This target has identified, amongst its key measures, sustainably increasing crop productivity and livestock grazing intensity. The challenge is, therefore, to achieve this in a changing climate and to make additional space for woodland expansion on former agricultural land.

One of the potential solutions to manage the risks associated with climate change would be crop diversity which may conflict with the assumed land optimisation agenda for Net Zero. However, there are also considerable synergies that can be delivered in improved use and management of land to deliver combined production and Net Zero goals whilst also aiming to avoid negative consequences.

Other areas to consider that could help to mitigate the risk to, and potentially enhance, productivity include integrated soil and water management, flood risk management, encouraging innovation and diversification, further research and better coordination between Government and the land use sector. Further details on each of these is given in the Technical Chapter cited below.
N7. Agriculture

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<tr>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>England Urgency Score</th>
<th>Risk Owner</th>
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<td>Pests, pathogens and invasive species</td>
<td>More action needed</td>
<td>Defra</td>
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Summary of risk definition and description

Invasive species are, by definition, harmful to other species or habitats. They do not include invasive pathogens which are harmful diseases or disease-causing agents. Invasive species can also be native or non-native, with the latter causing negative impacts but are not associated with disease. Many of the drivers of change and adaptation options for native pests and pathogens also apply to INNS, hence information provided here is highly relevant to both. The relationship with climate depends on the individual pest/pathogen but includes maximum and minimum temperature, precipitation, humidity and potentially wind direction.

Pests, pathogens, and INNS present serious risks to agricultural productivity, with consequences for livelihoods and businesses. Large-scale outbreaks or invasions may also have ramifications for food security. Observations on an increase in certain invasive species have already been seen in England, such as the Asian Hornet and *Haemonchus* and *Trichostrongylus* infections in sheep and lambs. Viruses such as bluetongue are also expected to increase due to climate change and a recent study suggests a bluetongue outbreak in England could happen every year by the 2070s due to milder winters. Another example is the *Septoria tritici blotch* which costs UK wheat growers alone around £100-200 million per year in yield losses.

The combined risk factors, both climatic and non-climatic, clearly suggest that the magnitude of this risk is increasing from medium at present to high in future across the UK. Current institutional risk assessment procedures provide some adaptive capacity that acts to reduce the risk to a lower level at present and this will also have benefits in reducing risk in the future, but most do not give explicit reference to long-term future climate change including considerations of +4°C at 2100 scenario. At present, the 25 Year Environment Plan for England and current UK National Adaptation Programme do not explicitly reference target outcomes for risk reduction for pests, pathogens or INNS.

There is, therefore, scope for more action to improve preparedness, especially considering recent analysis showing that INNS is one of the top five threats to England’s natural environment with estimates of the economic cost of INNS being in the region of £1.3 billion per year in England. There is also an expectation of increased risk due to further developments in globalisation and world trade, but a key uncertainty is the degree to which international agreements will be universally and rigorously enforced.
Benefits of further adaptation action in the next five years

Now that the UK has left the European Union, and is developing new international trade agreements, beneficial actions would include:

- Further development of international monitoring initiatives, surveillance, risk assessment procedures and biosecurity measures.
- Further expand the uptake of Integrated Pest Management rather than rely on current voluntary uptake schemes.
- Enhanced horizon scanning for INNS from Europe and based upon changing international trade portfolio.
- Cross-sectoral initiatives for risk assessment and contingency planning using a range of scenarios.
- Evaluation of risk reduction strategies for specific risks including prospects for resilient varieties and the use of increased diversification in plant and livestock species and varieties.
- Improved risk assessments with space and time dimensions to evaluate changing dynamics of individual pests, pathogens and INNS.
- Improved spatial profiling of risks including for extreme years to help better understand changing risk factors at a higher resolution across England.
N8. Forestry

Natural Environment and Assets

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<td>N8. Forestry</td>
<td>Pests, pathogens and invasive species</td>
<td>More action needed</td>
<td>Defra</td>
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Summary of risk definition and description

The definition and assessment of risk is the same as for agriculture (see N7) and, overall, pests, pathogens and INNS present serious risks to forest productivity, with consequences for livelihoods and businesses and for the multiple ecosystem services that forests provide. Due to the combined effect of climate and other risk factors like changing trade patterns, the magnitude of this risk is increasing, with a projected change from medium magnitude now to high across the UK in the future, particularly for higher levels of warming. Current management of forests limits the impacts at present, but the scale of climate change could see new threats emerging.

Specific examples of how pests, pathogens and INNS are affecting forests in England that are linked to climate change include Phytophthora ramorum (case study 1), especially in south-west England and areas with high moisture levels, the presence of bark beetles in western England’s softwood forests, oak processionary moth whose range has expanded across northern Europe into England due to warming, and early detection of the European spruce bark beetle.

The forestry sector has developed well-planned actions linked to specific threats as represented by Defra’s 2018 Tree Health Resilience Strategy. The associated Action Plan for Climate Change Adaptation of forests, woods and trees in England sets out how the sector will enhance protection against the threat of pests and diseases within the context of climate change for the following five years. However, like threats to agriculture, at present the 25 Year Environment Plan and National Adaptation Programme do not outline a measurable goal for managing and reducing the impact of existing plant disease.
Case study 1: Phytophthora ramorum

Phytophthora ramorum is a pathogen resulting in ramorum disease and is a fungal-like organism that causes the death of a wide range of trees and shrubs. The greatest impact so far has been on larch plantations, leading to many hectares of felling around England. Its name is literally translated as ‘the plant-destroyer’ and they have been responsible for some of the worst plant disease epidemics in history.

Phytophthora ramorum spores spread via wind-driven rain. When they land on a leaf, they grow into the tree by breaking down the cell walls in the leaf. This leads to the initial blackening symptoms. It then grows within the tree and blocks its water transport system leading to dieback and eventual death. While this process is happening, the pathogen will also be spreading onto other nearby trees and shrubs.

It was first recorded in the UK on viburnum plants in 2002 at a garden nursery site in Sussex but it was not until 2009 that it was found living on Japanese larch trees in the wider countryside in the south-west of England and, in the following years, it has been found throughout the west of England on larch and other trees such as sweet chestnut, especially in Devon and Cornwall. In south-west England, there are large areas that are composed of Japanese larch which is why the disease has had a huge impact on economic forestry in the region. Climatic conditions are also more favourable here due to the wetter and milder climate caused by the influence of Atlantic weather systems.

Climate projections suggest a further increase in favourability for this disease in future.

Source: CCRA3 Technical Report Natural Environment Technical Chapter, Woodland Trust, Forest Research, Exmoor National Park | Images: © Forestry Commission Plant Health Forestry Team (permission obtained)
Benefits of further adaptation action in the next five years

Preparedness would be improved through action to enhance surveillance, modelling, horizon scanning and addressing the increased prospect of emergent risks, together with:

- Further modelling of risk reduction measures and assessment of early warning factors.
- Better understanding of current and future risks and improving biosecurity, especially at ports of entry.
- Changing plant purchasing and sourcing practices to highlight the importance of secure sources and certification.
- Increasing emphasis on disease and pest resilience.
- Further investigation of management initiatives to enhance resilience, such as diversification.
- Improved understanding of current and future risks from non-native tree species used, or proposed, for enhanced production purposes.
N9. Agricultural and forestry productivity

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<td><strong>Risk or Opportunity</strong></td>
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Summary of risk definition and description

This opportunity is defined in the broader sense to include climate-related developments that are occurring through new species and varieties, together with new opportunities for cultivation. It also includes the potential for movement of existing species in one UK country or region into another country or region, therefore presenting novel opportunities in the new location. In each of these cases, agricultural or forestry productivity may be enhanced. However, while it is expected that the farming and forestry industries will ultimately take advantage of any market opportunities, government intervention is likely to be required for initial funding to help both industries transition to new markets (as has been the case, for example, for new technologies for climate change mitigation).

The level of opportunity is assessed to increase from medium at present to possibly high in future, although evidence is rather limited. Much of this opportunity remains unrealised and further investigation is recommended as the limited evidence does not allow specific actions to be identified beyond managing the risks/opportunities identified.

A typical example of how opportunities in agriculture could manifest is with the already observed growth in vineyards and wineries (insight 5). Approximately 700 vineyards exist in the UK with over 160 wineries. In 2018, 1.6 million vines were planted with a further 2 million planned for 2019. Overall, there has been an increase in vineyards of around 160% in the past ten years in the UK. Further similar opportunities could be realised in future, such as the potential for the establishment of red wine grapes (e.g. Merlot and Tempranillo) in favourable locations such as Kent, Essex, Norfolk and Cambridgeshire.

For forestry, trees that are presently restricted to lowland areas and southern England will have an increasingly suitable area in a warming climate, both for native and non-native species. This includes productive species, such as eucalyptus, radiata pine, red fir and silver fir, together with productive broadleaf species such as lime, false acacia, London plane, field maple and aspen, and those species which are valued for other distinctive properties, for example in woodcraft, those with amenity value, and fruits and nuts.

Benefits of further adaptation action in the next five years

Currently, crop breeding mainly focuses on yield and disease resistance but future climate change is not generally systematically considered. More detailed scoping and investigation of opportunities would be beneficial, allowing for consistency with changing patterns of land capability and individual crop suitability across England, factoring in the risks already outlined in this document. A major gap in knowledge and knowledge exchange appears to exist for opportunities for fruits, vegetables and horticultural crops in a future climate. More systematic investigation would be beneficial, which could include a review of barriers to the market taking up the opportunities for new species and outreach activities and collation of existing and new knowledge on species.
N10. Aquifers and agricultural land

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Summary of risk definition and description

This risk considers the threat that saline intrusion, as associated here with sea level rise, presents to coastal aquifers and agricultural land (risks to habitats and species from saline intrusion / sea level rise is referred to in N11 and N17). The risk is currently low and most likely to remain low in future unless a much greater rate of sea level rise was to occur than most estimates expect (the range for the UK being between 0.27 and 1.12 metres by 2100). Current risk management procedures should remain adequate to adapt to the risk subject to further review. However, it is noted that the risk in south-east England may be greater than the rest of the UK, partly because of the combination of saline intrusion and expected reduced summer rainfall. Some aquifers in England also provide public water supplies, for example in Dungeness in Kent which is underlain by the Denge gravel aquifer. However, at present, less than 1% of all failures to meet water quality standards were due to saline intrusion in England and Wales, hence the low risk status at present.

Benefits of further adaptation action in the next five years

Further research on changes in exposure and vulnerability would be beneficial, including in the context of the latest scientific data on sea level rise. This could occur alongside further investigation into the operational use of adaptation pathways related to changes in sea level rise, precipitation patterns and safe abstraction rates. There may also be a benefit to continue monitoring the impact on aquifers in England to assess whether risks are increasing, and building on this, additional benefits could come from analysing this in the local context, such as aquifer properties, precipitation, river flows and local sea level variations, especially in estuaries. Better storage and use of excess winter rainfall and other methods to maximise the sustainable use of surface water resources (e.g. rainwater harvesting and on-farm reservoirs) could also act to conserve groundwater resources at a sustainable level and mitigate against saline intrusion.
N11. Freshwater species and habitats

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Summary of risk definition and description

Freshwater habitats are particularly vulnerable to reduced water availability and higher water temperatures. These risks are both increasing as the climate changes and could lead to aquatic species exceeding their thermal tolerance or bringing about detrimental habitat changes, which can cause loss of sensitive species and changes in phenology and species composition. There are also potential risks related to saline intrusion/coastal inundation on freshwater species (see N10 and N17), the magnitude of which is dependent on local conditions.

Higher temperatures can also directly or indirectly increase the possibility of water quality problems, for example through increasing the rates of biological and chemical processes, especially algal growth rates and nutrients. Evidence points towards a projected increase in the number of algal bloom ‘risk days’ of between eight and 15 by 2069 in England. Additional complexity arises because climate change interacts with other stressors, such as nutrient enrichment, to affect the state of freshwater ecosystems.

There is also increasing evidence of subtle changes already occurring in English freshwaters as a result of climatic changes. For example, rising water temperatures in Windermere, England’s largest lake, are associated with a shift towards earlier perch spawning. Droughts have had notable impacts on England’s chalk streams including reductions in invertebrate abundance. In 2016, many rivers in England experienced poor recruitment of young salmon, which was thought to be caused by unusually warm winter temperatures and extreme flows.

Changing water temperatures also have the potential to fundamentally alter life cycles of aquatic insects. In the River Dove in the Peak District, the mayfly *Ephemera danica* was shown to shift from a two-year to one-year life cycle with greater growing degree day accumulation, under warmer conditions. It was inferred that this shift to a one-year life cycle would lead to an increased vulnerability of the insects to adverse weather, and reduced reproduction.

In addition, water temperature and the thermal effects of riparian shading may depend upon large-scale atmospheric phenomena. Analysing ~one million temperature records across England, a recent study showed that summer river water temperatures were especially sensitive to variations in the North Atlantic Oscillation (NAO) in northeast and west England, and at sites >300m in elevation.

At present, given the available evidence, the magnitude of current and future risks is judged to be medium by the 2050s. However, with increasing volumes of evidence on specific impacts and sensitive species, this risk could increase. The magnitude is scored as high for the 2080s if a 4°C global rise in temperature occurs, due to the likelihood of greater changes in water temperature, river flows and water quality. Given the currently incomplete knowledge of climate impacts on freshwater ecosystems, and the current shortfall in adaptation measures, there is a need for more action combined with further investigation on the scale of risk and effectiveness of these measures.
Benefits of further adaptation action in the next five years

A clear mechanism that accounts for the consequences of higher water temperature and drying up of water bodies in meeting the Water Framework Directive (WFD) targets, and their successors, would be beneficial. In England, it has been suggested that there needs to be consideration of what is the right regulatory framework that would be required to ensure a well-adapted water sector.

There are some potential future adaptation measures identified, such as natural solutions (case study 2) and weir removal, which could benefit habitats and enhance ecological resilience. For example, natural recovery was modelled as resulting in greater habitat quantity and quality for brown trout in the River Wharfe in Yorkshire.

Some of the public goods identified as being eligible for financial assistance under the new Environmental Land Management scheme, for example clean and plentiful water, may also contribute to adaptation, as could natural flood management schemes which are encouraged and supported in the National Flood and Coastal Erosion Risk Management Strategy for England (insight 4).

Case study 2: Stockdalewath Natural Flood Management Group

Good agricultural land management can lead to reducing the flood risk on both the farmland where interventions are implemented, improving productivity, and the surrounding land preventing run-off and flooding of other nearby assets.

The Stockdalewath Natural Flood Management (NFM) Group was set up in response to repeated flooding events that have severely affected assets within the Roe Beck and River Ivey catchments near Carlisle in Cumbria. The NFM group currently consists of 14 local farmers from within these two catchments.

The group is working closely with Eden Rivers Trust (ERT) and the local Catchment Sensitive Farming Officer for the River Eden catchment to identify and implement appropriate NFM (and water quality) measures throughout the area to delay the height and intensity of peak flooding by slowing and storing water within the wider catchment. As many of these measures involve good agricultural management, they will also benefit farm businesses as well as reducing flooding risks.

ERT staff have undertaken farm visits and identified sites within the two catchments where NFM measures such as hedgerow restoration, watercourse fencing and the installation of leaky woody dams will help to ‘slow the flow’ of rainwater. Research recently completed by ERT that involved modelling flooding in relation to a range of potential NFM measures has also found that soil aeration through the two catchments could also reduce flooding by up to 8%.
Adaptation measures were secured via the Countryside Stewardship Facilitation Fund and the next step is to look more in depth at soil management.

Further related activity in Cumbria is the Catchment Pioneer Pilot Project, the aim of which is to ‘test new tools and methods as part of applying a natural capital approach in practice’. New tools and methods underpinning the natural capital approach will be tested in three Cumbrian sub-catchments: Braithwaite, Glenridding and Staveley. The aim of Phase 1 of this project is to develop natural capital summaries for the three sub-catchments, with the regulation of flooding and climate change one of the main drivers. These summaries are to document the extent and quality of natural capital assets and bring together existing work on the mapping of ecosystem services in these areas. Natural capital summaries can then be used to design investment and intervention plans.

Source: © Countryside Stewardship Facilitation Fund case studies, Ecosystems Knowledge Network
Image: River Eden at Wetheral, Carlisle (Unsplash),
N12. Freshwater species and habitats

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<td>N12. Freshwater species and habitats</td>
<td>Pests, pathogens and invasive species</td>
<td>More action needed</td>
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Summary of risk definition and description

The impact of an increase in pests, pathogens and INNS on freshwater ecosystems are similar to the impact on other assets outlined earlier in this document (see N2, N7 and N8), and include competition with native species, predation, introduction of disease, harmless airborne pathogens becoming more infectious as the result of hybridising with formerly benign native microbes, and habitat alteration, which can lead to increased river flooding and economic costs. The risk to freshwater ecosystems was not included separately in the CCRA2 evidence review, but this has been re-assessed due to increasing evidence of how climate change could affect freshwater species and that there are indications that the number of INNS is likely to increase in future. Over 130 INNS are currently present in freshwater in the UK, including tompmouth gudgeon, water primrose, variable-leaved watermilfoil, ruddy duck, American bullfrog and floating pennywort.

The current and future level of risk for England is assessed as high, due to the likely increase in the number of pests, pathogens and INNS and their range and the potential role of climate change in facilitating this means that more action is needed.

The risk is assessed as higher for England than the other UK nations due to a combination of factors alongside climate change that are likely to increase the risk of INNS. Following a study of twelve INNS, conditions in England were most favourable for their survival, especially in the south-east due to environmental factors and proximity to the continent and port activity.

Policies in place such as water Resource and River Basin Management Plans and Water Framework Directive actions are all contributing to reducing other sources of harm in freshwater ecosystems and therefore improving their resilience. However, following the UK’s exit from the EU it is not yet clear what specific goals or actions will replace these policies and whether adaptation will be in integrated into them.

Benefits of further adaptation action in the next five years

- The costs of dealing with established pests, pathogens and INNS are considerably higher than the costs of biosecurity measures to prevent them becoming established, so continued action in monitoring, surveillance and early response will have high benefits.
- Other possible adaptation options include enhancing biosecurity measures; monitoring and enforcing of legislation; banning or restricting the possession, sale and release of other species; support for further research aimed at developing effective eradication methods; and rapid response for early invasion.
- In isolated cases, there would be a case for moving vulnerable species away from areas where INNS are present. The creation of isolated sanctuaries or ‘ark sites’ have been accepted for the white-clawed crayfish, which is under threat from introduced crayfish.
N13. Freshwater species and habitats

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<td><strong>OPPORTUNITY</strong></td>
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**Summary of risk definition and description**

The arrival of new species in the UK as the climate changes has the potential to enhance species richness and contribute to community adaptation to climate change. Examples include crustaceans arriving from south-east Europe that serve as prey for fish and mussels and provide habitat to other species. However, some freshwater species that are already present in England could also benefit due to more favourable, warmer waters. Out of six non-native fish species established in England and Wales, the common carp is predicted to be the most positively affected by 2050 due to increases in air and water temperatures, but this could lead to them becoming invasive, resulting in habitat destruction (N12).

Overall, the opportunities from climate change are assessed as low, both currently and in the future, as there is low evidence of these opportunities to date and climate change is likely to play a smaller part in the benefits of colonisation compared to other factors.

**Benefits of further adaptation action in the next five years**

Many of the adaptation actions that are taken to combat the risk to freshwater species (see N11) will facilitate species realising any opportunities associated with climate change. Additional consideration of how to promote a new or iconic species could present opportunities with regular observation and monitoring.
Insight 1: River Basin Management Plans refresh

The Environment Agency (EA) has now begun the statutory process of reviewing and updating the River Basin Management Plans, including three public consultations before publishing the updated plans in December 2021. One of these consultations focused on better joint working and climate change features prominently in the results of this, especially in the need to consider other plans and strategies.

Following this, the EA has committed to embedding the latest 2018 UK Climate Change Projections into the programme, stating that there is a programme of work to ensure that climate change projections of temperature, precipitation and sea level rise are being incorporated into the river basin planning process and that they are working with partners to determine the challenges and choices that we will face for our waters in the future.

The EA recognises that ‘it will be important to ensure the objectives of the Climate Change Committee and Adaptation Committee are incorporated so that sufficient notice is taken of the need to develop resilience and adaptation.’ Key to its success in helping to address risks set out in the CCRA Technical Report will be to ensure that all plans include climate change, and its likely impacts on river species and habitats, at the core of their actions. There is also an opportunity to ensure the plans outline how potential benefits, such as the impact of new species from climate change, could be best realised.

There is also recognition that aligning flood risk and river basin management plans provides a joined up approach to catchment planning and an opportunity to investigate how working with natural processes can better protect ourselves from flooding.

Source: Environment Agency ‘River basin planning: working together’
Image: River Aln, Northumberland (Alan Carr)
N14. Marine species, habitats and fisheries

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<td>RISK</td>
<td>N14. Marine species, habitats and fisheries</td>
<td>Changing climatic conditions, including ocean acidification and higher water temperatures</td>
<td>More action needed</td>
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Summary of risk definition and description

Marine ecosystems are impacted by climate change through both direct and indirect effects on the distribution and abundance of species groups. This includes the effects of warming seas and ocean acidification on the entire marine food chain, from plankton to invertebrates, fish, seabirds, marine mammals and their habitats. The general pattern for future change is likely to be the further replacement of cold-water species with warm-water species (i.e. northward range shifts), with the rate of change dependent on climate change scenario and regional sensitivities. Ocean acidification also has the potential to cause significant corrosion damage. For fisheries, rapid range shifts greater than 4km per year are projected over the next century. Changes in fisheries policy, international trade and access to markets resulting from the UK’s departure from the EU is also likely to have major implications for how the fishing industry adapts to climate change. The assessment gives a medium UK-wide risk now moving to high magnitude in the future, including the risk of large-scale extinctions from threshold effects like marine heatwaves or deoxygenation.

Projections for possible changes in the seas around England show that cold-water kelp species could be lost from southern England by the end of the century. This is an important finding as, like coral, kelp are fundamental to the whole ecosystem. Research in south-west England has also shown that in addition to direct effects on biodiversity through shifts from cold-water species to warm-water species, indirect effects occur through modification of marine ecosystems which has led to reductions in diversity and biomass.

The importance of the marine environment is increasingly recognised in national adaptation policies and fisheries also feature prominently, although detailed actions (that also include specific outcomes and plans for progress reporting) and monitoring activities to address climate change risks remain rather limited.
Benefits of further adaptation action in the next five years

Further development and regulation of the Marine Protected Area network associated with present biodiversity requirements and expected future shifts in distributions would be beneficial.

Consider the impact of the reduction of non-climate pressures, such as pollution, to maximise potential for species and habitat resilience, along with further development of habitat restoration initiatives.

A clearer assessment and implementation of sustainable fisheries yields in the context of present and future climate change would be helpful.

Improved monitoring schemes to better assess progress on biodiversity and fisheries goals would be beneficial.

There is benefit in undertaking further research on the climate sensitivity and interactions of plankton to fisheries, invertebrates, seabirds and mammals, as well as on the sensitivity of UK aquaculture species to multiple climate change drivers.

Pressure on existing fish stocks may also be alleviated by schemes to encourage the English population to diversify their choice of fish beyond a few familiar species (notably cod and haddock) and through further development of certification schemes to indicate sourcing from sustainable sources.
N15. Marine species, habitats and fisheries

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Summary of risk definition and description

The arrival of warm-water species into UK waters provides potential new opportunities for biodiversity and fisheries. Future climate projections indicate continued ocean warming to 2100 and beyond, with most projections in the range 0.2 to 0.4°C per decade. Hence, it is almost inevitable that there will be major changes in marine biodiversity and fisheries, providing significant opportunities for warm-water species as cold-water species are displaced. It is likely that the enhancement of the abundance of favoured species is due to physiological and life cycle effects, or indirectly by having comparatively negative effects on competitors or predators, or indirect positive effects by increasing prey species.

However, detailed evidence for individual species in terms of expected rates of change in occurrence and abundance remains limited and much of the adaptation opportunity for marine species and new fisheries remains unrealised. The opportunity is given a medium magnitude rating now, increasing to high in the future across England and the whole UK.

Benefits of further adaptation action in the next five years

For biodiversity, further investigation is especially linked to developing the role of Marine Protected Areas to maximise opportunities to enhance biodiversity value. Habitat condition is a crucial requirement to maximise new opportunities for biodiversity and current marine plans need to be further developed to recognise the key challenges for each priority habitat in the context of climate change adaptation, including their varying locations and viability as a coherent ecological network.

For fisheries, opportunity would arise through assessments linked to improved data on current and projected movements of key species together with sustainable yield assessments.
N16. Marine species and habitats

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Summary of risk definition and description

The scientific consensus is that risks from pests, pathogens and INNS to the marine environment will increase in proportion to the degree of future additional marine warming but there is considerable uncertainty on how this will occur, due in a large part to the scale and complexity of the marine environment. Warming of UK shelf seas is projected to continue to 2100 and beyond with most projections indicating increases of between 0.2°C and 0.4°C per decade, but with regional differences and the greatest warming in the English Channel and southern North Sea.

In addition, many other stressors, including ocean acidification and changes in salinity levels due to stratification and modification of currents, are likely to continue, increasing the vulnerability of marine organisms to INNS or pathogens. Furthermore, at higher magnitudes of climate change there is an increasing possibility of emergent unknown risks. For aquaculture, the impact of antimicrobial resistance (AMR) increasing in severity in association with climate warming is also an issue because antibiotics are commonly used in feedstuffs to control bacterial infections.

One example where there is increasing evidence of change is the dispersal of Pacific oysters. A recent analysis showed a potential for Pacific oyster expansion across England by the 2080s as temperatures increase, in some locations potentially threatening native oysters. Greatest gains in suitable areas for Pacific oysters were observed in England, which was driven predominantly by large areas of the shallow North Sea around Dogger Bank.

In May 2019, the UK Government published its comprehensive pathway analysis (as required then by EU Regulations) which identified three priority pathways for controlling INNS in the marine environment: (i) hull fouling, (ii) ballast water and (iii) contaminants of aquaculture animals. Further measures to provide increased prevention have been identified including: (i) ensuring vessels arriving or leaving UK waters have stringent hull cleaning and (ii) all ships to have a ballast water management plan.

Benefits of further adaptation action in the next five years

Collecting long-term data to better understand how marine pests, pathogens and INNS are affected by extreme events, climate variability and climate change would be beneficial, along with improving horizon scanning and modelling capability for INNS and pathogens, including through international collaboration.

Improving biosecurity awareness and promotion of best practice across all relevant sectors including in habitat enhancement, recovery, restoration and creation will also be important, alongside enhanced emphasis on prevention measures as crucial for marine INNS, including implementing action plans for priority pathways identified through risk assessments. Other possible improvements could be made to public awareness, including further use of citizen science, understanding of factors that contribute to disease-resistant organisms, and understanding and contingency planning for emergent risks, especially for novel pathogens.
N17. Coastal species and habitats

<table>
<thead>
<tr>
<th>Natural Environment and Assets</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Risk or Opportunity</strong></td>
</tr>
<tr>
<td><strong>RISK &amp; OPPORTUNITY</strong></td>
</tr>
</tbody>
</table>

**Summary of risk definition and description**

Coastal habitats occur at the boundary of terrestrial and marine environments and include both intertidal and supratidal environments, notably saltmarsh, machair, shingle, sand dunes and sea cliffs. In addition to their biodiversity value, these areas provide many ecosystem services such as flood and erosion protection, climate regulation and tourism opportunities, which were valued to be worth at least £48 billion in 2007, whilst in 2016 an indicative net present value over 50 years of £22.7 billion was calculated based upon those services that are more easily quantified. The CCRA covers both coastal erosion and flooding together, recognising that they are inter-related and that changes in one type of hazard can affect the other and the resultant risks and opportunities.

The risk is assessed as increasing from medium at present to high in future as it is especially influenced by the rate and magnitude of sea level rise, which the most recent assessments indicate may be at a higher rate and magnitude than assumed for the CCRA2 review. At present, adaptation responses are inadequate to match the scale of the risk or even to realise potential opportunities for habitat creation. Therefore, this topic remains a priority for more policy action.

There is much evidence that emphasises the high urgency of this risk. There is increasing evidence of the acceleration of sea level rise, which in turn increases the flood risk for low-lying habitats and their dependent species in England. In addition, 28% of the coast has been identified as experiencing erosion at greater than 10cm per year and 42% is at risk from coastal cliff erosion, of which 82% is undefended. Approximately 600 hectares of Sites of Special Scientific Interest (SSSI) are projected to be at risk from erosion by 2025 and 2,800 hectares by 2100. Around 72% of the intertidal flats and marshes in England are considered at risk of coastal squeeze because of the presence of landward sea defences.

Habitat quality is also an issue. Out of 40 coastal/transitional water bodies assessed in England, only 15 were deemed to be of good quality, reducing habitat extent. Saltmarshes are also at greater risk of being lost in England compared to the rest of the UK, with estimates of an 80% probability of marsh retreat in south-east England by 2040 or 2100 depending on the severity of climate changes. Based on indicative analysis, many designated conservation sites are also at risk of more frequent flooding, as demonstrated in figure 3. Flooding can result in negative and positive effects depending on the habitat and circumstances in any given location. It can also affect coastal species and habitats through frequency of saline inundation (see N10 and N11).
### Assets at significant risk

<table>
<thead>
<tr>
<th></th>
<th>Baseline (Hectares)</th>
<th>2050s +2°C warming</th>
<th>2080s +2°C warming</th>
<th>2050s +4°C warming</th>
<th>2080s +4°C warming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most important habitats exposed to frequent flooding</td>
<td>48,434</td>
<td>57%</td>
<td>64%</td>
<td>65%</td>
<td>69%</td>
</tr>
<tr>
<td>Ramsar areas</td>
<td>18,649</td>
<td>49%</td>
<td>55%</td>
<td>56%</td>
<td>58%</td>
</tr>
<tr>
<td>Special Areas of Conservation</td>
<td>11,647</td>
<td>68%</td>
<td>76%</td>
<td>79%</td>
<td>85%</td>
</tr>
<tr>
<td>Special Protection Areas</td>
<td>18,139</td>
<td>59%</td>
<td>65%</td>
<td>66%</td>
<td>69%</td>
</tr>
</tbody>
</table>

Figure 3: Increase in designated areas at significant risk of coastal flooding (frequency of 1 in 75 year or greater) for England, including +2°C and +4°C at 2100 scenarios with low population. The risk is assessed to areas to landward of coastal defences but does not include changes in inundancy frequency and associated risk for habitats on seaward side (taken from Natural Environment and Assets technical chapter).

A further complicating factor in some locations is the interaction with invasive species (N16) that can modify the natural succession of coastal ecosystems. A notable example is the presence of the invasive hybrid cord grass *Spartina anglica*, notably in southern England. This can increase local sedimentation rates and colonisation of mudflats to saltmarsh, whilst also negatively impacting pioneer communities of saltmarsh.

However, there are opportunities to improve the situation which in part have already been initiated. Since 2000 in England, over 900 hectares of intertidal saltmarsh and mudflat have been created (case study 3) and a further 300 hectares is being developed, therefore current estimates suggest a net gain of 296 hectares based upon a 1994 baseline. In addition, approximately 770 hectares of reedbeds and coastal grazing marsh have been created in England since 2011. Overall habitat compensation shows a net gain when measured over recent decades in England, albeit this is due to significant creation of habitats in the Humber estuary. In addition, there are also long-term plans in England to realign 10% of the coastline by 2030, rising to 15% by 2060.

There are a number of policies and strategies related to managing this risk in the future for England; the recent Policy Statement and Strategy for Flood and Coastal Erosion Risk Management, Shoreline Management Plans (SMPs), local flood risk management strategies and local initiatives to create new coastal and wetland habitats. These will all contribute to the protection of coastal habitats in light of climate risks, assuming that any institutional barriers that act to prevent implementation of the management policies that benefit adaptation defined by SMPs are considered.

### Benefits of further adaptation action in the next five years

Currently, in England and Wales, a SMP refresh is underway to incorporate new legislation, knowledge and information since the plans were first developed, including climate change projections, and to provide supplementary guidance for helping to manage the implementation of SMP policies, including a consistent template for SMP action plans. There is an opportunity here to improve current action, given that the aspirations of current SMPs for coastal realignment, and thereby new habitat creation, are not being met.

Managed realignment (case study 3) can provide added adaptation benefits in England. However it should be noted that some coastal habitats may be able to accommodate additional coastal flooding whereas for others it may be detrimental. If managed realignment is implemented to set back the defence line and maintain or enhance intertidal habitats, however, then there could be further benefits in terms of the additional flood and erosion protection provided by those habitats.
In England, a broad-scale assessment of potential restoration and recreation sites for intertidal habitat has also been developed which would provide a basis for more detailed appraisal and implementation at local level. There are also plans in England for a second national saltmarsh survey and improved monitoring could also be achieved through increased support for Coastal Observatories; at present there are currently six regional programmes in England and Wales.

### Case study 3: The multiple benefits of managed coastal realignment

Managed realignment is an environmental management approach that involves altering the location of the line of defence, working to provide a more sustainable position from which to manage flood and erosion risks. The need for managed realignment is driven by a number of factors, including historic and proposed development, climate change and increasing costs of maintaining fixed, linear coastal defences in the dynamic coastal environment.

Two large-scale managed realignment schemes in England, and the benefits the projects have shown, are demonstrated below. They show how the schemes were prioritised and what local conditions were prevailing to accelerate the schemes, and what impact they have had on the local environment.

**Alkborough Flats, Lincolnshire**

The managed realignment scheme at Alkborough Flats is a key part of the Environment Agency’s long-term strategy to reduce flood risk at the Humber Estuary. It also delivers important environmental benefits by creating and preserving wildlife habitat.

The scheme was developed via a partnership approach involving the Environment Agency, Natural England, Associated British Ports and Lincolnshire County Council. Designed by Halcrow and constructed by Volker Stevin, the project cost £10.2 million to deliver. Upon completion in 2006, it was the largest managed realignment scheme in Europe. Alkborough was prioritised as around 90,000 hectares of land surrounding the Humber Estuary is at risk from flooding. The estuary has a highly dynamic tidal range, and much of the land sits below the high tide level. Major industries, power stations, farmland, the country’s biggest port complex and the homes of 400,000 people are all based on the floodplain. The estuary also holds environmental importance and is designated under UK Habitats Regulations.

The existing flood embankment wall was retained, both to prevent re-meandering of the river and to protect navigation in the estuary. A 20 metre-wide breach was created, through which water can flow in and out to inundate the site, according to the tidal cycle. The remaining 1,500m of the wall was lowered to act as a weir and prevent overtopping in extreme flood events. A new section of flood bank was also built on the landwards side.

New intertidal habitat has developed at the inundation zone, including mudflats, saltmarsh and reedbeds. These areas provide food and habitat for a wide range of bird and fish species, allowing the estuary to meet the requirements of habitat directives. The estuary is one of the most important areas in Europe for birds, especially during winter. The new habitat will also help replace mudflats and saltmarsh lost elsewhere in the estuary due to rising sea levels.
Medmerry, Sussex

An issue in the wider region of The Solent has been the loss of environmentally important coastal habitat, because of coastal squeeze. The impacts of development and flood defence infrastructure around the large, urbanised areas of Southampton and Portsmouth have caused local sea levels to rise and wetland and intertidal habitats to be lost to the sea. The Medmerry scheme is the first site in the region to offer large-scale provision of compensatory habitat. In addition, this scheme was also prioritised as coastal flooding had long been a problem and presents a serious risk to the nearby towns of Selsey and Pagham. The previously existing flood defence, a 3km shingle bank, was subject to regular breach, mostly recently in 2008 when over £5m of damage was caused.

New flood banks were built around the perimeter of this new flood inundation zone and while they sit much closer to the surrounding communities than the previous shingle bank, the result is significantly increased flood protection. The inundation zone absorbs the energy and impact of the waves while also offering important new habitat.

The site contains 300 hectares of habitat of principle importance under the UK Biodiversity Action Plan, including mudflats, reed beds, saline lagoons and grassland. This includes 183 hectares of newly created intertidal habitat important to wildlife on an international level and crucial in compensating for losses due to development around The Solent, allowing the region to meet its European directive targets. Birds and other new wildlife began to appear at the site long before the scheme was completed. In addition, around £90 million of direct economic benefit is expected from the scheme.

Source: CCRA3 Technical Report Natural Environment Technical Chapter, Institute of Civil Engineers (Alkborough and Medmerry) | Image: Medmerry © Environment Agency (permission obtained)
N18. Landscape character

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>England Urgency Score</th>
<th>Risk owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISK &amp; OPPORTUNITY</td>
<td>N18. Landscape character</td>
<td>Climate change</td>
<td>Further investigation</td>
<td>Defra</td>
</tr>
</tbody>
</table>

Summary of risk definition and description

This topic is broadly defined to include risks and opportunities relating to landscapes and landscape character, with important links to cultural heritage (H11). Due to this integrating effect of other risks and opportunities at landscape scale, this topic is assessed as increasing in magnitude from medium at present to high in future, especially with higher climate change scenarios.

There are many examples of landscapes that are integral to the UK’s landscape character and that are important in ecological terms, but that could also be affected by climate change. These include mountains, moors, coastal wetlands, hay meadows, coppices, orchards and some parklands. Future changes to landscape character will occur from a range of natural responses to a changing climate, including changes to biodiversity, agriculture and forestry. Landscapes have already been modified by a combination of changing conditions, including warmer temperatures, through eutrophication in freshwater landscapes, increasing incidence of wildfire and climate-related changes in agricultural landscapes.

Recent developments and a greater recognition of landscape character and the impact of climate change has allowed for a more refined assessment to be made of the risks and opportunities. Some important recent initiatives have also shown how adaptation could be integrated with landscape concepts, but evidence is still limited, therefore further investigation and trialling of these approaches is recommended.

Some of the evidence whereby extreme weather incidents have affected landscape character in England include changes in drought-prone woodland and downland communities in south-east England (e.g. South Downs National Park) and the poor flowering of heathlands habitats in 2018 and 2019 as a delayed consequence of excessively dry conditions in summer 2018 and an increase in heather beetle damage, reported anecdotally from several locations including Exmoor, Shropshire and the North Pennines.

Benefits of further adaptation action in the next five years

Improved collaboration between local and national government in developing a cross-scale planning framework for Landscape Character Assessment (LCA) that integrates climate change responses would be advantageous. There are an increasing number of examples where climate change has been integrated into LCAs, such as the South Downs National Park Authority Adaptation Plan (case study 4). Some of these plans are also being further developed using concepts of ecosystem services and natural capital and are considering adaptation and mitigation initiatives in the context of enhancement of green and blue infrastructure.

Further investigation of public perceptions would also be beneficial. Use of ‘landscape narratives’ may be a useful process to better understand different perceptions of change to help reveal underlying understandings of nature, climate and human-environment relationships together with how this helps people rationalise different adaptation
options. Support for existing pioneering approaches linking climate-smart adaptation measures with Net Zero carbon emissions planning in the context of national planning frameworks would also help.

### Case study 4: Climate adaptation and landscape character in South Downs National Park

How the impacts of climate change could impact on landscape character is a key component of the South Downs National Park Climate Change Adaptation Plan. It also represents an example of good practice in terms of producing a climate change risk assessment and adaptation plan.

Risks to landscape character are embedded into the Plan’s principal assessment of risks and opportunities, and the actions to be taken to address these. The authority has used UKCP09 to assess the magnitude and nature of the risk and a mitigation strategy for each. It also shows how the CCRA3 process could be used to inform more local adaptation planning, by using the headline risks for England and applying them to a more local setting.

*Source: CCRA3 Technical Report Natural Environment Technical Chapter, South Downs National Park website*

*Image: South Downs at Heyshott (Unsplash)*
5. Infrastructure

Infrastructure is a key enabler of England’s economy and underpins many activities. This section uses the latest evidence to update the level of risk and adaptation measures for 13 climate risks, including risks to energy, transport, telecoms and water infrastructure.

Flooding remains a key risk to infrastructure in England. Many high profile events, for example the floods of east Yorkshire in 2020, the flooding of Gatwick Airport in 2013 (case study 5) and the Toddbrook Reservoir incident in 2019 (case study 6) which highlight, with increasing confidence, the magnitude of such risks and their interacting risks and consequences. However, there has been some limited progress across the infrastructure sector in both assessing and adapting to the risk via a suite of flood protection measures.

Water scarcity in summer remains an issue. To maintain the current levels of resilience in the face of rising population, environmental and climate pressures to 2050, would require additional capacity of about 2,700-3,000 Ml of water per day in England. Measures that reduce demand rather than improve supply are most likely to be effective as an adaptation strategy. Risks to England’s energy infrastructure from extreme weather events and the risks of extreme heat to transport links, especially railways, also remain a significant concern.

The interconnected nature of infrastructure systems means that any unmitigated risk has the potential to have a propagating impact across the network, or lead to cascading failures, the consequences of which are far reaching social and economic disruption beyond the initial impact. This interaction between risks is becoming better understood but research is still required.
Finally, there will be implications for many of the climate risks detailed in this chapter in relation to achieving the UK’s Net Zero emissions target. In particular, the anticipated infrastructure transformation in response to delivering Net Zero goals will encompass significant changes in energy generation and transport (figure 4).

<table>
<thead>
<tr>
<th>Risk affected</th>
<th>Examples of changes associated with Net Zero</th>
<th>Implications for UK infrastructure risk</th>
</tr>
</thead>
</table>
| Transport     | • Electrification of rail and road transport (electric vehicles) including smart charging infrastructure  
• Use of alternative fuels. Hydrogen for rail; low carbon alternatives such as biokerosene for aviation  
• Increased active travel (walking, cycling etc.)  
• Increased use of public transport.  
• Increased use of blue infrastructure (e.g. London Blue Ribbon Network) | • Increased reliance on electricity and ICT with associated potential for cascading risks from weather-related damage and disruption to these infrastructure  
• New flood risks to new infrastructure (e.g. electric vehicle charge points)  
• As yet unassessed risks associated with new infrastructure (e.g. Hydrogen production, distribution and storage)  
• Health and safety risks to increased numbers of cyclists and pedestrians from extreme weather |
| Land Use       | • Afforestation  
• Changed farming practices (e.g. low carbon / restoring peatlands) | • Potential to reduce infrastructure flood risk management and reduce extreme river flows and their impact on hydropower output (although afforestation is also vulnerable to droughts)  
• Conversely, flood risk could increase due to increased debris in rivers |
| Energy and Water Supply | • Potential quadrupling of low carbon electricity needed to meet demand from other sectors including electrolysis (BEIS 2020). Rising from ~300TWh/year in 2017 to 600 TWh/year under the CCC Further Ambition Scenario with potential for further electrification up to 1,300 TWh/year (CCC, 2019b Figure 2.3)  
• Increased use of renewables: wind, solar, bioenergy with carbon capture and storage (BECCS)  
• Development of a Hydrogen industry  
• Increased development of bioenergy supply chains  
• Smarter control systems to improve efficiencies  
• Reductions in the demand for fossil fuels  
• Changes in water demand due to a changing energy mix | • Increased reliance upon electricity supply increases the consequences of power outages  
• Uncertain projections for future wind generation  
• Increased significance of loss of offshore infrastructure to electricity supply  
• Increased requirements for water for Carbon Capture and Storage (CCS) and Hydrogen (H₂) increases vulnerability to water restrictions or coastal erosion and sea level rise if they are sited on the coast  
• Bioenergy crops can be impacted by drought resulting in undersupply  
• Changes in the spatial distribution of supply to accommodate greater renewable generation.  
• Increased dependencies (e.g. on ICT) makes cascade failures to other networks more probable  
• Changes in water quantity and distribution needs to accommodate a changing energy mix |

*Figure 4: Potential changes associated with Net Zero and implications for UK infrastructure risks*

Some of the risks and opportunities affecting infrastructure have remained the same, but in some cases their urgency has increased as shown in the table below. Risks to offshore infrastructure from storms and high waves is the only risk to have reduced in urgency.
<table>
<thead>
<tr>
<th>Risk, Opportunity or Risk and Opportunity</th>
<th>Urgency Score CCRA2</th>
<th>Urgency Score CCRA3</th>
</tr>
</thead>
<tbody>
<tr>
<td>I6. Risks to hydroelectric generation from low or high river flows</td>
<td>Watching brief</td>
<td>Further investigation</td>
</tr>
<tr>
<td>I7. Risks to subterranean and surface infrastructure from subsidence</td>
<td>Watching brief</td>
<td>Further investigation</td>
</tr>
<tr>
<td>I9. Risks to energy generation from reduced water availability</td>
<td>Watching brief</td>
<td>Further investigation</td>
</tr>
<tr>
<td>I10. Risks to energy from high and low temperatures, high winds, lightning*</td>
<td>Research priority/Sustain current action</td>
<td>Further investigation</td>
</tr>
<tr>
<td>I11. Risks to offshore infrastructure from storms and high waves</td>
<td>Research priority</td>
<td>Sustain current action</td>
</tr>
<tr>
<td>I12. Risks to transport from high and low temperatures, high winds, lightning*</td>
<td>Research priority/Sustain current action</td>
<td>More action needed</td>
</tr>
<tr>
<td>I13. Risks to digital from high and low temperatures, high winds, lightning*</td>
<td>Research priority/Sustain current action</td>
<td>Further investigation</td>
</tr>
</tbody>
</table>

*These risks were split between hazards rather than infrastructure asset in the CCRA2 evidence review, but overall, the risk levels for each have increased.

There follows a summary of all climate risks and opportunities for England related to infrastructure.
I1. Infrastructure networks (water, energy, transport, ICT)

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>England Urgency Score</th>
<th>Risk Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISK</td>
<td>I1. Infrastructure networks (water, energy, transport, ICT)</td>
<td>Cascading failures</td>
<td>More action needed</td>
<td>Cabinet Office</td>
</tr>
</tbody>
</table>

Summary of risk definition and description

Infrastructure operates as a system of systems. It means that vulnerabilities on one network can cause problems on others, both within and beyond the infrastructure sector (figure 5). Given the wide ranging nature of the linkages, a full understanding of the impacts of cascading failures is difficult to ascertain. However, recent international research has indicated that the vulnerability of interconnected systems may be significantly underestimated. The risk of network failures is already high, potentially affecting hundreds of thousands or millions of people per year in urban areas in particular.

Figure 5: Example of how risks can interact with each other when extreme temperatures and reduced summer rainfall affect infrastructure. The three outcomes of heatwaves, wildfire and soil desiccation can result in a series of impacts on infrastructure which can lead to other impacts across the sector and beyond (from Infrastructure technical chapter).

An example of a cascading risks event in England includes interruptions to the supply of biomass to power stations following flooding of the Port of Immingham and on the M23 motorway and nearby railway stations, hampering the ability of staff to travel to Gatwick airport in December 2013 (case study 5). Flooding of substations during the event at Gatwick also resulted in the disruption of 13,000 airline travellers. Another example is the loss of electrical power at a major exchange in Birmingham which led to the loss of broadband connection to hundreds of thousands of UK
customers. More recently, power outages in England on 9 August 2019 demonstrated the potential for cascading infrastructure failures (case study 7). The event was triggered by a lightning strike on the Eaton Socon-Wymondley circuit between Cambridgeshire and Hertfordshire, causing a routine fault on the national electricity transmission system and the disconnection of a number of small generators connected to the local distribution network. In another study, it has been estimated that the total economic loss resulting from the failure of five electricity substations (worst case scenario) to be around £27 million per day.

Overall, there is plenty of evidence that can be used to assess the current magnitude of this risk with high confidence, which is high now and in future.

**Case study 5: Gatwick Airport Christmas Eve flood**

According to the Met Office, the winter of 2013-14 saw the highest rainfall levels for almost 250 years in the south-east of England. As part of this exceptional winter, Gatwick Airport and its airlines and passengers were faced with an extraordinary set of circumstances on Christmas Eve 2013.

Very high winds on the day before had left many aircraft out of position and unexpected and unprecedented levels of river flooding led to the loss of three airfield electrical sub stations that serve the runway’s lighting system. Similarly, unprecedented quantities of rainfall caused the North Terminal basement to be flooded leading to the loss of electrical power and of some key systems, and local transport networks, both road and rail, were also severely impacted by the weather.

The event immediately demonstrates how one problem can lead to another, with a mix of infrastructure assets being affected upon the occurrence of other failures.

The Non-Executive Director of Gatwick Airport, David McMillan, was subsequently asked by the Board to lead the production of a report on the events of the day and identified three overarching lessons:

- Flood prevention and alleviation planning: A previous £20 million investment in flood defence infrastructure prevented the south terminal from flooding, but the severity of the flood was much greater than modelling expectations. The next step is to reassess this and accelerate further planned defences.
- The adequacy of the airport’s contingency and resilience plans: there was a recognition that the Airport’s flooding plans were not as robust as those for snowfall events.
- The execution of these plans on the day, particularly in relation to passenger welfare: ensuring that systems and staff are in place to ensure passengers are appropriately informed about the evolving situation on a day of difficulty and that this is treated on a par with operational issues.

On the back of his assessment, he made 27 recommendations to ensure better preparedness for future events. This is a promising step, as when events like this occur and cause a range of negative impacts, the minimum requirement should be to assess what went wrong and how problems could be prevented in future.

In 2016, Gatwick Airport published its Climate Change Adaptation Progress Report under its Adaptation Reporting Power disclosure. This included information on further action the Airport has taken to strengthen flood resilience since the Christmas Eve 2013 incident, and to ensure that this also contributes to local communities’ flood resilience. This includes expediting the existing flood prevention and alleviation works, revising the Upper Mole flood modelling in partnership with the Environment Agency and developing additional flood alleviation schemes with the Environment Agency as a result of re-modelling. It is also developing a long-term strategic approach to power resilience which ‘focuses on the customer journey and in doing so views the
Airport as a whole, made up independent yet interconnected systems, all of which must function and be resilient within the context of stable operations.’ The next step will be to ensure success of these interventions.

Source: CCRA3 Technical Report Infrastructure Technical Chapter, Gatwick Airport, Gov.uk

Benefits of further adaptation action in the next five years

There are beneficial adaptation actions which could be enacted during the next five years. For example, relating to energy, if bringing forward adaptation work in the protection of electricity substations took place, a study found cost benefits of building walls in all cases, raising the substation height in half of cases and relocating the substation in few cases. It is also estimated that if National Grid was to bring forward the entirety of planned works, scheduled for 2022, this would result in additional savings of £133.3 million in avoided expected annual losses.

Opportunities to address this risk would come with engaging with English Local Resilience Forums, who operate across geographical and organisational boundaries, with whom data could be shared. It is thought that enhanced arrangements for information sharing on critical risks are required, to assist in creating the appropriate institutional conditions for adaptation. Common standards of resilience (such as ISO 14091) may also help with investment planning and help emergency planners to better understand the potential for service disruption arising from assets in their area.
## I2. Infrastructure services

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>England Urgency Score</th>
<th>Risk Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISK</td>
<td>I2. Infrastructure services</td>
<td>River, surface water and groundwater flooding</td>
<td>More action needed</td>
<td>Defra</td>
</tr>
</tbody>
</table>

### Summary of risk definition and description

River and surface flooding is a perennial risk to English infrastructure (figure 6), with each season adding new evidence to underpin the significant magnitude of the threat. The latest research indicates that most infrastructure types assessed in the CCRA continue to face an increased risk from surface water flooding; the risk increases significantly in the future, potentially doubling the risk in a +4°C at 2100 scenario. Railways and sewage treatment works are also looking increasingly exposed to fluvial flooding, but considering adaptation, the risk of fluvial flooding appears to now be reducing for energy and freshwater infrastructure assets. However, across all infrastructure types, the risk remains with a high magnitude score across England.

<table>
<thead>
<tr>
<th>Infrastructure Asset</th>
<th>Exposure to surface water flooding (1:30 or greater)</th>
<th>Exposure to river flooding (1:75 or greater)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water sites (no.)</td>
<td>43</td>
<td>19</td>
</tr>
<tr>
<td>Sewage treatment works (no.)</td>
<td>601</td>
<td>478</td>
</tr>
<tr>
<td>Power stations (no.)</td>
<td>170</td>
<td>53</td>
</tr>
<tr>
<td>Electricity substations (no.)</td>
<td>463</td>
<td>143</td>
</tr>
<tr>
<td>Rail length (km)</td>
<td>1,691</td>
<td>444</td>
</tr>
<tr>
<td>Rail stations (no.)</td>
<td>450</td>
<td>44</td>
</tr>
<tr>
<td>Landfill sites (no.)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*Figure 6: Number or length of infrastructure assets currently exposed to ‘significant’ surface water or river flooding in England (from Infrastructure technical chapter).*

Examples of impacts from England that reflect the significance of the risk include:

- Severe flooding of the River Lune during Storm Desmond in 2015 caused defences to be overtopped at an electricity substation, and a decision was taken to switch off supplies to 60,987 customers.
- At Kirkstall in north Leeds, the defences were overtopped during Storm Eva in 2015 when the River Aire burst its banks. Consequently, electric supplies to over 27,000 customers in the nearby Leeds Central Business District were lost.
- The best estimate for the impact on rail transport from a combination of the 2007 summer and 2013 -2014 winter floods was £121 million at 2015 prices (with a range of £103 million to £129 million).
- An assessment of the 2015-2016 storms gives a best estimate for the costs to road transport as £220 million (with a range of £165 million to £275 million).
Extensive modelling of future flood risks to infrastructure has been carried out. For England, in a +4°C at 2100 scenario there is double the risk of surface water flooding of power stations, electricity substations and railways -the increase in risk ranges from 57% for railway stations to 114% for electricity substations in England. Under the same scenario for river flooding, there is a projected 32% increase in sewage works and length of rail at risk, with a 45% increase in railway stations at risk.

The Environment Agency provides guidance on adaptation schemes and strategies for infrastructure from river flooding for England, which includes projections of the anticipated change for peak river flows (see insight 4). They vary by river basin district, and with the period of time into the future. They are currently being updated with UKCP18 data, with ranges up to a high emissions scenario that exceeds a +4°C scenario at 2100. This information provides asset owners with a basis upon which to develop their own flood risk assessments as well as to underpin assessments for new developments.

**Case study 6: Toddbrook reservoir**

Designed to supply water to the Peak Forest and Macclesfield Canals, the Toddbrook reservoir, located in the Peak District, hit the headlines after heavy rain over a six day period between 27 July and 1 August, following a period of record summer warmth, caused significant damage to the auxiliary spillway. As a precaution, nearby roads and businesses were closed and 1,500 residents were evacuated from the nearby town of Whaley Bridge.

Fortunately, an urgent response consisting of a rapid lowering of the water level, accompanied by emergency bolstering of the spillway, was sufficient to avert disaster with residents able to return to their homes six days later. But how did the damage get so bad? An independent review concluded that the most probable cause of the failure was poor design followed by a gradual deterioration and erosion of the slipway because of intermittent maintenance over the years.

Temporary resilience work commenced in January 2020 to further reinforce the dam and spillway by means of a waterproof nib to prevent seepage flows undermining the spillway. However, a longer term repair is required which is estimated to cost in the region of £10 million and will take several years to implement.

Dams such as Toddbrook are currently engineered to withstand rainfall events of much higher magnitude than this one and, therefore, should not have been a key factor in the failure of the asset.
This incident demonstrates that a new review based on the latest climate projections is overdue, as is engagement with [Adaptation Reporting Power](#) requirements by infrastructure owners. Overall, the incident underlines the need for further analysis on the future impacts of climate change on dam infrastructure, particularly considering ongoing maintenance regimes which need to be specifically tailored to the dam type and age. The incident has potential to kick start improvements of dams across England, thus reducing the risk of similar, or worse, incidents in future.

*Source: CCRA3 Technical Report Infrastructure Technical Chapter, Canal & River Trust, Gov.uk*

Images: © Canal & River Trust (permission obtained)
Benefits of further adaptation action in the next five years

An analysis for England suggests that if current policies that focus on this issue continue to be implemented, the risk of flooding still increases in future compared to the present day for all infrastructure types identified above.

It would, therefore, be beneficial to develop consistent indicators of resilience to flood risk across all critical national infrastructure sectors and networks. Such indicators would help to create the institutional conditions for adaptation and would allow for improvements to be measured over time. This could build on improvement in local hazard information, such as the Cabinet Office’s Resilience Direct platform which provides street-level surface water flood forecasts to authorities and category 1 and 2 responders.

In summary, there are many types of adaptation measures that could be implemented to minimise the risk to infrastructure from flooding (case study 6), including integrating green infrastructure solutions into road junction developments, implementing sustainable drainage solutions, bringing forward the adaptation of electricity substations, changes in policy and supporting decision making with tools and information.
I3. Infrastructure services

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>England Urgency Score</th>
<th>Risk Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISK</td>
<td>I3. Infrastructure services</td>
<td>Coastal flooding and erosion</td>
<td>Further investigation</td>
<td>Defra</td>
</tr>
</tbody>
</table>

Summary of risk definition and description

Global mean sea levels are currently rising at an accelerating rate. Coastal erosion and coastal flooding, which have always occurred around the UK will become worse as sea levels rise; current projections show the rise to be between 0.27 and 1.12 metres by the end of the century. Coastal flood and erosion risk to infrastructure services (figure 7) has therefore grown. However, overall, the consequences of flooding in the recent past have been tempered due to improvements in flood defences, together with advances in flood forecasting, warning and emergency response and spatial planning. Despite this, notable coastal flooding incidents have still occurred.

<table>
<thead>
<tr>
<th>Infrastructure Asset at 1:75 or greater risk of coastal flooding (present day)</th>
<th>Assets at risk in England</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water sites (no.)</td>
<td>3</td>
</tr>
<tr>
<td>Sewage treatment works (no.)</td>
<td>53</td>
</tr>
<tr>
<td>Power stations (no.)</td>
<td>34</td>
</tr>
<tr>
<td>Electricity substations (no)</td>
<td>23</td>
</tr>
<tr>
<td>Rail length (km)</td>
<td>114</td>
</tr>
<tr>
<td>Rail stations (no.)</td>
<td>5</td>
</tr>
<tr>
<td>Landfill sites</td>
<td>0</td>
</tr>
</tbody>
</table>

*Figure 7: Number or length of infrastructure assets currently exposed to 'significant' coastal flooding across England (from Infrastructure technical chapter).*

The railway line at Dawlish provides the highest profile historic example of infrastructure at risk of coastal flooding in England. In the absence of further adaptation, the line would be projected to suffer serious reliability issues due to flooding by 2040, with line restrictions increasing from ten days per year to 30 to 40, and maintenance costs tripling or quadrupling to between £6.9 and £8.7 million per year, including over £1 million in compensation. Information on the Network Rail website shows, however, that adaptation in this area is beginning to take place.

The overall number of rail stations and rail length exposed to high risk of coastal flooding will increase significantly with climate change in the absence of adaptation (figure 8). In a +4°C at 2100 scenario with low population growth, the length of railway track exposed to coastal flooding could potentially increase five-fold in England. Sewage treatment works at risk could also increase three-fold and there is a ~55% increase in risk for electricity substations. Water sites and power stations are projected to have lower risks compared to today in the baseline scenario.
Table: Present day and end of the century estimates of coastal erosion risk for infrastructure assets in England

<table>
<thead>
<tr>
<th>Infrastructure asset</th>
<th>Present day coastal erosion risk (range from ‘mid-estimate’ to ‘high-estimate’)</th>
<th>End century coastal erosion risk (range from ‘mid-estimate’ to ‘high-estimate’)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorways and A-roads (km)</td>
<td>5 – 6</td>
<td>68 – 93</td>
</tr>
<tr>
<td>Other public roads (km)</td>
<td>30 – 49</td>
<td>440 – 602</td>
</tr>
<tr>
<td>Railway lines (km)</td>
<td>8 – 12</td>
<td>60 – 76</td>
</tr>
<tr>
<td>Railway stations (no.)</td>
<td>0</td>
<td>12 – 15</td>
</tr>
<tr>
<td>Historic landfill sites (ha)</td>
<td>21 - 31</td>
<td>181 - 239</td>
</tr>
</tbody>
</table>

Figure 8: Present day and end of the century estimates of coastal erosion risk for infrastructure assets in England (taken from Infrastructure Technical Chapter). Values do not include erosion rates from complex cliffs.

The risk is medium both now and in future and extreme water levels are very likely to increase during the 21st century and beyond and, without further adaptation such as raising flood defences and managed retreat, the projected increases in extreme water levels will significantly increase coastal flood and erosion risk.

Different infrastructure sectors have different flood and coastal risk management strategies which are highlighted in the Infrastructure technical chapter, alongside the national policies in place that consider coastal change.

Benefits of further adaptation action in the next five years

Not all coastal locations can be defended from flooding and erosion in the future, therefore realistic plans to adapt to the inevitability of change are needed now. This raises the fundamental questions of how to plan our future shoreline on the open coast and along estuaries, and deliver practical portfolios of adaptation options that are technically feasible, balance costs and benefits, can attract appropriate finance, and are socially acceptable.

The use of adaptation pathways for the long-term planning of flood risk management, first used in developing the Thames Estuary 2100 flood risk management strategy, has been shown to be a promising technique that can be applied more widely (e.g. in developing the Humber 2100+ flood risk management strategy). In addition, more accurate numbers on the scale of risk from coastal erosion and flood risk for roads, ports, airports would be beneficial for future climates, alongside better monitoring and evaluation of existing policies to determine to what extent these are managing the risk. Given the uncertainties around sea level rise, ‘what if’ planning for high coastal risk scenarios would also be beneficial for understanding what could be done in the event of very high rates of change.
I4. Bridges and pipelines

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>England Urgency Score</th>
<th>Risk Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISK</td>
<td>I4. Bridges and pipelines</td>
<td>Flooding and erosion</td>
<td>Further investigation</td>
<td>Defra</td>
</tr>
</tbody>
</table>

Summary of risk definition and description

Currently, there are no quantitative projections for climate change impacts for bridges and pipelines with results limited to the identification of weather events and environmental hazards which underlie the risk. Further research would be beneficial to define links between the forecasted risk and the actual impact at the local, regional and national level, including how rainfall and flooding, wind, erosion, land and ground movement could affect these assets. Therefore, further investigation is needed given the low quality of available evidence.

However, there is some evidence that points to the impact that severe weather events can have on bridges. In 2016, post Storm Desmond, critical transportation assets were remediated including 278 bridge repairs at an estimated cost of £123.6 million in Cumbria. This adds to evidence of the impact of floods on bridges reported in the CCRA2 evidence review, such as the 2009 Cumbria floods, where several bridges were lost, and the 2015 winter floods where a major bridge connecting the town of Tadcaster collapsed, causing major transport disruption and the rupturing of gas pipelines and loss of fibre optics communications.

In future, some modelling has been done for bridges in the UK, that states that increased winter precipitation and river flows will increase scour at bridges, potentially increasing the rate of failure to an average of one bridge per year in the UK. However, detailed analysis has not been carried out and no modelling completed for pipelines at all.

Benefits of further adaptation action in the next five years

For pipelines, improving drainage in areas that regularly flood, monitoring of river and coastal erosion and the development of flood, coastal and updated contingency defence measures are potential adaptation strategies.

For bridges, the most significant adaptation is likely to come through changes in maintenance operations, improving collaboration with emergency managers and recognising emergency management as an integral function of managing infrastructure. There are also some adaptation interventions already being considered around issues such as scour and drainage which would represent a good starting point for a framework to embed adaptation into decisions and investments.
### I5. Transport networks

<table>
<thead>
<tr>
<th>Infrastructure</th>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>England Urgency Score</th>
<th>Risk Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISK</td>
<td>I5. Transport networks</td>
<td>Slope and embankment failure</td>
<td>More action needed</td>
<td>DfT</td>
<td></td>
</tr>
</tbody>
</table>

#### Summary of risk definition and description

Increased incidence of high rainfall combined with preceding periods of dry weather and subsequent cracking are expected to lead to an increase in incidents of slope failure within the transport network. Rainfall is seen as the main trigger of deterioration and extreme weather is expected to increase the rate of these deterioration processes, albeit with some uncertainty. Therefore, the current and future risk magnitude is medium and more action is needed overall.

There were, on average, 55 earthwork failures a year across the rail network in England and Wales between 2003/04 and 2013/14. The busy West and East Coast Main Lines averaged nine and seven failures a year, respectively.

In future, modelling shows that soil moisture fluctuations will lead to increased risk of shrink-swell related failures. This will be most acute in the high plasticity soils of south-east England and, therefore, is likely to be the most significant geological hazard to England’s infrastructure.

#### Benefits of further adaptation action in the next five years

Both the industry and regulator recognise that historic investment in ageing structures has been insufficient to deliver acceptable levels of risk in the long-term. This is despite £2.3 billion being spent on renewing civil engineering structures between 2013/14 and 2018/19 in England, Wales and Scotland.

Adaptation methods could include providing improved numerical tools for infrastructure asset owners to predict failure occurrence, improved instrumentation and monitoring systems to detect pre-failure slope behaviour linked to decision support systems, more detailed characterisation of engineered soil assets, continued use of slope inspection programmes and greater use of soft engineering techniques such as vegetation management to reinforce vulnerable slopes. The cost of such measures across rail and road networks is usually offset by improvements to repair costs and travel time delays.
I6. Hydroelectric generation

<table>
<thead>
<tr>
<th>Infrastructure</th>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>England Urgency Score</th>
<th>Risk owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISK</td>
<td>I6. Hydroelectric generation</td>
<td>Low or high river flows</td>
<td>Further investigation</td>
<td>BEIS</td>
<td></td>
</tr>
</tbody>
</table>

Summary of risk definition and description

Hydroelectric generation is vulnerable to both low river flows and extremely high river flows, which are dependent on rainfall amounts. Low flows reduce power output and very high flows can damage generation equipment and the associated infrastructure, but conversely, moderate high flows have the potential to improve the output. The current risk is low, rising to medium in the future but with a high degree of uncertainty, hence further investigation is required. Most of England’s large hydro installations are in the north of the country.

Since the CCRA2 evidence review was undertaken, where this risk was not included, some evidence has come to light showing how weather conditions can affect hydro power. A reduction in all hydro generation of 7% in 2018 compared to 2017 was in part attributed to lower rainfall. The magnitude of revenue from electricity sales associated with this reduction in output is in the order of tens of millions of pounds.

The future impact of climate change on hydro output is very much dependent on future patterns of rainfall and temperatures together with changes in the water catchment area. Studies referenced in the technical chapter suggest that both winter increases in rainfall and summer droughts combine to have an overall effect on hydro output; different studies have suggested both increases or decreases in total output with 2°C global warming, and one study which quantified the effects of 4°C global warming indicated an overall reduction in hydro power output of 10% by 2050. However, differences of these expected trends in England specifically are difficult to determine.

Benefits of further adaptation action in the next five years

For new schemes, it would be beneficial to include climate impacts in both site selection and design to enable owners to maximise the system outputs under a future climate and minimise risks of damage. For existing schemes, retrospective climate risk assessments would better inform operational planning and take action to protect assets and the downstream environment from harm during high water flows.

For existing plants, there are a set of no-regret adaptation options for high flows, notably with weather and climate services, for both extreme events and early warning but also more general reservoir operation optimisation. There are also various engineering options for additional spillways and measures such as fusegates which can be added. There are more structural options to address changes in flood return periods and peak intensity, but these tend to be much more expensive. The large downside risks for hydropower revenues are from low flows during periods of drought. Most adaptation studies focus on turbine upgrades which are more cost-effective than larger structural changes.
I7. Subterranean and surface infrastructure

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>England Urgency Score</th>
<th>Risk Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISK</td>
<td>I7. Subterranean and surface infrastructure</td>
<td>Subsidence</td>
<td>Further investigation</td>
<td>Defra</td>
</tr>
</tbody>
</table>

Summary of risk definition and description

Most subsidence is due to shrinkage and swelling of high plasticity clays which are typically found in the south and east of England and London. Damage to infrastructure often occurs as a direct result of interaction with vegetation and associated water content changes. This form of subsidence is regarded as the most damaging geological hazard in Britain today. Transport infrastructure and buried infrastructure is vulnerable to damage and disruption due to climate change driven subsidence effects.

The potential scale of the problem is demonstrated when considering that 35% of high voltage subterranean electricity cables and 12% of high pressure natural gas pipelines in England are in areas of high susceptibility to shrink-swell subsidence. A study referenced in the technical chapter has shown that there is an increased risk of shrink-swell subsidence in high plasticity soils in the south-east of England due to moisture content changes which has the potential to impact road and rail corridors. Additionally, 10% of clean water treatment works, 15% of small telecommunication masts, 8% of high voltage electricity pylons, 22% of category one rail lines, 29% of major train stations and 9% of the major road network are also in high susceptibility areas.

The current risk is deemed low rising to medium in future and confidence in this assessment is also low, hence further investigation is required.

Benefits of further adaptation action in the next five years

More detailed information on sub-surface composition would be beneficial in predicting future behaviour but would be costly to achieve. Quantifying the uncertainty in soil properties may also be beneficial. Removal of trees from railway embankments has been shown to reduce shrink-swell movement though this comes at a cost of reducing the reinforcement effect of tree roots and increases in pore water pressure leading to loss of stability. Increased ground and weather monitoring and the use of real-time decision support tools has been proposed as a potential method to mitigate the risks of shrink swell.
I8. Public water supplies

<table>
<thead>
<tr>
<th>Infrastructure</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>England Urgency Score</th>
<th>Risk Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk</td>
<td>I8. Public water supplies</td>
<td>Reduced water availability</td>
<td>More action needed</td>
<td>Defra</td>
</tr>
</tbody>
</table>

Summary of risk definition and description

The UK faces an increased demand for water in a changing climate. While the south-east of England is the only region with a present-day nominal deficit, in future it is projected that a deficit of between 1,220 and 2,900 Ml per day could arise, spanning across all regions in England under a central population scenario and a +4°C at 2100 scenario by the late-century without adaptation, equating to the daily water usage of between 8.3 to 19.7 million people. In England, current and announced adaptation is likely to be less successful in reducing the magnitude of deficits in the late-century, hence why the risk in England is medium now and high in future, therefore more action is needed (figure 9).

The Environment Agency’s National Framework for Water Resources work focuses on the regional requirements for the five regional water resources groups to meet future demand. Analysis using the Water Resources Management Plans demonstrate that if no action is taken between 2025 and 2050 around 3,435 Ml per day extra capacity would be needed in England by 2050, and 5,500 to 6,000 Ml per day by 2100.
England shows the largest range in supply-demand balance compared to other nations. This is most likely because more water sources are yield constrained in England and therefore cannot provide any more water than they currently do without exceeding environmental protection measures.

Water is often stored in reservoirs, which are also vulnerable to high water flows and increased temperatures which can have implications on bank integrity. Groundwater is also an important water resource in England, supporting public water supply, agricultural and industrial water uses and water stresses during summer is a major concern. Eastern England, East Midlands, north-east England, south-east England, West Midlands and Yorkshire and Humber would have the largest reductions in potential groundwater recharge. Groundwater depletion could interact with declines in river flows and combine with hotter and drier summers to significantly impact public water supply under climate change scenarios.

**Insight 2: National Water Framework for England**

The organisations responsible for England’s water supplies have worked together to understand the water needs for England from 2025 to 2050 and beyond. This involved looking at each region and across all sectors. The result is a Framework that marks a move to strategic regional planning, setting out the principles, expectations and challenges for five regional groups made up of the 17 English water companies and other water users.

One of the main objectives of the Framework is to address a key pledge in the 25 Year Environment Plan, that of ‘improving resilience to drought and minimise interruptions to water supplies.’

Each of the regional groups are required to produce a plan by September 2023 that will focus on the following concerns:

- Increasing resilience to drought.
- Reducing long-term water usage.
- Reducing leakage.
- Reducing the use of drought permits and orders.
- Increasing supplies.

As a result of these plans, a series of future priorities hope to be addressed, which will include:
• A more sustainable abstraction regime.
• Reducing the use of drought measures in sensitive areas.
• Developing modelling to continue to build our understanding of future water needs.
• Supporting reductions in water demand by introducing a new monitoring framework to track progress on demand reduction.
• Establishing a sub-group to recommend how daily water use targets can be achieved, such as through policy changes and public campaigns.
• Enabling collaboration by removing barriers that currently prevent water companies and others working together.

Source: Gov.uk ‘Meeting our future water needs: a national framework for water resources – accessible summary.’
Image: Dry cropland in Berkshire (Kathryn Brown)

Benefits of further adaptation action in the next five years

There is already positive action taking place to help address this risk. English Water Resource Management Plans set out how water companies have committed to more ambitious targets to reduce leakage and many have considered possible options for new water supply infrastructure and improving resilience to extreme weather. Water companies are also investing to improve resilience but it is not clear if this investment will be adequate to address future risks, particularly in the context of a +4°C at 2100 scenario.

Up to £469 million has been allocated to help companies work together on solving long-term drought resilience challenges in England, through measures such as reservoirs and the national transfers of water from the north-west to the south-east. Companies also plan to invest £650 million in the installation of at least two million new water meters over a five year period up to 2025. There are several options for further adaptation to reduce the risk of deficits further, including tightening building regulations, metering, demand management and drought research (insight 2).

The CCRA3 Technical Report water resources research project finds that the only scenarios that result in a significant English supply-demand balance surplus are the ones in which additional adaptation action is taken to reduce demand or where the current and announced adaptation scenario is applied to the central population. This scenario includes the water companies own ambitions for reducing per capita consumption for England and Wales. Establishing appropriate leakage targets using a sufficiently wide assessment framework considering all potential users may also improve multi-sector resilience and economic efficiency of water and water rights use. Defra announced it is looking to bring in a statutory long-term water demand target by October 2022.
I9. Energy generation

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>England Urgency Score</th>
<th>Risk Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISK</td>
<td>I9. Energy generation</td>
<td>Reduced water availability</td>
<td>Further investigation</td>
<td>BEIS</td>
</tr>
</tbody>
</table>

Summary of risk definition and description

The electricity supply industry dominates surface and groundwater abstractions in England, accounting for 49% of estimated actual abstraction and 65% licenced abstraction in 2016 and 2017. Thermal power generators, including energy from waste plants, sited inland are the main type of generation vulnerable to reduced water supply, as 60% (by capacity) of all such sites are cooled with sea and tidal water, including all nuclear generation.

Analysis of future risks to the sector suggest there are particular areas of the UK where existing inland thermal plants source water from areas which are likely to be vulnerable to water scarcity. However, the UK’s commitment to Net Zero should see a decrease in the use of thermal power generators and therefore reduce the potential risk over time. This is especially important, as an assessment on electricity prices attributable to disruption to the supply from thermal plant due to restricted water availability caused by climate change estimate that in the period 2020-2049 costs would be in the region of £93 million and, in 2070-99, £129 million a year. While the CCRA analysis has mostly focused on risks to the UK’s current energy portfolio, it also highlights that potential future energy generation technologies rely on freshwater availability and considers the risks, including to Carbon Capture and Storage (CCS), biomass and biofuel production, hydrogen, and possibly shale gas.

Studies assessing future freshwater availability conclude that there could be restrictions in certain areas, particularly around the Thames and Trent Basins and Yorkshire Ouse by 2030. As a result, the risk for England is low now and medium to high in future scenarios, but with low to medium confidence hence further investigation is required.
Benefits of further adaptation action in the next five years

In general, long-term monitoring of the risks to energy generation due to reduced river flows would be beneficial, alongside greater consideration of the potential influence of water scarcity for the UK’s Net Zero commitments, which requires regional risk assessments to assess the impact of low flows for new developments.

The National Planning Policy Statements in England would benefit from the latest climate projections to be considered when major new thermal energy infrastructure projects are developed, but impacts on smaller schemes may not be considered in as much detail.

With respect to guiding small new schemes, further actions would be beneficial given that abstraction reforms remain to be implemented in England. Together with climate projections for the future water resources available in different catchment areas, this would guide new infrastructure siting and cooling technology choices. The evidence for risks to energy generation due to higher water temperatures and/or reduced river flows could also be kept under review, with long-term monitoring of risk levels and adaptation activity with additional consideration of how an expansion in the hydrogen and biofuel production would affect vulnerability to reduced water availability.

Another no regret adaptation option is for further analysis of the possible risks with respect to water demand of new generation plants. These factors would lead to important adaptation options around siting and technology options and, at the very least, the cost implications for any water use under a changing climate.
I10. Energy

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>England Urgency Score</th>
<th>Risk Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISK</td>
<td>I10. Energy</td>
<td>High and low temperatures, high winds, lightning</td>
<td>Further investigation</td>
<td>BEIS</td>
</tr>
</tbody>
</table>

### Summary of risk definition and description

The risks to energy infrastructure from extreme weather are already an issue in the current climate. Examples include: a reduction in the amount of energy generated from thermal generators and solar PV cells (caused by hot temperatures), line faults (caused by cold temperatures, snow and ice), damage from debris (caused by wind) and power cuts (caused by lightning), such as the power outage in south-east England in August 2019 (case study 7) that affected over a million people, causing the shutdown of electric train services and disruption to hospitals, airports and manufacturing plants. It was later found that this outage was partly caused by lightning.

The future risks related to the energy sector are also influenced by the future profile of energy demand and supply together with the resilience of society and the economy to constraints on or interruptions to supply. Differing generation and supply technologies have their own profile of vulnerability to weather and climate and therefore the balance of these technologies in future will influence the energy sector’s vulnerability to climate change. Infrastructure policies can also have profound impacts on resilience.

### Case study 7: 2019 Power Outage

The power cut that affected nearly a million people in August 2019 was, according to official investigations, ‘thought to have been caused by a lightning strike to an overhead transmission line and the near simultaneous loss of a number of generators at approximately the same time.’

The investigation found that the combined loss of two large generators, as well as the smaller loss of generation at a local level, triggered the subsequent disconnection and loss of power. Two large power stations, Hornsea One Ltd and Little Barford, did not remain connected after the lightning strike. They agreed to make a voluntary payment of £4.5 million each into Ofgem’s Redress Fund. Many key infrastructure assets were affected by the outage. This included:
• **Railways**: The detected drop in frequency on the electric system caused 60 trains to shut down. While around half of the affected trains were restarted by their drivers, the rest required engineers to be dispatched, blocking tracks and causing huge disruption on lines into St Pancras International and King’s Cross. In total, 371 services were cancelled and 873 delayed.

• **Hospitals**: Three hospitals were affected but, in all cases, back-up generators kicked in sufficiently, albeit one of the 11 back-up generators in one hospital did not work.

• **Water**: Approximately 3,000 people experienced water supply disruptions due to booster water pumping stations failing to automatically switch over to back-up power supplies. Some of these customers would have experienced a temporary loss of running water in their homes, albeit they were mostly restored within 30 minutes.

• **Energy**: An oil refinery was disconnected and due to the complexity of restarting large process units it took a few weeks to restore normal operations.

• **Airports**: Two airports were affected and, in one case, power to some services including baggage and security were delayed and restarted in approximately 50 minutes.

The incident shows how just one lightning strike can cause a huge impact on power supplies and the knock-on effect this then has on infrastructure and services. The Government report on the incidents states that ‘more work is required to understand the root cause behind these disconnections and whether it would be appropriate to establish standards for critical infrastructure and services setting out the range of events and conditions on the electricity system that their internal systems and business continuity plans should be designed to cater for.’

This is in line with the CCRA’s view on this risk as a whole, stating that further investigation on activities being implemented by the energy sector on existing plans to protect assets from increased lightning strikes is also needed. Adaptation needs to occur at both Distribution Network Operator level, to reduce the likelihood of the incident happening in the first place, and at the local level, so that railways and hospitals can be confident in their preparedness should a power failure like this occur.

Source: **CCRA3 Technical Report Infrastructure Technical Chapter, Ofgem, Gov.uk, BBC**
Image: **Electricity pylon (Mat Burhouse)**

Future modelling has been carried out especially on the impacts of temperature, for example a reduction in output for solar PV of between 1-3% and thermoelectric generation of 5-14% (in scenarios up to a 3°C rise in global temperature) is possible in future due to increasing temperatures, but the ramifications of this is less certain due to the implications of the UK’s Net Zero emissions target on the future energy mix. However, the impacts of temperature are likely to be felt to a greater extent in England due to higher projected temperature changes. The future changes to the impacts of lightning strikes and wind are uncertain and not discernible by nation. Therefore, the current and future risk magnitude is high but with significant uncertainty, hence further investigation is required.
Benefits of further adaptation action in the next five years

A better understanding of the risks from passing specific thresholds that affect energy supply would be beneficial. For example, communications infrastructure supporting telemetry components in the national gas grid have been found to have a maximum operating temperature of 40°C (where external temperature and the load on the asset are contributing factors). Summer operation of some facilities is already being affected and this will be exacerbated by projected increases in summer temperatures.

Regarding high winds, further investigation of the future risks of damage from falling trees would be beneficial, alongside a watching brief on the evidence regarding potential changes to wind speeds in future due to climate change. Further investigation on activities being implemented to protect assets from increased lightning strikes would also be helpful (case study 7). Recent years have shown that multiple events (e.g. concurrent lightning strikes) can have severe knock-on impacts on energy supply, and scenario studies looking at the effects of different hazards (high winds and lightning, or high temperatures and lightning for example) would be prudent.
I11. Offshore infrastructure

Summary of risk definition and description

Offshore infrastructure includes equipment used by the oil and gas industry, wind, tidal and wave energy, and gas pipelines and power cables on or under the seabed. Their vulnerabilities as a result of storms and high waves include the destabilisation or degradation of mechanical systems and structures, reduced energy output and operating periods, damage to cabling systems during storms and prevention of access for maintenance and inspection activities. The current risk to offshore infrastructure is low, based on good evidence which has changed little since the previous CCRA.

In future, the risk is allocated as medium magnitude in part due to increasing offshore renewable energy infrastructure linked to the UK’s Net Zero emissions target. Currently there are about 3,000 offshore wind turbines installed or under construction in UK waters and Net Zero projections indicate approximately 50% of our electricity will be generated by offshore wind in UK waters, so our energy security will be strongly dependent on the continued operation of around 10,000 offshore wind turbines, five times more than are currently installed. A large fleet of oil and gas platforms might also be repurposed for carbon sequestration storage. There is also some evidence that changes to wave height, wind speed and sea level rise could exacerbate the risks to offshore infrastructure in future. Current projections show the rise in sea level to be between 0.27 and 1.12 metres by the end of the century.

There is also no documented evidence of any difference in the risk to offshore infrastructure in English waters compared to assets off other coasts.

Benefits of further adaptation action in the next five years

Changes to the accessibility of offshore infrastructure would facilitate easier maintenance and crew transfer. Given the anticipated expansion of offshore renewable energy in order to meet the UK’s Net Zero emissions targets and current uncertainties about changes in marine conditions as the climate changes, further investigation into the potential changes in relevant climate metrics including wind and wave heights would better inform design and siting choices.
## 112. Transport

### Summary of risk definition and description

Evidence that demonstrates how extreme temperatures, high winds and lightning strikes can affect the rail, road, air and water networks is plentiful. The current risk is medium, rising to high in the future and Technical Chapter four states that the risk is not currently being fully managed across the system. Risks to transport infrastructure and associated impacts are included in figure 10:

<table>
<thead>
<tr>
<th>Risk</th>
<th>Documented impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High temperatures</strong></td>
<td></td>
</tr>
<tr>
<td>Railways</td>
<td>• Responsible for over £20 million in compensation payments to Train Operating</td>
</tr>
<tr>
<td></td>
<td>Companies (TOCs) between 2006 and 2016.</td>
</tr>
<tr>
<td></td>
<td>• Heat-related incidents on major routes such as around London and at Manchester</td>
</tr>
<tr>
<td></td>
<td>Piccadilly caused major disruption during the July 2015 heatwave.</td>
</tr>
<tr>
<td></td>
<td>• 40-80% increase in infrastructure failure on south-east England’s railway network</td>
</tr>
<tr>
<td></td>
<td>during the summer 2018 heatwave.</td>
</tr>
<tr>
<td><strong>High winds</strong></td>
<td></td>
</tr>
<tr>
<td>Railways</td>
<td>• Accounted for approximately £145 million in compensation payments between</td>
</tr>
<tr>
<td></td>
<td>Network Rail and TOCs between 2006 and 2016.</td>
</tr>
<tr>
<td></td>
<td>• Of the 37,820 weather related incidents in England between 2006/07 and 2017/18,</td>
</tr>
<tr>
<td></td>
<td>31% were attributed to wind.</td>
</tr>
<tr>
<td></td>
<td>• Presence of trees near to the railway line and wind direction can affect the</td>
</tr>
<tr>
<td></td>
<td>level of impact; a study on the Anglia railway showed that the likelihood of an</td>
</tr>
<tr>
<td></td>
<td>incident was shown to be greatest for north-easterly winds and decreased by more</td>
</tr>
<tr>
<td></td>
<td>than 60% for south-westerly winds.</td>
</tr>
<tr>
<td><strong>Lightning strikes</strong></td>
<td></td>
</tr>
<tr>
<td>Railways</td>
<td>• £40 million in compensation payments to TOCs due to the impact of lightning on the</td>
</tr>
<tr>
<td></td>
<td>network between 2006 and 2016.</td>
</tr>
<tr>
<td></td>
<td>• Impacts can include damage to electronic equipment, line-side trees and buildings</td>
</tr>
<tr>
<td></td>
<td>as well as line-side fires.</td>
</tr>
<tr>
<td><strong>High and low temperatures</strong></td>
<td></td>
</tr>
<tr>
<td>Roads</td>
<td>• High summer temperatures can increase thermal loading on bridges and pavements</td>
</tr>
<tr>
<td></td>
<td>causing significant damage.</td>
</tr>
<tr>
<td></td>
<td>• Cold weather, including snow and ice, caused 16% of all weather-related delays to</td>
</tr>
<tr>
<td></td>
<td>the strategic road network in England between 2006 and 2014.</td>
</tr>
<tr>
<td><strong>High winds</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• High sided vehicles can become unstable in gusts of wind over 45mph.</td>
</tr>
</tbody>
</table>
### Risk

<table>
<thead>
<tr>
<th>Risk</th>
<th>Documented impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roads</td>
<td>• Damage to roadside furniture, such as traffic signs, and blowing nearby vegetation onto the road.</td>
</tr>
<tr>
<td>High and low</td>
<td>• As documented by Heathrow Airport, higher temperatures can cause problems with runways and the flashpoint of aviation fuel resulting in greater fuel usage and potentially longer runways for take-off.</td>
</tr>
<tr>
<td>temperatures</td>
<td>• Overheating of standing aircraft occurs at 25-30°C.</td>
</tr>
<tr>
<td>Aviation</td>
<td>• Disruption caused by snow and ice.</td>
</tr>
<tr>
<td>High winds Aviation</td>
<td>• <strong>Time Based Separations</strong>, such as those introduced in 2015 at Heathrow, can be used to reduce delays and cancellations due to strong headwinds. This can add four plane movements per hour on strong wind days, leading to a 50% reduction in annual delays attributable to strong winds.</td>
</tr>
<tr>
<td>High winds Water</td>
<td>• The Port of Dover reported closure during sustained wind speeds above 55 knots.</td>
</tr>
<tr>
<td></td>
<td>• A wind speed of 37 knots was given as a threshold for overtopping at Admiralty Pier.</td>
</tr>
<tr>
<td>Lightning Water</td>
<td>• Lightning strikes at Felixstowe were reported to cause temporary dips in power causing failure of quay crane equipment.</td>
</tr>
</tbody>
</table>

*Figure 10: Summary of recent impacts of lightning and extreme temperatures and wind speeds on England’s transport network.*

Modelling also suggests a worsening of many of these risks under future climate change scenarios:

- Potential eight-fold increase in the impacts of infrastructure buckling, quadrupling of temporary speed restrictions, more required maintenance and increase in worker heat stress all cited as future risks to high temperatures on the railways. Many of these would be most significant in England, especially in the south-east.
- London Underground lines could experience near complete passenger discomfort during the summer by the 2050s.
- Highways England highlighted climate change hazards with potential to impact their services and network users, including increases in extreme summer temperatures and increased wind speed leading to more frequently exceeding operational limits.
- Clear-air turbulence during the cruise phase of flights is projected to increase due to climate change, increasing journey length and fuel consumption.

There is less available evidence that documents how climate change could affect transport infrastructure in addition to what is listed above, such as wind speed and lightning. As such, the future magnitude is high but with low confidence at present.
Benefits of further adaptation action in the next five years

Actions being taken to reduce risk by the rail industry are likely to be reducing vulnerability in some areas, but evidence is currently lacking. This may be due to the current indicators of resilience which may not directly indicate how the physical vulnerability of assets is changing. Enhanced weather incident reporting, asset condition monitoring and revised standards would help with this gap. It would also be beneficial to undertake a formal assessment of the future electrified transport systems that will be required to meet the UK’s Net Zero emissions commitments.

For local roads, it is not clear whether there has been a systematic evaluation of climate change risks. Similar to rail, the development of better indicators of climate resilience for roads would be beneficial. The same goes for ports and airports, where a lack of observed engagement with the Adaptation Reporting Power process may also be a barrier to adaptation.

For existing infrastructure, improved monitoring and information and improvement of maintenance practices and operations are considered low-regret adaptation options. For new infrastructure, there are opportunities for mainstreaming climate change adaptation into planning and design, to avoid retrofitting later (case study 8).
Case study 8: London Mayor’s Transport Plan

Climate change resilience is a central part of the 2018 London Mayor’s Transport Plan and contains principles replicable in other areas. The recognition of the importance of climate resilience is on the back of climate change already having a detrimental effect on transport in London, such as the closure of much of London’s rail network after flooding in 2016.

The plan also recognises future risk, stating that ‘without adequate mitigation, climate change will reduce comfort, safety and reliability on public transport and will ultimately have a negative effect on London’s economy. The risks in the CCRA are translated by the analysis by Transport for London that key challenges to public transport posed by climate change include protecting rail assets and streets from flooding, managing heat on public transport and maintaining service reliability in periods of extreme weather.

Initial interventions include:

- Including adaptation measures in construction and asset renewals to provide resilience in the most cost effective manner.
- Ensuring major projects are designed to be future-proof against severe weather conditions for their entire lifetime.
- Identifying high-priority locations for proactive severe weather resilience interventions.
- Create Sustainable Drainage Systems (SuDS) to enable, each year, an additional effective surface area of 50,000m² to first drain into SuDS features rather than conventional drains and sewers.

Next steps would be to identify actions that have been implemented and how any adaptation measures can be scaled up or tested considering a changing climate.

Source: CCRA3 Technical Report Infrastructure Technical Chapter, London Mayor’s Transport Strategy
Image: River Thames, London (Kathryn Brown)
I13. Digital

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>England Urgency Score</th>
<th>Risk Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISK</td>
<td>I13. Digital</td>
<td>High and low temperatures, high winds, lightning</td>
<td>Further investigation</td>
<td>DCMS</td>
</tr>
</tbody>
</table>

Summary of risk definition and description

Climate-related risks have the potential to disrupt the availability and reliability of digital technology via:

- Failure of telecommunications leading to reduced capacity in a wide range of other essential services.
- Mobile base station power failure because of extreme weather.
- Local outages, given consumer reliability on digital technology today.
- Ground shrinkage can lead to failure of electricity, gas and water pipes, thereby damaging co-sited ICT infrastructure.
- High summer temperatures, as well as rapid fluctuations in temperature and humidity, pose challenges to data centres, which need to be kept cool to operate.
- Poorer performance of radio systems due to heavy rainfall.
- Greater international communication disruption due to increase sea temperatures.

Risks to digital services associated with climate change are likely to be of medium magnitude by the 2050s. However, the evidence to support this is of low quality. While there is a general understanding of the interactions between ICT infrastructure and weather, quantitative projections assessing how climate change will affect the frequency and magnitude of these interruptions are lacking, meaning that further attention to the climate resilience of this sector and quantitative information on current and future risks under climate change would be beneficial to better assess its vulnerability and exposure.

Outage incidents to networks and services between 2016 and 2017 showed that 1% (five out of 648) of incidents were caused by severe weather (flood, storms or snow). However, there is little information on the current and future risks to digital services for England compared to other nations. Hence, further investigation is required to assess how climate change will affect the frequency and magnitude of interruptions to digital services across England.

Benefits of further adaptation action in the next five years

Further attention to the climate resilience of this sector and quantitative information on current and future risks under different climate change scenarios would be beneficial to better assess its vulnerability and exposure, alongside incorporating digital infrastructure into existing infrastructure climate adaptation plans. It is important to recognise the importance of ICT provision in underpinning the operation of most other forms of infrastructure. The ownership of a large proportion of ICT infrastructure, particularly data centres, base stations and network connections, are spread across the private sector.
6. Health, Communities and the Built Environment

This section summarises the evidence regarding the key risks and opportunities posed by climate change for the population of England, with a particular focus on health and wellbeing, communities and the built environment. The evidence is divided into 13 climate risks and opportunities and the risks are either focussed on climate hazards (for example heat or flooding) that affect multiple sectors, or around particular policy areas (for example health systems or food safety).

The risks from coastal and river flooding to people, communities and buildings remains the most severe risk for the UK, with most of the present and future flood risk in England. High temperatures also affect a very wide range of health and social outcomes. The heatwaves in recent summers have caused thousands of deaths and disruptions to daily activities, including hospital services and education. Interactions between risks from combined exposures from air pollution, drought and wildfires are increasingly recognised.

Climate change is also likely to increase the risk of contamination of food and drinking water and sea level rise and coastal change threaten communities in the south and east coasts of England.

Most of the risks and opportunities affecting health, communities and the built environment have remained the same compared to the CCRA2 evidence review, but in some cases their urgency has increased as shown in the table below.
It should also be noted that the COVID-19 pandemic may have long-term implications for the resilience of the health and social care sector. The pandemic has caused an additional stress on the health and social care system due to increased demand (likely to last until 2022) and additional pressures on local finances (likely to last longer term). More positively, the impacts of COVID-19 may have raised awareness of the importance of understanding major threats that can disrupt lives and livelihoods, including low probability, high impact flood events.

There follows a summary of all climate risks and opportunities for England related to health, communities and the built environment.
H1. Health and wellbeing

### Health, Communities and the Built Environment

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>Urgency Score</th>
<th>Risk Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISK</td>
<td>H1. Health and wellbeing</td>
<td>High temperatures</td>
<td>More action needed</td>
<td>Ministry of Housing, Communities and Local Government (MHCLG)</td>
</tr>
</tbody>
</table>

#### Summary of risk definition and description

High temperatures will lead to increased numbers of people becoming ill or dying across the UK and affect a very wide range of health and social outcomes. There has been a large increase in research on heat effects since the CCRA2 review was undertaken. Interactions between risks from combined exposures from air pollution, drought and wildfires have been increasingly recognised. There is more evidence about the risks of overheating in buildings and the effectiveness and limitations of strategies for space cooling and there have been improvements in how to design buildings and use technology that could ensure homes have high levels of thermal efficiency (staying warm in winter while cool in summer), while considering moisture and air quality levels. However, there is still little preventative action being taken to address health risks from overheating in buildings and restrictions associated with the COVID-19 pandemic may have increased exposure to heat as people had to spend more time indoors during hot weather.

The impacts from recent heatwaves in England have been well documented, as follows:

- The total impact in **summer 2018** was 863 deaths, with impacts highest in the London region. There was also an excess in mortality associated with a high temperature period in April 2018.
- **In 2019**, the estimated impact was 892 excess deaths over the summer period. There is evidence of an excess in the 0-64 year age group for the heatwaves in 2019 at the regional level, especially in London and the West Midlands. During this heatwave, the record maximum daily temperature of 38.7°C was set in Cambridge.
- The total cumulative all-cause excess mortality during the 2020 heatwave was estimated to be 2,556, with 2,244 excess deaths observed in the 65+ years group, and impacts were greatest in London and the south-east (**case study 9**).

More information on how extremes of weather, including heatwaves, can impact on social care delivery, is provided later in this report (**risk H12**).
Case study 9: Summer 2020 heatwave

During summer 2020, there were three episodes that met the Public Health England (PHE) heatwave definition, which were as follows:

- Day(s) on which a Level Three Heat Health Alert (HHA) is issued.
- Day(s) when the mean Central England Temperature (CET) is greater than 20°C.

These three episodes were as follows:

<table>
<thead>
<tr>
<th>Date</th>
<th>Locations</th>
<th>Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 July – 1 August</td>
<td>Various parts of England</td>
<td>CET reached 20°C</td>
</tr>
<tr>
<td>5-15 August</td>
<td>East of England, London and south-east England</td>
<td>HHA Level Three CET reached 20°C</td>
</tr>
</tbody>
</table>

The early August episode had the greatest impact, seeing a long run of days with temperatures reaching 34°C, along with several ‘tropical nights’ where night-time temperatures did not drop below 20°C. 34°C has been recorded in the UK during seven out of the last ten years, compared to seven out of the previous 50 years from 1961 to 2010. This suggests that temperatures of 34°C or higher occurring at some point during the summer are becoming a more common occurrence.

In terms of ‘tropical’ night-time temperatures, when temperatures remain above 20°C overnight, these occurred for five nights on a row in parts of England in August. The number of such nights have nearly doubled between the periods 1961-1990 and 1991-2020.

The health and mortality rate impact from this year’s heatwave was significant and complicated. The total cumulative all-cause excess mortality when factoring out the impact of COVID-19 was estimated to be 2,556, with the vast majority of these in people aged over 65, although several deaths also occurred in under 65s. This was the highest observed since the introduction of the Heatwave Plan for England. Whilst the third summer heatwave episode was prolonged, with very high temperatures recorded during the day and overnight, the severity and intensity of the heatwave alone does not fully explain the magnitude of the impacts observed. Further work is required to explore how the concurrent risk of COVID-19 and heatwaves may have intersected to amplify these impacts.

Given the perceived lack of preparedness for the impact of heatwaves on people’s health and the increasing evidence demonstrating that such events will increase in frequency and intensity in future, there is an opportunity for key national actors to work together and prioritise where interventions will be most beneficial to protect the most vulnerable, in a similar way to the COVID-19 pandemic.
The rates of overheating in English dwellings are estimated to be around 20%. Further analysis shows that there is increased risk of overheating in flats and more energy efficient dwellings. Overheating tends to be higher in bedrooms and dwellings with high levels of insulation and lack of ventilation, which have been observed to overheat twice as frequently. A study has also demonstrated that all new build homes have the potential to overheat in England. The research also showed that mitigation techniques, such as solar shading and increased ventilation, are highly effective at reducing indoor temperature, which in turn reduces the risk of mortality and the impact on productivity associated with sleep loss. Evidence also indicates the key role that occupant behaviours can play in indoor heat exposures. For example, 70% of people surveyed opened only one or two windows at night in London for security reasons. High temperatures can also increase the risk of accidents, affect maternal health, mental health and labour productivity. These issues are of particular concern for workers in the health and social care sectors.

Studies find that many different types of housing are at increased risk of overheating in future because of an increase in the frequency and intensity of heatwave events and extreme high temperatures, leading to a greater number of heat related deaths (figure 11). As such, the present and future magnitude of this risk is high in England.
The Ministry of Housing, Communities and Local Government (MHCLG) published a consultation in 2021 proposing to introduce an overheating standard in new residential buildings, including houses, flats, care homes and residential educational settings, as part of the Future Buildings Standard. If brought into policy this would help tackle the risk of overheating in new buildings. For existing dwellings, there remains little incentive to retrofit adaptation measures to reduce overheating across England.

Benefits of further adaptation action in the next five years

For housing to be suitable for future climates, there is a requirement for coordinated action and optimisation of outcomes against a range of objectives (climate and non-climate related). The evidence indicates that decarbonisation and adaptation policies and strategies are not well aligned. There is also a need for cross-departmental policy and it is important that overheating risks are addressed in all types of buildings where people spend significant time. The Climate Change Committee have made a number of recommendations to Government in relation to housing:

- A legal standard or regulation should be introduced to address overheating risk for current and future climates at design stage of new-build homes or renovations.
- Ensure that passive cooling measures are prioritised over mechanical cooling where a risk of overheating is identified.
- Further action is needed to better understand when overheating occurs in existing homes in order for passive cooling measures and behaviour change programmes to be targeted effectively.

Climate change presents several risks for housing such as flooding and damp and it can be more effective and less expensive, especially for social housing landlords, to address these risks at the same time through retrofitting. Continuous preventative planning to include long-term risks would also have benefits. Other potential solutions include better heatwave warning systems, more investment in adaptive management approaches and better building design.
H2. Health and wellbeing

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>Urgency Score</th>
<th>Risk Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPPORTUNITY</td>
<td>H2. Health and wellbeing</td>
<td>High temperatures</td>
<td>Further investigation</td>
<td>Department for Health &amp; Social Care (DHSC)</td>
</tr>
</tbody>
</table>

**Summary of risk definition and description**

Higher temperatures in winter are likely to reduce the number of cold-related deaths and associated burdens on the NHS, though population aging is likely to offset some of the benefit from warmer winters for cold-related mortality. As well as reducing the risks from cold, there could be health benefits from warmer temperatures that would in turn also reduce disease burdens on the health and social care system.

The physical and mental benefits of increased physical activity and contact with nature are well established, though there remains limited evidence of whether a warmer climate will increase these activities, and this is an area requiring further research to quantify the benefits. Possible benefits of increased time outdoors may, however, include increased Vitamin D exposure, which is important for bone health and the immune system. The introduction of new crops due to warmer temperatures, such as soya, lupins, borage and evening primrose may also have the potential to improve nutrition.

There may also be opportunities through policies such as the National Planning Policy Framework, which sets out that planning policies and decisions that should aim to achieve healthy, inclusive and safe places, and the Environment Bill, which should require developers to deliver at least a 10% improvement in biodiversity value. With increasing temperatures, people may be able to go outdoors more and take advantage of investment in such activities.

However, the opportunities that could arise are currently limited in their understanding and, as such, the opportunity is low in magnitude now and medium in future, therefore further investigation is required. It should also be emphasised that the burden of ill-health from cold homes remains significant in England and is a priority for public health and local government action.

**Benefits of further adaptation action in the next five years**

- There would be benefits of further investment in research as well as strategies to increase physical activity and improve mental health from greater outdoor recreation and active travel (e.g. walking and cycling) due to warmer temperatures.
- Despite a projected reduction in risk, it will be important to maintain planning within the health and social care system for cold weather impacts. The burden from ill-health associated with cold weather and cold homes will still remain significant in the future, even with some decline in hazard due to climate change.
H3. People, communities and buildings

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>Urgency Score</th>
<th>Risk Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISK</td>
<td>H3. People, communities and buildings</td>
<td>Flooding</td>
<td>More action needed</td>
<td>Defra</td>
</tr>
</tbody>
</table>

Summary of risk definition and description

The risk of flooding to people, communities and buildings is one of the most severe climate hazards for the population, both now and in the future. Most of the present and future flood risk is in England, given its larger population. Risk of flooding from rivers is the dominant source, but surface water flood risk accounts for a greater number of properties at risk. Coastal flooding is the most dangerous in terms of impacts for life and property but accounts for a lower number of properties at risk than those affected by surface water or river flooding. Groundwater risk dominates flood risk in some areas but has a limited contribution to the scale of national risk.

Considerable advances have been made regarding the strategic management of flood risk at national and local levels since the last CCRA and whilst flood events have occurred, a larger number of properties have been protected than affected. Despite this, the risk magnitude remains high now and in the future in England with more action needed due to the scale of the risk. Key areas of challenge relate to continued development on the floodplain, the management of surface water flooding via Sustainable Drainage Systems (SuDS), the take up of Property Flood Resilience and the lack of UK-wide standards.

Evidence from Technical Chapter five outlines why England’s communities and buildings remain at a high risk from flooding, commencing with figure 12:

<table>
<thead>
<tr>
<th></th>
<th>Fluvial</th>
<th>Coastal</th>
<th>Surface Water</th>
<th>All Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. people</td>
<td>476,000</td>
<td>102,000</td>
<td>976,000</td>
<td>1,554,000</td>
</tr>
<tr>
<td>Expected annual damages (£m)</td>
<td>172.0</td>
<td>59.5</td>
<td>59.8</td>
<td>291.3</td>
</tr>
</tbody>
</table>

Figure 12: Present day number of people at significant risk of flooding (top row) and present day expected annual damage residential (direct, £m) (bottom row). (Recreated from Health, Communities and Built Environment technical chapter).

In addition:

- Of the 1.9 million people exposed to frequent flooding from either fluvial, coastal or surface water sources, approximately 82% of those live in England.
- In total, there are 2.5 million properties at risk of flooding from rivers and the sea, 3.2 million at risk of surface water flooding and 660,000 properties at risk of all three in England.
- In England, the 2007 floods caused 10-15 deaths. Deaths may occur from drowning and physical injury, car accidents, persons falling into fast flowing water and the impacts on mental health.
Figure 13 shows the significant floods that have occurred since the CCRA2 evidence review in England:

<table>
<thead>
<tr>
<th>Event/date</th>
<th>No. properties flooded</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 2018</td>
<td>520</td>
<td>England: south-east, Midlands</td>
</tr>
<tr>
<td>June 2019</td>
<td>380</td>
<td>England: south-east, Midlands, east</td>
</tr>
<tr>
<td>November 2019</td>
<td>1,100</td>
<td>England: Yorkshire, north</td>
</tr>
<tr>
<td>February 2020: Storm Ciara</td>
<td>1,350</td>
<td>England</td>
</tr>
<tr>
<td>February 2020: Storm Dennis</td>
<td>1,570</td>
<td>England</td>
</tr>
<tr>
<td>Late February 2020</td>
<td>520</td>
<td>England</td>
</tr>
<tr>
<td>December 2020: Storm Bella</td>
<td>400</td>
<td>England</td>
</tr>
<tr>
<td>January 2021: Storm Christoph</td>
<td>675</td>
<td>England: central, north</td>
</tr>
</tbody>
</table>

Figure 13: Recent flood events in England (Recreated from Health, Communities and Built Environment technical chapter).

Figure 14 outlines the estimated economic damages from large scale flooding events in England since the 2007 floods, although it is noted that the economic damage avoided from the flood protection provided is at least 14 times greater:

<table>
<thead>
<tr>
<th>Event/date</th>
<th>Estimated economic losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer 2007</td>
<td>£3.9 billion</td>
</tr>
<tr>
<td>Winter 2013-14</td>
<td>£1.3 billion</td>
</tr>
<tr>
<td>Winter 2015-16</td>
<td>£1.6 billion</td>
</tr>
<tr>
<td>Winter 2019-20</td>
<td>£0.3 billion</td>
</tr>
</tbody>
</table>

Figure 14: Economic losses from recent flood events in England (Recreated from Health, Communities and Built Environment technical chapter).

There is also considerable evidence of the mental health impacts of being affected by flooding, including increases in anxiety, post-traumatic stress disorder (PTSD) and depression. A study has found that the prevalence of probable depression amongst those whose homes were flooded was 20.1%, anxiety 28.3% and PTSD 36.2% a year later.

In future, climate change will increase the number of properties at risk of flooding from all sources, including in areas that have not previously been at risk of flooding. In addition to climate change, housing need and economic growth requiring more development will also exacerbate flood risk. Building within the floodplain needs to be minimised, and properties developed in flood risk areas need to incorporate appropriate resilience measures and sustainable drainage design for the lifespan of the development. Future flood risk changes are projected to include the following:

- Overall, for the UK, the largest projected increase in risk relates to coastal flooding in England.
- Current risk is most prevalent for surface water flooding and therefore future increases result in substantial numbers at risk but the impacts for households are generally lower for surface water flooding compared with river and sea flooding.
- Expected annual damages from flooding in England is projected to rise 137% by the 2050s and 269% by the 2080s.
• At the local level, the largest future flood risk is evident in coastal areas including the top three risk locations of Hull, Portsmouth and Sedgemoor District Council.
• Current budgets for maintenance and repairs of flood protection assets in England may need to increase annually by between 30% and 80%, some £30 to £75 million per year, to address the greater potential for deterioration.

In England, there are various plans to tackle different sources of flooding and increasingly these are more holistic, helping to overcome previous concerns regarding the lack of a statutory, long-term strategy that addresses the likely climate change risks and their differing time and spatial scales. The Government has also committed to double its capital investment in flood and coastal defences in England to £5.2 billion to 2027. This new investment is intended to ensure that a further 336,000 homes and non-residential properties are better protected from flooding and coastal erosion. The investment also aims to avoid the disruption caused by flooding to the daily life of over four million people, avoid £32 billion of wider economic damages, create or improve 5,440 hectares of natural habitat and enhance 830km of rivers. Such policy and investment is fundamental to ensuring projected increases in flood risk can be managed. More information on relevant policy and progress relating to this risk is England is given in technical chapter 5.

Benefits of further adaptation action in the next five years

• It would be beneficial to understand how new developments built in at-risk areas are being made safe and resilient, for all new properties in high risk locations. This information should be publicly available by development.
• The lack of a statutory requirement and monitoring for SuDS across England remains a continued challenge. With surface water flood risk projected to increase under all scenarios and the need to achieve biodiversity (and soon environmental) net gain in all new development, there is a strong argument for greater enforcement (case study 10).
• Data collected for England shows that the uptake of property flood resilience measures remains much lower than the potential cost-beneficial rate of uptake. Actions now need to be implemented to address this.
• Whilst there is a substantial body of research being conducted to inform and facilitate a change in approach from protection to embracing a range of measures that achieve resilience, working across the UK nations and widely sharing outcomes from case study examples and initiatives such as the Flood and Coastal Resilience Innovation programme in England is needed to enable a more integrated approach.
• This could also generate fuller public engagement about the respective roles of different actors in reducing risk and taking adaptive measures, as well as helping to promote community level responses that could build resilience.
• There is an economic case for increasing investment in socially vulnerable areas and introducing new metrics focused on reducing social vulnerability to flooding in UK government and devolved administration outcome measures could help further mitigate the social costs of flooding, which could improve upon current approaches.
Case study 10: Leicester SuDS Programme

This project, led by Leicester City Council, involved the establishment of an advisory group, comprising district and county councils, to inform developers in the Leicester area about using SuDS. Running in parallel to a surface water management scheme, it was primarily a capacity-building project comprising of stakeholder engagement through training workshops and the production of a Sustainable Drainage Guide.

The project has helped catalyse initiatives such as installing areas of permeable paving, swales, a connected rain guard scheme on Mill Lane, creating of Ellis Meadows and re-naturalising channels, the latter of which has reported to have led to the protection of 1,200 properties from flooding.

Capacity building is a key part of the programme and involves strengthening the knowledge base for taking to developers by gathering evidence, and therefore having the ability to provide people with practical options. Lessons from this scheme can be learnt and copied in other locations in England. Indeed, it has been reported that this project has influenced projects beyond Leicester, with other local authorities adopting the guidance.

Some of the outputs and outcomes of the programme include:

- The production of the Sustainable Drainage Guide.
- Approximately 15 training sessions delivered to stakeholders external to Leicester City Council, each session attracting 20-30 attendees.
- The guide has influenced the delivery of several successful SuDS projects in the city.
- Two of the schemes that have been implemented through the programme (Mill Lane and Ellis Meadows) have won industry awards in recognition of their approach to the use of SuDS in developments.

H4. Viability of coastal communities

Summary of risk definition and description

This risk is focused on coastal change, that is, the physical change to the shoreline caused by coastal erosion, coastal landslip, permanent inundation or coastal accretion that is of such severity that the long-term sustainability and viability of coastal communities is threatened.

Parts of the south and east coasts of England already face risks to their viability because of coastal change. England’s east coast has, indeed, seen the most catastrophic coastal flooding events in 1953 and 2013 (figure 15). Climate projections suggest greater sea level rise than had been projected previously and in response to this, considerable work has been conducted to enhance both an understanding of coastal risk and policy and strategy development. Whilst the threats to the viability of coastal communities are widely recognised and Shoreline Management Plans include policies to support managed realignment, there is little evidence of a strategic approach to identify and support communities at risk. The current picture in England is as follows:

- Approximately 1,800 kilometres (40%) of England’s coastline and 8,900 properties are at risk from erosion if coastal defences are not considered.
- Since 1996, around 50 permanent properties and 30 temporary properties have been lost because of coastal erosion, plus around 100 beach huts.
- North Norfolk, especially villages along the coast between Cromer and Great Yarmouth, are particularly at risk.
- All but one of the SurgeWatch severe coastal flooding events have affected England, as follows:

<table>
<thead>
<tr>
<th>Date</th>
<th>Category</th>
<th>Locations in England affected</th>
<th>County, region or country</th>
</tr>
</thead>
<tbody>
<tr>
<td>January 1953</td>
<td>6</td>
<td>Norfolk, Kent, Spurn Head, Humber, London</td>
<td>North Sea (England), Thames</td>
</tr>
<tr>
<td>October 1927</td>
<td>5</td>
<td>Mersey, Fleetwood, Blackpool, Sandilands</td>
<td>Mersey, Fleetwood, Blackpool, Sandilands</td>
</tr>
<tr>
<td>January 1928</td>
<td>5</td>
<td>London (City), Southwark, Putney, Hammersmith, Westminster, Mersea, Maldon (Essex), Norfolk</td>
<td>London (City), Southwark, Putney, Hammersmith, Westminster, Mersea, Maldon (Essex), Norfolk</td>
</tr>
<tr>
<td>November 1977</td>
<td>5</td>
<td>Fleetwood, Morecambe, Pilling, Blackpool, Lytham</td>
<td>Irish Sea (England)</td>
</tr>
<tr>
<td>January 1978</td>
<td>5</td>
<td>Wells-next-the-Sea, King’s Lynn, Cleethorpes, Wisbech, Sandilands, Mablethorpe, Trustrhorpe, Ingoldmells, Walcott, Deal, Alnmouth, Amble Harbour, Berwick-upon-Tweed, Blyth, Hayling, Cowes, Bembridge</td>
<td>North Sea (England), English Channel (the Solent)</td>
</tr>
</tbody>
</table>
In future, these impacts could become more significant as outlined below with the risk assessed as becoming medium in 2050s and high in 2080s:

- Sea level rise of half to one metre could lead to 200km or more of coastal defences becoming particularly vulnerable to failure in some conditions and may not be cost-effective to maintain in the future. This is around 4% of the English coastline and 20% of the coastline with coastal defences.
- Under a worst-case scenario, the number of people in England at significant risk from coastal flooding is projected to increase from a baseline of just over 100,000 now to 757,000 by the 2080s.
- The areas, identified as Coastal Change Management Areas, will be at more threat with regards to their viability in the future due to climate change impacts, specifically sea level rise, and therefore the magnitude of this risk rises from low at present to high in future.
- Tabled below (figure 16) is the estimated increase in the number of residential properties at risk from coastal erosion.

<table>
<thead>
<tr>
<th>Date</th>
<th>Category</th>
<th>Locations in England affected</th>
<th>County, region or country</th>
</tr>
</thead>
<tbody>
<tr>
<td>December 1981</td>
<td>5</td>
<td>Somerset (Burnham on Sea, Brean, Weston, Uphill, Sand Bay, Wick St Lawrence, Kingston Seamoor, Clevedon, Pawlett), Portsmouth, Hayling Island, Langstone, Fareham, Ryde, Cowes, Freshwater, Yarmouth, Southampton</td>
<td>English Channel (the Solent), Bristol Channel</td>
</tr>
<tr>
<td>January 2005</td>
<td>5</td>
<td>Warkworth (River Coquet, Northumberland)</td>
<td>North Sea (North East)</td>
</tr>
</tbody>
</table>

In England a new Policy Statement and accompanying Flood and Coastal Erosion Risk Management (FCERM) Strategy (insight 4) were published in 2020. The Strategy has a strategic objective to help coastal communities transition and adapt to climate change.
Benefits of further adaptation action in the next five years

Defra has recently highlighted ways to improve coastal change in adaptation which could be enacted over the next five years.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Possible action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strategic planning</strong></td>
<td>• Interpretation of and required actions relating to Coastal Change Management Areas.</td>
</tr>
<tr>
<td></td>
<td>• How to bring adaptation planning in line with Shoreline Management Plan (SMP) delivery.</td>
</tr>
<tr>
<td></td>
<td>• Improved strategies across SMPs and policy unit boundaries.</td>
</tr>
<tr>
<td><strong>Legal</strong></td>
<td>• Perceived needs related to legal issues include guidance on and support with articulating a clear legal framework around adaptation planning, roll back and other adaptation policy implementation processes.</td>
</tr>
<tr>
<td><strong>Funding</strong></td>
<td>• Perceived needs related to funding include guidance on and support with:</td>
</tr>
<tr>
<td></td>
<td>o Developing and delivering long-term investment strategies.</td>
</tr>
<tr>
<td></td>
<td>o Full suite of financing options available.</td>
</tr>
<tr>
<td></td>
<td>o How to best incentivise roll back.</td>
</tr>
<tr>
<td></td>
<td>o Development of new financial products that could enable vulnerable communities to adapt cost-effectively.</td>
</tr>
<tr>
<td><strong>Community engagement</strong></td>
<td>• Raising awareness of SMP and policies generally, including how to convey that there may be risks with policy non-deliverability due to longer term funding gaps.</td>
</tr>
<tr>
<td></td>
<td>• Securing funds for dedicated and skilled community engagement individuals to reduce future risk and raise awareness.</td>
</tr>
<tr>
<td></td>
<td>• Securing engagement and buy-in from elected councillors.</td>
</tr>
<tr>
<td></td>
<td>• Strategic planning for supporting community infrastructure.</td>
</tr>
<tr>
<td></td>
<td>• Strategic planning for caravan park businesses and their inhabitants.</td>
</tr>
<tr>
<td><strong>Monitoring</strong></td>
<td>• Perceived needs related to monitoring include guidance on and support with monitoring coastal erosion, monitoring property and infrastructure at risk and when lost to coastal erosion (including temporary infrastructure e.g. caravans).</td>
</tr>
</tbody>
</table>

*Figure 17: Potential adaptation in coastal areas (Recreated from Health, Communities and Built Environment technical chapter).*
H5. Building fabric

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>Urgency Score</th>
<th>Risk Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISK</td>
<td>H5. Building fabric</td>
<td>Moisture, wind and driving rain</td>
<td>Further investigation</td>
<td>MHCLG</td>
</tr>
</tbody>
</table>

Summary of risk definition and description

As well as occupants, the bricks and mortar of homes are also at risk from climate change. Examples include increased damp due to flooding and intense rain, structural damage due to high winds and subsidence caused by drought. These can cause harm to occupant health and wellbeing and create significant repair costs for homeowners.

It is difficult to separate out how this risk is likely to change in future specifically in England, but in summary the likely future impacts on building fabric due to climate change are included as follows:

<table>
<thead>
<tr>
<th>Future climate change variable</th>
<th>Projected future impact</th>
</tr>
</thead>
</table>
| Increases in precipitation     | • Requirement for increased ventilation to remove indoor moisture.  
                                | • Winter ingress in building fabric after heavy rainfall events.  
                                | • Water penetration of vertical walls in dwellings. |
| Increases in temperature       | • May help to reduce mould growth and enable damp to dry faster, provided there is adequate ventilation. |
| Increases in windstorms        | • There is little evidence that windstorms will increase due to climate change, but should this happen more damage to buildings would occur. |
| Increase in heatwaves          | • This could lead to an increase in subsidence, especially in prone areas such as London, the Cheshire Plain and the Vale of York leading to greater damage and insurance claims. |

Figure 18: How climate change could affect building fabric (Recreated from Health, Communities and Built Environment technical chapter).

The two main risks that are of most concern for England are wind-driven rain in the north and subsidence in the south. In terms of insurance costs and costs to households, subsidence represents the biggest impact related to this risk. Therefore, the overall risk in England is higher than the rest of the UK, at medium today rising to potentially high in future.

However, the impact of climate change on these specific hazards is highly uncertain as they are not well described in climate scenarios and evidence of the impact of climate hazards on building fabric, particularly the prevalence of current impacts and costs to households, is limited. The presence of at least some relevant building standards means that the present-day risk is being considered for new build homes or those undergoing refurbishment. However, there is little evidence that the future risks from climate change in both +2°C and +4°C at 2100 scenarios are yet being integrated into planning, building design or retrofit.
Benefits of further adaptation action in the next five years

- Most adaptations related to building fabric are currently reactive, i.e. they happen after the damage has occurred to repair the home. There would be benefits to more proactive action to assess risks, including measurement of indoor environmental quality and better prediction of risks like subsidence. This would include factoring in the possible impact of climate risks based on +2°C and +4°C at 2100 scenarios into planning, building design and retrofit.
- Measures to improve energy efficiency in new and existing housing, such as increased insulation and airtightness can lead to increased risk of moisture-related damage to building structure and the internal environment if additional ventilation is not also included. Taking a more integrated approach to design for new builds and retrofit will have multiple benefits, not least to avoid issues like higher indoor vapour and mould growth.
- An important response to windstorm risks is household insurance. Retrofit interventions to existing homes like stronger doors and windows have high up-front costs but also high benefits. New builds would benefit from more consideration of siting, orientation, design and materials used in advance of construction to reduce the risks from wind.
H6. Household energy demand

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>Urgency Score</th>
<th>Risk Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISK &amp; OPPORTUNITY</td>
<td>H6. Household energy demand</td>
<td>Summer and winter temperature changes</td>
<td>More action needed</td>
<td>BEIS</td>
</tr>
</tbody>
</table>

Summary of risk definition and description

Household heating demand dominates energy use in housing at present. Future heating demand will be reduced by climate change due to warmer winters, and cooling demand is likely to increase in summer, though this is very dependent on how much households take up mechanical cooling measures like fans and air conditioning. Winter fuel poverty could reduce in the future, but ‘summer fuel poverty,’ where householders may not be able to afford cooling, could rise.

The exact level of risk or opportunity, trading off between reduced heating and increased cooling, remains hard to quantify. In addition, changing energy policy to meet the UK’s Net Zero carbon targets will have a high influence on this opportunity as there will be big changes in energy efficiency, fuel types used, total electricity demand given increasing electrification of the energy grid, and also what types of heating and cooling devices will be most effective in homes given these changing demands in winter and summer.

As outlined above, while there are benefits everywhere from reduced winter heating, the changes in cooling demand with climate change are likely to be strongest in England. A study outlined in technical chapter 5 reports a potential rise from 5.1 million to 12.8 million households with cooling by 2050 with an associated demand ranging from 5TWh to 13TWh in extreme hot weather. Other estimates suggest that the costs for cooling could be in the range £10-99 million per year in the 2020s, £100 million-£1 billion per year in the 2050s and in excess of £1 billion per year by the 2080s, which are large but still much lower than the benefit in reduced costs in winter heating. Therefore, the risk magnitude score for summer cooling is medium now in England but high in future. The opportunity for reduced winter heating is low now but high in future all UK nations.
Benefits of further adaptation action in the next five years

Policies and strategies for space heating and cooling in dwellings would be more successful if they include consideration of the changing climate and its effect on energy demand in homes alongside the need to decarbonise. The size of the potential for reduced household energy costs, lower emissions and better indoor environmental quality is enormous if an integrated approach is taken that looks at adaptation and emissions reduction together. At the same time, the fast pace of development of Net Zero carbon policies at the moment could lock-in future options that do not represent the best approach if adaptation is left out. There is a need for better integration of this issue in Net Zero policy analysis, and in subsequent government intervention to deliver Net Zero.

This risk/opportunity has been highlighted in the risk assessment as particularly likely to benefit from an ‘adaptive pathway’ approach, meaning various policy choices are mapped out against different future climate change and Net Zero scenarios, and the choices are narrowed down over time as uncertainty decreases. Adaptive pathways are used routinely in the flooding and water sectors, but to date have not been used widely in energy policy.

There is also a need to build increased cooling demand into energy policy, including:

- Incorporating future changes in energy demand from warmer winters and hotter summers into energy efficiency and low carbon heating policy and technologies being rolled out across the UK.
- Incentivising the uptake of passive cooling over mechanical cooling measures as far as is appropriate.
- Providing support to households that might experience ‘summer fuel poverty,’ for example by an inability to afford air conditioning if this is required.
H7. Health and wellbeing

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>Urgency Score</th>
<th>Risk Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISK</td>
<td>H7. Health and wellbeing</td>
<td>Changes in indoor and outdoor air quality</td>
<td>Further Investigation</td>
<td>DHSC</td>
</tr>
</tbody>
</table>

Summary of risk definition and description

Weather patterns can affect the formation and dispersion of air pollutants. Climate change may also change emissions of some pollutants or precursors of health-relevant pollutants. The incremental change in risk from climate change only, compared to non-climate causes, is uncertain. Air quality issues have been divided into three areas based on the different policy approaches:

- Outdoor air quality associated with anthropogenic sources (including traffic, industry and agricultural sources) and wildfires. The main health-related hazard is particulates (PM2.5 and PM10) and nitrous oxides, though ground level ozone also affects health but levels have declined in recent decades. Recent heatwave events have not been associated with high levels of ground-level ozone in England. Air pollution emissions from combustion are falling rapidly and are expected to decline significantly under most Net Zero carbon scenarios, thus the baseline level of pollution and interactions with climate change is likely to reduce the future risk for outdoor air quality.

- Indoor air quality is dependent on building characteristics, ventilation, emissions from indoor sources and external air quality. Indoor air quality could be affected by interventions for Net Zero that can affect the ventilation of buildings. Higher temperatures may also improve or reduce indoor air quality; if temperatures are higher then people may open windows more which could provide increased air circulation. However, in instances of poor outdoor air quality this could reduce the quality of indoor air. Overall, however, there is very little evidence on the impact of climate change on indoor air quality.

- Natural (non-anthropogenic) sources of air quality related to pollen and mould (see H5) that affect health. Pollen risks are likely to change with climate change although the implications for health are not clear.

Evidence specific to England is difficult to determine for this risk, but wildfire could be one significant contributor to outdoor air pollution, more so in England than compared to other UK nations. The summer of 2018 was a particularly hot and dry summer which likely contributed to more favourable conditions for the outbreaks and severity of wildfires, including two major wildfires that were declared as major incidents in the north-west of England, as well as several smaller wildfires in various other parts of England (case study 11).

There is uncertainty over the degree to which climate change will impact on some air pollutants such as wildfire-induced air pollution, pollen and the interactions with extreme heat or changing wind patterns, and further research is needed here. In addition, there is some uncertainty over the future baseline that climate change will be acting upon, as it is uncertain how far current policies will be effective in reducing air pollution.
Benefits of further adaptation action in the next five years

The main action that will have benefits in the next five years will be the implementation of the Clean Air Strategy (2019) and Net Zero policies. Any further actions that reduce levels of outdoor pollutants in general will also have a positive effect on future air quality. In addition:

- Further research on climate change impacts on wildfire and pollen risks, and their effects on health, would be beneficial, especially in England where wildfire risk is expected to grow (case study 11).
- More research on the relationship between air pollutants and extreme heat would also be beneficial.
- Considering health co-benefits and trade-offs of potential adaptation actions for air quality may be helpful, for example nature-based solutions and improving green spaces.
- Consideration of how interventions to increase airtightness of buildings may worsen indoor air quality would be beneficial.
Case study 11: Saddleworth Moor wildfire

The summer of 2018 was a particularly hot and dry summer which likely contributed to more favourable conditions for the outbreaks and severity of wildfires, including two major wildfires that were declared as major incidents in the north-west of England, as well as several smaller wildfires in various other parts of England. The Saddleworth Moor wildfires, near Manchester, were some of the largest UK wildfires on record (approximately 8km² at their peak) and lasted for approximately three weeks, resulting in various consequences, especially with respect to increasing air pollution.

The fires emitted large quantities of smoke, trace gases and aerosols which were transported downwind over the highly populated regions of Manchester and Liverpool. Surface observations of PM2.5 indicate that concentrations were 4 to 5.5 times higher than the recent seasonal average, shown by the black lines on the graphs reflecting emissions in nearby locations. In addition, emission rates of carbon monoxide (CO) and Carbon Dioxide (CO₂) were similar to values expected from a medium sized power station.

Emissions from peat are poorly understood but it is thought that during the flaming stage, fires emit large amounts of soot and nitrogen oxides (NOₓ), while in the smouldering stage they emit much more CO, methane (CH₄), volatile organic compounds (VOCs) and particulate matter (PM).

Due to the vastness and longevity of the fire, more than 50 homes were evacuated in Carrbrook near Stalybridge, Greater Manchester, and 150 people affected in total. The local fire service said that the smoke levels in the air were not "toxic" but could be an "irritant," and local residents were advised to close windows. It was reported that the smoke was making people cough and cover their mouths. Four local schools also had to be closed.

In more recent years, the UK has experienced several substantially larger fires than were generally recorded previously, which have reduced air quality and resulted in the evacuation of surrounding populated areas. Learnings from Saddleworth Moor would be extremely helpful to better understand potential adaptation measures that could prevent the commencement and reduce the spread of wildfires, in light of a projected increase in favourable conditions due to climate change in future. Such measures could also focus on working with local residents in prone areas to prepare them for potential increases in air pollution when fires occur.

Source: Environmental Research Communications journal; BBC News
Image: © Environmental Research Communications journal, image freely available to download
H8. Health

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>Urgency Score</th>
<th>Risk Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISK</td>
<td>H8. Health</td>
<td>Vector-borne disease</td>
<td>More action needed</td>
<td>DHSC</td>
</tr>
</tbody>
</table>

Summary of risk definition and description

Some diseases transmitted by insects and ticks (vectors) are likely to change in prevalence in the future due to warmer temperatures changing the distribution of the vector in the UK as well as diseases acquired by people overseas and being brought back into the UK (see ID9). The key factors associated with the former include the following:

- **Lyme disease** cases may increase with climate change due to an extended transmission season and increases in person-tick contact. Northern and south-west England is especially at risk.
- **Culex is a species of mosquito.** The risk of Culex-transmitted diseases may increase in England. West Nile Virus was found established in two marshland sites of the Thames Estuary and has since been found at other sites in south-east England.
- The risk of mosquito-transmitted diseases (such as Chikungunya and Dengue fever) is likely to increase in England and climate modelling indicates that southern England could become warm enough for establishment of the mosquito (*Aedes albopictus*) which carries these diseases. The risk that malaria may become established remains low.
- Exit from the EU may undermine actions to control vector-borne diseases through reduced access to international surveillance systems. However, at the time of writing, it is not known whether the UK will have continued access to international public health surveillance systems such as those coordinated by the European Centre for Disease Prevention and Control (ECDC).

As the examples above suggest, more action is needed to tackle the potential impacts of this risk in England.

The current magnitude score for England has been assessed as medium now reflecting evidence of existing vector-borne disease cases from ticks and mosquitoes. The risks from lock-in are high, because once a new disease or vector is established, it may not be possible to eradicate. The economic costs could be potentially very high if any of the diseases assessed become established. There may also be indirect costs due impacts on leisure, travel and tourism. The future score for England has been assessed as medium in 2050s, moving to high in 2080s due to projected increases in temperature leading to the possible establishment of *Aedes albopictus* mosquito. All future scores have been assessed as a low confidence due to the uncertainty around whether vectors will become established.

Benefits of further adaptation action in the next five years

Disease and vector surveillance is a public good and there are likely to be direct benefits to improve this given how important it is to catch vectors and pathogens before they become established. The main benefits of further action are in enhanced monitoring and surveillance systems, including early warning, and these can be considered a low-regret option. Surveillance programs are highly cost effective. There are also studies that show that vaccinations for tick-borne encephalitis may be cost effective, although there is currently no vaccine for Lyme disease.
H9. Food safety and food security

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>Urgency Score</th>
<th>Risk Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISK</td>
<td>H9. Food safety and food security</td>
<td>Higher temperatures (food safety) and extreme weather (food security)</td>
<td>Further Investigation</td>
<td>Defra</td>
</tr>
</tbody>
</table>

Summary of risk definition and description

Increases in extreme weather patterns, variations in rainfall and changing annual temperatures will impact the occurrence and persistence of bacteria, viruses, parasites, harmful algae, fungi and their vectors in crops and livestock produced in the UK. Animal products (meat and eggs) carry a higher risk than vegetables. In terms of food security, access to healthy and affordable food is a public health issue; food insecurity driven by stock shortages or higher prices is often associated with inadequate intake of fruit, vegetables and some essential micronutrients. Some studies project an average rise in price of 20% by 2050, though with a large uncertainty range. Due to the large burden of disease associated with food safety and the potential for very significant impacts from near term shortages in access to healthy foods, this risk is already considered to have a medium-high magnitude, rising to high under higher emissions scenarios across the England.

Risks specific to England are hard to determine, but there is some evidence of the impacts of climate change on food safety and security. Regarding food safety, there have been incidences of weather related toxin presentations in shellfish which can be harmful for human health and it was indicated by a recent survey that quantifiable amounts were present in shellfish from southern England where waters are slightly warmer. In relation to food security, an example of how climate change could affect this comes from the reduction in crop yields (see N6).

Warmer temperatures have implications for longer periods suitable for crop growth and livestock to be outdoors, presenting possible opportunities for England’s agricultural sector. However, the growing season is likely to be disrupted by heat stress and reduced summer precipitation. Climate change could also have an impact on food supply, prices and quality internationally. However, the UK currently is lacking in specific policies to address the implications of climate change for food safety or food security and the magnitude of all related future risks is high with low confidence, hence further investigation is required.

Benefits of further adaptation action in the next five years

For food safety, food regulations and education on food handling and safety, coupled with horizon scanning and continuous monitoring for emerging risks, are likely to be low-regret options.

For food security, the private sector and Government both have a role to ensure a higher level of resilience along supply chains. Routine monitoring of food security across England is also essential to protect public health and limit unnecessary costs for the health and social care system. Predicting future climate risks to the food system will ensure vulnerable groups to food insecurity are protected and the impacts to public health are minimised.
H10. Health

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>Urgency Score</th>
<th>Risk Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISK</td>
<td>H10. Health</td>
<td>Poor water quality and household water supply</td>
<td>Further investigation</td>
<td>Defra</td>
</tr>
</tbody>
</table>

Summary of risk definition and description

Climate change and reduced summer precipitation resulting from climate change will increase the likelihood of periods of water scarcity and droughts. Together with demand increases from economic and population growth, this may lead to interruptions of household water supplies and associated health, social and economic impacts, particularly for vulnerable households. Private water supplies are most vulnerable to current and future climate hazards that affect water quality (outbreaks) and quantity (interruption of supply), and are particularly important for more isolated communities. Climate change may also increase the risk of contamination of drinking water through increased runoff and flooding events that overwhelm current water treatment approaches. Risks to health from contact with bathing water (sea, lakes and rivers) and harmful algal blooms may also increase with climate change.

South-east England is already water stressed and analysis of the impacts of climate change on future water supply identify that deficits are likely by the middle of the century in other parts of England too. Around 16.7 million people currently live in water resource zones that are in deficit, with 7.9 million of these in London. There are other specific concerns around this issue in England, as outlined by the below evidence.

- Two dry winters in 2011 and 2012 caused conditions in April 2012 that were worse than any historic drought for the south and east. It was one of the most significant ‘near-miss’ events in recent years and significant disruption was only avoided by an exceptionally wet summer.
- There were 504 water treatment failures in 2017 due to heavy rainfall events, which risked maintaining good quality. Of these, 216 were significant and ten were serious. Contamination can be in the form of waterborne pathogens such as Cryptosporidium and E.Coli and they can be caused by heavy rainfall.
- In 2019, 3.4% of private water supplies failed to meet European quality standards. However, this is an improvement since 2010 where the figure was 9.6%.
- In early September 2018, a notable blue-green algal bloom was recorded in the Lake District persisting into November, despite it being unexpected to detect blooms in winter months, and this was thought to be due to warmer temperatures.

In terms of water quality impacts this risk is scored as medium for current and future risks because the burden on health and welfare in terms of disease incidence across the UK.

There is very little evidence about the effects of droughts and household water supply interruptions on human health and wellbeing. There is a large potential impact but the evidence is limited due to uncertainties in the future climate. The risk of major drought increases in the future with water supply deficits projected for parts of England (with the highest risk in the south east where current water supply is limited). At present, water supply deficits in the south east are not resulting in health and wellbeing implications for people in terms of TUBs or other use restrictions. However, a major drought leading to loss of water to thousands or hundreds of thousands of households is possible and therefore the future risk for England (2050s and 2080s, both climate futures) is assessed as being high magnitude.
Benefits of further adaptation action in the next five years

There are likely to be benefits of further actions to improve water quality by reducing the risk of surface water flooding, such as the development of SuDS, catchment management and wetland creation. Nature-based solutions can also help reduce this risk, as well as helping to reduce the effect of the urban heat island.

Increased consideration in emergency planning may also be beneficial, so that responses to emergencies (e.g. exposure to chemicals in flood waters, private water supplies being cut off or major droughts) can be ramped up quickly as needed. Further activities may be required to protect private water supplies too. Alongside this, there are a complementary set of water saving measures that can be introduced by homes, many of which are no and low-regret.
H11. Cultural heritage

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>Urgency Score</th>
<th>Risk Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISK</td>
<td>H11. Cultural heritage</td>
<td>Changes in temperature, precipitation, groundwater, land, ocean and coastal change</td>
<td>More action needed</td>
<td>DCMS</td>
</tr>
</tbody>
</table>

Summary of risk definition and description

This risk describes the effects of climate change on cultural heritage, including moveable heritage (museum collections and archives), archaeological resources, buildings and structures, cultural landscapes and associated communities, and intangible heritage (folklore, traditions, language, knowledge and practices). The impacts of climate change on cultural heritage across England are being observed now, with the main risks being extreme weather fluctuations, increasing temperatures (heatwaves or fires), precipitation and flooding, coastal processes, and from unintended consequences of climate mitigation and adaptation within the heritage sector and across other sectors.

There have been recorded incidents in recent years that show how climate related pressures can impact on heritage assets, including waterlogging of archaeological sites, damp problems and water ingress issues at historic properties, loss of archives and cultural heritage from flooding, changes in groundwater levels affecting historic gardens, new pest species threatening heritage landscapes, risks to health and buildings during heatwaves and damage to assets caused by wildfires (figure 19). Coastal heritage is particularly at risk from climate change due to sea level rise. Heritage organisations and communities may need to accept the loss of some heritage assets.

There are opportunities too, for example increasing footfall to heritage assets in warmer summers, although increased visitors can also lead to erosion of heritage sites. Heritage organisations have undertaken assessments to scope the risk to assets. Regarding flooding, there is evidence of maladaptation occurring where traditional materials in a building’s fabric are replaced with more modern materials after it has been flooded. If well maintained with appropriate materials, traditionally constructed buildings can recover well from flooding, often better than their modern counterparts. The magnitude for this risk is medium at present but rising to high in future across England.

<table>
<thead>
<tr>
<th>Climate hazard</th>
<th>Impacts on cultural heritage</th>
<th>Examples of observed impacts in England</th>
</tr>
</thead>
</table>
| Heavy rainfall | • Failure of building envelope, with subsequent moisture/damp problems.  
• Possible increases in roof leakage due to modern roofing designs, including the addition of insulation at rafter level and associated waterproofing materials.  
• Waterlogging of gardens and archaeological sites. | • Wimpole, Cambridgeshire  
• Westbury Court Gardens  
• Studley Royal Water Garden  
• Arden Mill  
• Derwent Valley Mills |
| Drought       | • Increased risk of subsidence and shrink-swell impact on buildings.  
• Drying of waterlogged archaeological sites.  
• Exposure of new archaeological sites. | |
- Invisible deterioration of archaeological deposits (buried and full impact only apparent when excavated).
- Changes in groundwater levels affecting parks and gardens.
- Long-term impact on resilience of plants and trees.

**Nymans Gardens, Sussex**

- Flooding (fluvial, pluvial)
  - Harm to buildings from water ingress.
  - More modern listed buildings may be at risk of catastrophic damage in a flood.

- Carlisle Civic Centre was demolished because it was not possible to dry

- Grinton smelting mill and watercourse

- Ironbridge Gorge

- **High summer temps**
  - Overheating of buildings leading to problems for fabric, building use and for sensitive collections.
  - Increasing demand for air conditioning, which increases problems such as condensation and deterioration of sensitive materials.
  - Increased visitor numbers, leading to some positive impacts.

- Yorkshire Dales Barn

- Knebworth House

- Ham House

- **New pest species**
  - More common and more rapid deterioration of stone and wood structures.
  - Risk of new pests able to metabolise building timbers.
  - Increased bioturbation of archaeological sites.
  - Increased water temperatures leading to new pests affecting marine archaeology.
  - Pests and diseases of landscape plants, including increased numbers and new variants.
  - Threats from pests and diseases such as *Xylella*, *Emerald Ash Borer Beetle* and *Plane Wilt* will have an impact upon our designed landscape.

- Appearance of overwintering populations of termites; Asian longhorn beetle, Shipworm

- Clothes Moth, Brodsworth Hall

- Mompesson House

- Castle Drogo

- Hardwick Hall

- Knole

- English Heritage's Operation

- **Changed growing seasons**
  - Impacts on raw materials for repair of buildings.
  - Increased plant growth on historic structures.

- 2020 failures of long-straw harvests

- Blooming of desert plants across Royall Horticultural Society gardens

- **Wildfire**
  - Potential loss of heritage assets.
  - Potential to discover new archaeological sites.
  - Changes to landscape management to reduce risk, e.g. fire breaks may harm cultural heritage.

- Woolbsbarrow hillfort, Dorset

- Saddleworth Moor

- Winter Hill

- **Coastal change**
  - Greatly increased rate of loss of coastal assets.
  - Impact of adaptation schemes, e.g. construction of coastal defences.
  - Changes to salinity of groundwater affecting plant growth in historic landscapes, parks and gardens.

- Liverpool Bay

- Orfordness

- Dunwich Greyfairs

- Happisburgh Village, Hallsands

- The Garrison, St Mary's

- Hurst Castle, Hampshire

- **Oceanic changes**
  - Changes to water chemistry leading to breakdown of marine heritage.

- Some warm-water marine species (e.g. squid, anchovies) more common and targeted by fishers
Fishing is one of the UK’s most important maritime activities: changes in distribution of marine species change traditional fishing.

- Disruption of traditional foods as cod might not be able to persist around the UK in the future, if sea water temperatures continue to rise
- Increased acidification disrupt shellfish growth and harvest

Figure 19: Observed impacts on cultural heritage from climate hazards (Recreated from Health, Communities and Built Environment technical chapter).

There is no current overall comprehensive assessment of future risks to heritage in England. Although Historic England reports annually on the Heritage at Risk (HAR) Register, this does not specify climate change nor does it consider future scenarios of climate change. It does consider some hazards that are linked to current climate risks, such as flooding from all sources, erosion and plant and insect growth/damage. This reveals that over 23% of listed buildings in England are at risk of flooding along with approximately 18% of Scheduled Monuments. More than half of all parks, gardens and battlefields are at flood risk but this is likely to be less damaging to these assets than to built heritage.

However, awareness of climate risk to heritage has increased. Historic England is undertaking research to map risks to buildings and heritage assets to improve decision making. The organisation has also taken measures to increase flood resilience and recovery in historic and traditionally constructed buildings.

The risk magnitude for England is medium at present but rising to high in future due to the large number of assets thought to be at risk, and more action is needed.

Benefits of further adaptation action in the next five years

Further action would be beneficial to map climate related hazards and understand the vulnerability of different heritage assets, and identify those types of assets and locations most at risk. The complexity of ownership of heritage assets and overlaps with landscape, land management and the natural environment mean that this is complex. Standardising data collation and facilitating sharing would help further understanding of risks and opportunities.

The top priority challenges and emerging issues which need to be addressed are as follows:

- Communicating the emerging prominence of ‘managing loss’ of heritage assets as a result of climate change and the need for more robust systems of prioritising assets for action.
- Demonstrating the value of heritage in understanding what the impacts of climate change are, and how these assets and the landscapes they occupy have a valuable role to play in managing the impacts of climate change and in how they can motivate people to take action.
- The need for longer-term data capture to better understand the impacts of climate change on heritage assets and a better understanding on how to assess the impact of climate hazards in combination, as damage will occur not just from one single climate driver.
- Greater awareness and cross-sector working to address potential conflicts between retaining the integrity of historic assets, and enhancing their resilience, in order to reduce the risk of maladaptation.
- Intangible cultural heritage has a lower profile than buildings and assets and is more difficult to protect. More research is required into the impact of climate change on intangible heritage and the adaptation actions required.
H12. Health and social care delivery

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>Urgency Score</th>
<th>Risk Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISK</td>
<td>H12. Health and social care delivery</td>
<td>Extreme weather</td>
<td>More action needed</td>
<td>DHSC</td>
</tr>
</tbody>
</table>

Summary of risk definition and description

Climate change will create disruption to health and social care services due to both the direct effects of floods, heatwaves and other extreme weather on hospitals and other health and care settings. This may damage buildings or disrupt the ICT and transport infrastructure upon which services rely, and indirectly, through the detrimental effects of extreme weather on people’s health and wellbeing, which will increase demand for services. These impacts will be felt in hospitals, residential and nursing homes for older people, respite centres for disabled people and home care services and they may prevent people from accessing critical services, such as GPs. Impacts are already being felt in England and future projections are being modelled, as shown below.

- In 2019-20, there were 3,600 instances of overheating above 26°C reported in NHS England Trusts. In 2018-19, there were 4,482 instances and in 2017-18 there were 2,462 instances. Further risks to health and wellbeing due to high temperatures are included earlier in this report (risk H1).
- In the UK, it is estimated that up to 90% of hospital wards are at risk of overheating during hot weather.
- Thermal modelling of future overheating risk in care homes showed overheating in most areas modelled in England.
- In terms of flooding, there are currently over 6,200 health and social care assets (hospitals, care homes, GP surgeries and emergency services) at risk of flooding, the majority of these at greatest risk from surface water flooding.
- A comprehensive study of rainfall and ambulance services in England has shown that even low-magnitude floods can cause a reduction in ambulance response times, leading to impacts in provision for vulnerable groups at locations such as care homes, sheltered accommodation, nurseries and schools.
- Figure 20 outlines the projected risk to these assets from flooding in the 2050s and 2080s depending on whether there is 2°C or 4°C global warming at 2100 and on projected population changes. In all scenarios, significant increases in flood risk are expected.
As a result of the current and future projected picture, the risk magnitude is medium now rising to high in future, therefore more action is needed.

**Insight 3: Care provision fit for a future climate**

A report in 2016 by Joseph Rowntree Foundation reviews existing evidence and presents primary research in four case study care settings (two residential and two extra care) in England to assess the risks of summertime overheating, and investigate the preparedness of the care settings both now and in the future.

The report shows that:

- Summertime overheating is both a current and future risk in care schemes, yet there is currently little awareness or preparedness at all levels, from designers to frontline staff, to implement suitable and long-term adaptation strategies.
- There is a perception that older people ‘feel the cold’, but less recognition that heat can also present a significant health risk.
- Design for overheating is not commonplace and there is low prioritisation of overheating and future climate change in briefing and design.
- There is a mismatch between the overheating risks projected by climate modelling and those measured by empirical monitoring, which underplays present-day risks from high temperatures.
- There is a lack of effective heat management due to a number of design and management issues, including lack of investment in appropriate strategies such as external shading, conflicts between passive cooling strategies and occupant requirements.
Collaboration among Government departments and professional institutions is necessary to harmonise and standardise health-related and building thermal comfort-related overheating thresholds, with consideration for care settings.

There follows a series of recommendations for national Government departments such as Public Health England and the Department for Health and local actors such as councils and designers to minimise these risks as more heatwaves, as is projected, occur. Pages 71-73 of the report outline these in detail. This report represents a very helpful resource in tackling the issue of care home overheating.

Source and image: © Care Provision fit for a Future Climate, JRF. Image shows external shading features at one of the case study sites.

Benefits of further adaptation action in the next five years

- There would be benefits to managing this risk strategically at a national level with regional and local level climate risk assessments carried out by Trusts, Health Boards, and local government social services, where these are not already happening.
- Ensure that designs for new care homes, hospitals and other health and social care assets are considering future temperatures as well as flood risk. Regarding overheating risks in residential care buildings, adaptations through design measures can help to reduce this risk.
- Use adaptive measures such as improved glazing, draught proofing, shutters, reflective surfaces, green cover and green space and ceiling fans, where appropriate.
- Further investigation and economic analysis of the range of adaptation options available for mitigating risk in residential care buildings would be highly beneficial (Insight 3).
H13. Delivery of education and prison services

<table>
<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>Urgency Score</th>
<th>Risk Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISK</td>
<td>H13. Delivery of education and prison services</td>
<td>Extreme weather</td>
<td>More action needed</td>
<td>Ministry of Justice (MoJ), Department for Education (DfE)</td>
</tr>
</tbody>
</table>

Summary of risk definition and description

This section covers the climate-related risks to all aspects of the education sector (schools, universities, nurseries and other early years settings) and justice services (prisons, courts, and secure units).

Education

Most current evidence on climate risks and education services relates to the impact of heat in schools and on children’s health and cognitive performance. The Chartered Institution of Building Services Engineers (CIBSE) Schools Design Group on climate change adaptation, funded by the DfE in 2018, have modelled 2°C and 4°C global warming at 2100 scenarios and made recommendations based on their studies of the modelled response of recently build schools in England to these scenarios.

A study of school children in Southampton revealed that out of nine factors, the summer heat had the largest detrimental impact on learning experience. Furthermore, the Greater London Authority (GLA) interviewed schools in London who reported the concentration levels of children had been affected because of high temperatures in recent years. In future, the risk in south-east England and London is likely to be more severe due to the urban heat island effect. It could also be combined with a greater likelihood of water scarcity due to an increase in drought conditions.

The Department for Education (DfE) has published revised guidelines on ventilation, thermal comfort and indoor air quality in new and refurbished schools. It sets out the regulatory framework and gives performance levels for compliance with UK regulations and further non-statutory guidance.

The risks to flooding are less well understood, although is likely to increase in future (figure 21), particularly surface water flooding. A study found that schools in London will be at a high risk of surface water flooding in the future due to increases in precipitation, especially during winter months. In 2007, 158 London schools flooded due to heavy rainfall which led to surface water flooding. Schools were closed across England with a total of 400,000 pupil school days lost which was estimated to have an economic cost of £12 million, not including property damage. Another more recent example of flooding occurred at a primary school in Northwich in January 2021, which was severely damaged by Storm Christoph and could not be used for two months, with pupils receiving lessons in the local leisure centre.
Prison services

There is limited published evidence of the impact of climate hazards on prison buildings and inmate and staff health in England. According to the 2008 National Flood Risk Assessment, ~13% of prisons are at risk of flooding and within London, three prisons are at risk of a 1 in 30-year flooding event and seven are vulnerable to a 1 in 100-year event. Future risks are highlighted as being more flooding, storms and drought due to the risk of loss of building use and increased financial costs of repair or finding alternative accommodation for inmates.

England’s prisons are vulnerable to high ambient temperatures and, in the summer, temperatures exceed comfortable conditions due to thermal efficiency and limited natural ventilation. The Ministry of Justice (MoJ) received nearly 500 reports and complaints of overheating in 2016-17. A report included concerns from inmates during inspections which included difficulty of breathing, continuous heating, high ambient temperatures in cells and limited oxygen from poor ventilation. Overheating is likely to be more of an issue in future and the MoJ has responded to this risk by publishing Preparing for Climate Change: A Climate Change Adaptation Strategy in 2020, which highlights the key risks to prisons across the UK.

The magnitude of this risk is medium, rising to high in future, hence more action is needed.

Benefits of further adaptation action in the next five years

Education

Further adaptation measures will help to avoid lock-in due to building designs, and adapt to the future risks of overheating, flooding and other climate hazards. For schools, it is beneficial to develop a school climate adaptation plan with specific targets, strategies, tasks and roles to ensure its delivery and effectiveness. This plan must be centred to ensuring child health and wellbeing thus engagement across the whole school system including school decision makers and external support is necessary with the aim to increase the school’s adaptive capacity. A detailed set of adaptation options is available from the 2020 published document ‘How London Schools and Early Years Settings Can Adapt to Climate Change,’ which is relevant to all schools.
Overheating in schools can be managed in part by operational measures including installation of automatic ‘off’ switches, isolating or re-locating heat sources, installing presence sensors for lighting, ensuring calibration of thermostats and sensors, ensuring windows are accessible for opening and have proficient night-time ventilation. Further measures include dress code relaxation, regular hydration, encouraging of sun cream and hat use, limiting outdoor activity and using shade and regulating temperature through window ventilation and use of blinds (case study 12).

Additional operational changes for reducing flood risk in schools include regular maintenance of roofs, gutters, and drains, raising equipment to be above flood level and where possible having backup power generation to prevent power outages. Effective adaptive strategies for school outdoor grounds include rain planters and gardens; tree and shade structures; drain filters and permeable or green surfaces to manage heat, flood and water scarcity risks through increasing shade, water availability, biodiversity and promoting draining of excess water.

Schools may also benefit from considering ways to reduce the risk of water shortages by limiting the reliance on the mains water supply, such as by low flow taps and low flush toilets. Additional building modifications include increasing the permeability of surfaces to replenish the water table which has added benefit for reducing flood risk and harvesting rainwater for non-drinking purposes.

Prison services

There are a set of similar adaptation options as those highlighted for schools, including both non-technical and technical responses. The MoJ Preparing for Climate Change: A Climate Change Adaptation Strategy also provides options. However, there is less evidence and no analysis of costs and benefits to date.
Case study 12: St. Faith’s School, Cambridge

The St. Faith’s School Masterplan is one out of 50 projects across the UK commissioned by the Technology Strategy Board (now Innovate UK) as part of the Design for Future Climate program.

The study details three of the building types found across the campus, their risk exposure to the projected future climate and the adaptation strategy developed for the school to improve resilience to climate change. It has studied retrofitting a school in the driest region in England, with the principal low impact goal to keep the buildings and outside environment cool in summer without increasing carbon emissions.

The adaptation team put together to take forward the study established that maintaining comfortable internal temperatures is a key risk area for St. Faith’s School due to the projected hotter, drier summers because of climate change, determined by utilising UK Climate Projections. The classrooms have high occupancy levels and internal loads have been increasing. The occupancy pattern differs in schools with a relatively short day and term times on which the school operates. The hours of occupation are within the hottest parts of the day and there was recognition that children are a higher risk group as they cannot regulate their body temperature or recognise heat stress as well as adults.

Increased ground shrinkage was also deemed likely there is also a risk of urban flash flooding. The school has already implemented efficiencies in water fittings and use, however additional water conservation measures are needed.

The risk assessment translated into a series of adaptation options including better ventilation, ground cooling, water butts, rainwater harvesting, insulation and upgrades to the green roof. It also includes lower cost measures and quick wins, such as the installation of more water points, changes to dress codes in hot conditions, relocating vulnerable teaching spaces, planting drought/heat tolerant plants and a review of working conditions.

7. Business and Industry

This section considers current and future impacts from extreme weather events or changing climatic conditions on business activity in England. The focus is on domestic (from climate change in the UK) risks. However, risk to UK businesses is mainly international and emerges via investments, supply chains, distribution networks and other business relationships (relying on adaptation outside UK control), therefore working with international partners is very important. We refer to international risks in this chapter and some others that are relevant are included in section 7, but the urgency scoring in this chapter is related to domestically-driven risks only.

Flooding is the most costly hazard to businesses. Across the different types of flooding, surface water, groundwater and drainage-related risks tend to be less understood by businesses than flooding from rivers or the sea. Extreme windstorm events can also cause significant disruption and cause indirect losses, for example from failure of infrastructure or supply chains.

Heat impacts on businesses are recognised in the context of labour productivity but there is growing evidence of wider opportunities and risks. For example, high temperatures can cause irregularities for the cycle of agriculture such as fruit farms, which can damage the quality of the crops or lead to lower yields.

Subsidence caused by drying clay soils may increase with hotter, drier summers and can affect the structural integrity of buildings and underground telecommunications cables, damaging assets and commercial buildings, in turn influencing business continuity.

The evidence base has increased since CCRA2, which broadly reflects growing awareness, regulatory pressures, particularly in the financial sector, and interest from investors. However, the evidence is still too limited for a
systematic assessment of risks across sectors, company sizes and regions. There is potential regulation across the whole economy using the G7’s framework on the Task Force on Climate-Related Financial Disclosure which has the potential to substantially increase this evidence base going forward, although the use of a separate methodology assessing transition and physical risks will make it more challenging to map to the CCRA3 methodology.

The table below provides a comparison of the urgency scores compared to CCRA2 related to business. In most cases the urgency scores have increased.

<table>
<thead>
<tr>
<th>Risk, Opportunity or Risk and Opportunity</th>
<th>Urgency Score CCRA2</th>
<th>Urgency Score CCRA3</th>
</tr>
</thead>
<tbody>
<tr>
<td>B2: Risks to businesses and infrastructure from coastal change from erosion, flooding and extreme weather events</td>
<td>Research priority</td>
<td>More action needed</td>
</tr>
<tr>
<td>B3: Risk to businesses from water scarcity</td>
<td>Sustain current action</td>
<td>Further investigation</td>
</tr>
<tr>
<td>B4: Risks to finance, investment and insurance including access to capital for businesses</td>
<td>Watching brief</td>
<td>Sustain current action</td>
</tr>
<tr>
<td>B6: Risks to business from disruption to supply chains and distribution networks</td>
<td>Sustain current action</td>
<td>More action needed</td>
</tr>
<tr>
<td>B7: Opportunities for business from changes in demand for goods and services</td>
<td>Watching brief</td>
<td>Further investigation</td>
</tr>
</tbody>
</table>

There follows a summary of all climate risks and opportunities in England related to businesses.
B1. Flooding of business sites

<table>
<thead>
<tr>
<th>Business and Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk or Opportunity</td>
</tr>
<tr>
<td>RISK</td>
</tr>
</tbody>
</table>

Summary of risk definition and description

Current and future risks to business sites and functions from flooding are significant, with high magnitude impacts expected across England. The current picture is that the expected direct annual damages for non-residential properties in England at present is £463 million, comprising 69% of total UK damages. Costs to businesses arise from damage to sites as well as from business interruption and indirect losses, such as lost production time and associated costs. Figure 23 outlines the risk flooding poses to England from an economic perspective.

![Figure 23: Preliminary Flood Risk Assessment for England. Units in left figure: number of non-residential properties at high risk of river and sea flooding. Units in right figure: key services at high risk of river and sea flooding. All are absolute numbers. (Taken from Business and Industry technical chapter).](image)

A survey looking at the effects of flooding on Small to Medium Sized Enterprise (SME) sites reported that between 2012 and 2014, 15% suffered direct damage to premises, at an average cost of £5,410. Some evidence is also available

by sector. For example, there are nearly 190,000 hectares of grade one and grade two coastal agricultural land at high risk of coastal flooding which represents nearly 9% of such land in England.

Recent examples of flooding events that have affected businesses in England are well documented. Nearly 5,000 businesses across Northumberland, Cumbria, Lancashire, Yorkshire and Greater Manchester were affected by the winter 2015/16 storms, including the United Biscuits factory and Brunton Park football stadium in Carlisle and the Jorvik Viking Centre in York, a Historic England site. Storm Desmond caused large scale flooding to an area in northern England, particularly Cumbria, which witnessed similar scenes in 2005 and 2009. The flood protection wall in Keswick, constructed following the 2009 flooding, was overtopped on 5 December 2015, inundating 730 residential and business properties.

Figure 24: Future risks; percentage change in expected annual damages to non-residential properties for a +2°C and +4°C at 2100 scenario, all sources of flooding, direct, £millions. (Taken from Business and Industry technical chapter).

In future, the expected annual damages for non-residential properties in England are projected to increase by 36% by 2050 and 50% by 2080 given present day levels under a 2°C warming scenario and assuming no additional adaptation measures, and to increase by 54% by 2050 and 88% by 2080 under a 4°C warming scenario (figure 24). Action on flood protection, including business continuity, is encouraging but given the scale and the wider implications for the economy and society at large, more action is needed. Thresholds including availability of insurance and costs of capital could increase magnitude even further unless risk levels are reduced through corporate as well as community-level adaptation action.

Given the expected annual impacts, which is in the hundreds of millions of pounds for England, the magnitude of this risk is high now and in the future. This is also supported by other evidence.

This strategy, published in July 2020, describes what needs to be done by all risk management authorities involved in flood and coastal erosion risk management for the benefit of people and places. It seeks to better manage the risks and consequences of flooding from rivers, the sea, groundwater, reservoirs, ordinary watercourses, surface water, sewers and coastal erosion.

There is a section dedicated to ‘climate resilient places,’ and a recognition that, when it comes to flooding, ‘we need to be able to plan to adapt to a range of climate change scenarios, including higher scenarios such as (4°C global warming by 2100).’

There are numerous strategic objectives and measures setting out the pathway to delivery of these which, if successful, will significantly help to reduce future flood risk to businesses, as set out in risk B1, as well as to people, communities and buildings, infrastructure and the natural environment.

Measures include including climate scenarios in investment decisions, factoring in the potential for 4°C global warming at 2100, updating guidance, better partnership working, utilising UKCP18 projections, implementation of more natural and hard flood defences, working with the planning system and much more.

All partners reading this document can contribute to these aims to ensure that the future risk from flooding is not as extreme as the worst-case scenarios suggest it will be.

Source: © Gov.uk/Environment Agency
Image: Coastal flooding at quayside (iStock)

Benefits of further adaptation action in the next five years

There will be significant benefits from further action in the next five years from low-regret actions to improve the evidence base and provide further awareness raising, advice and support to businesses to improve their resilience to flooding. Quantifying risks and impacts is difficult, particularly for individual business sectors, where data is often commercially sensitive. However, if further adaptation measures are taken in addition to what is currently planned, then the UK-wide expected annual damages for non-residential properties will decrease by -5% by 2050 and increase by 1% by 2080 compared to present day levels of expected damage, under a +2°C at 2100 scenario. Figures for a +4°C at 2100 scenario are a 5% increase by 2050 and a 21% increase by 2080.

Businesses should also make use of the flood forecasting and warning services to plan for and respond to flooding in their areas. It is likely that improving the uptake of property flood protection by businesses will also have significant benefits in the next five years.
B2. Coastal business locations and infrastructure

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<td>Nature of risk/opportunity</td>
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<td>RISK</td>
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**Summary of risk definition and description**

A considerable amount of industrial and commercial activity and infrastructure exists along the coast. The current impact to coastal business locations from climatic hazards is mainly driven by coastal flooding and extreme weather events, such as the major storms of 2013/14 affecting southern England and floods in 2015/16 in northern England, rather than coastal erosion. However, coastal erosion (from existing conditions and higher seas) and coastal flooding from sea level rise (with or without storm surge) is likely to become increasingly important in future. At present, there are a total of 144,985 non-residential properties within Flood Zone 3 in England, which represents a 0.5% a year risk from coastal flooding.

![Figure 25: Future risks; percentage change in expected annual damages to non-residential properties for a 2-degree and 4-degree scenario, coastal flooding, direct, Emillions (taken from Business and Industry technical chapter).](image-url)
Flooding and coastal change risk to businesses is a medium risk now and, as demonstrated by figure 25, is expected to increase in the future in England. There is also evidence that sea level rise could lead to loss of coastal business locations and the infrastructure they rely on, for example, those that provide access, power and communications.

Since the CCRA2 evidence review was undertaken, the biggest changes to risks that businesses face come from the changing policy context. In England, evidence is growing on the changing risks and adaptations being used in the form of risk assessments and Shoreline Management Plans. More action is needed to better understand and respond to the levels of risk and adaptation required for businesses. Cascading risks for businesses arising from the failure of critical infrastructures after flood damage (see I1) are increasingly recognised but there is no evidence base that can be easily accessed.

**Benefits of further adaptation action in the next five years**

Financial resources will not be available in the future to defend the entire coast of England and so it would be beneficial to prioritise the allocation of resources for coastal protection. Without this prioritisation, all assets could be at risk of damage. In the context of generic coastal risks to businesses, respondents to a London School of Economics (LSE) business survey highlighted adaptation strategies that were occurring, common across both coastal and non-coastal businesses:

- Investing in ‘hard’ engineering solutions, for example upgrades to flood protection, new water saving devices and heat reduction in offices.
- Developing and implementing enhanced business continuity plans that consider current and future risks including regular reviews and tests.
- Investing in ecosystem services and green solutions to reduce risks, for example natural water storage and drainage, green roofs and tree planting.

Some potential benefits of these and other adaptation measures and policy interventions include:

- Transparency about protection levels and protection limits to avoid false sense of security.
- Link future risks into coastal management and development visions of coastal communities to set realistic expectations and increase public engagement.
- Investments in community resilience.
- Research into business opportunities in high risk coastal locations.
- Reduced financial instability.

- Community engagement, for example strategic planning for caravan park businesses and their inhabitants needs to be inclusive. This would ensure adaptation strategies are most suited.
### B3. Business production processes

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<th>England Urgency Score</th>
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<td>B3. Business production processes</td>
<td>Water scarcity</td>
<td>Further investigation</td>
<td>Defra</td>
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#### Summary of risk definition and description

Water is used by businesses for cooling and heating, washing products, dissolving chemicals, suppressing dust and as a direct input to products. Water is also being used by people working in businesses for drinking, washing and sanitary purposes similar to domestic users. Water-intense manufacturing sub-sectors such as chemicals, basic metals, paper, beverages and food products are more vulnerable to water scarcity. In terms of highest overall use, the manufacturing sector is the biggest abstractor, being responsible for between approximately 45% and 55% of direct abstractions. The degree to which businesses will change their water requirements due to socioeconomic circumstances is highly uncertain but potentially a significant driver of risk. If not well managed, risk of water shortage is projected to become material in investment and employment for water-intense sectors. As such, water scarcity risks require further investigation due to significant gaps in analysis with the magnitude of risk being low now, but medium to potentially high in the future.

In England, around one billion litres of water per day are used by industry, power generation and farming. At present, there is a national surplus of around 400Ml per day in the public water supply with no immediate restrictions for business users. However, in future, the risks to businesses from water scarcity are potentially very large but also very uncertain. These risks are not just about loss of production, but also health and safety risks to employees if water supplies at site premises are cut off and this is a risk for all businesses not just intensive water users.

For England’s industries, the greatest increase in water usage is expected in the west, south-east and West Country. Environment Agency modelling assumes that around 700 million litres per day of water that comes from unsustainable abstractions will need to be replaced by other means between 2025 and 2050. However, a separate modelling exercise looking at all abstraction gave a much larger value depending upon which future scenario was used, with a range from 1,160-2,200 million litres per day. Future demand in water in England is also expected to outstrip supply to varying degrees of severity, depending on rates of population growth and the level of climate change that occurs. England is projected to move into a supply-demand balance deficit by the 2050s.

England’s Supply-Demand Balance in the mid-century could be between 40 and -2,700 million litres per day, depending on the extent of climate change and population growth and assuming no additional adaptation to today. The Supply-Demand Balance for a central population projection is between -1,100 to -1,330 million litres per day in +2 and +4°C global warming scenarios respectively. In the late-century, England’s Supply-Demand Balance could be between 40 and -5,230 million litres per day depending on the extent of climate change and population growth and assuming no additional adaptation to today. The Supply-Demand Balance for medium population projections is between -1,660 and -3,180 million litres per day in +2 and +4°C global warming scenarios respectively.

The 25 Year Environment Plan includes a goal to reduce the risk of drought and it sets a target of ensuring interruptions to water supplies are minimised during prolonged dry weather. Defra’s Environment Bill, at the time of writing, also proposes a water demand target that would include business use of public water supplies.
Benefits of further adaptation action in the next five years

Evidence has found that there are high benefits (although also high potential costs) of further action to reduce the risk of water scarcity. The costs and benefits do not just fall under the category of businesses but are part of a larger picture of action to reduce demand and increase supply across business, infrastructure, and households, with an aim of protecting and enhancing the natural environment. There are also a complementary set of demand-side measures that can be introduced by businesses, many of which are no-regret and low-regret.

Currently, there is a lack of incentives for water companies to help reduce commercial water use, and reduction efforts have been left to the retail market, unlike in the domestic sector. Further understanding of sectoral usage is required for this.

Some simple steps to adaptation include increased collaboration between wholesale and retailers through Water Resource Management Plans, improving meter reading and quality of water consumption data and increased coordination during unplanned events and incidents.

Some of the key business benefits of handling water stewardship effectively include reduced water related business risk, increased drought preparedness, reduced carbon emissions from supply and heating of water, continuity of supply from sourcing locations for retail businesses, cost savings associated with water efficiency, strong engagement with the local community and reputational benefits. Furthermore, it would be beneficial to have a strong framework for the sustainable management of water, for example, by:

- Targeting efforts to bring non-compliant farmers in England into compliance and that ensuring basic legislation is sufficient to support further achievement of good health, as defined by the Water Framework Directive.
- Reforming abstraction licensing to ensure environmental needs are met as a function of every licence and that abstraction charges encourage efficient use.
- Continuing investment in the Catchment Based Approach including by exploring ways to encourage private sector support and funding.
### B4. Business access to finance, investment and insurance

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<td><strong>Risk or Opportunity</strong></td>
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<td><strong>RISK</strong></td>
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</table>

#### Summary of risk definition and description

There is a risk that access to finance, investment, insurance, and capital for businesses are negatively impacted by climate change through decline in availability and affordability of insurance, a reduction in the value of assets and investment and increased credit risks and cost of capital. Moreover, risks and opportunities to financial services can be distinguished between those arising from sudden and slow-onset physical events, which generate increased losses for insurers and slower-onset events such as increasing insurance needs, reduced value of real-estate assets but increased infrastructure investment needs and mortgage defaults or growing capital needs for resilience. Across England this is currently a medium risk but has the potential to rise to a high magnitude in future, both to individual companies, but also the stability of the financial system overall.

This interplay between financial flows and physical climate risks can impact financial stability. Although these climate risks are currently moderate, they are expected to increase. Similarly, the exposure of the UK finance sector through international channels is currently medium risk but going forward there could be further implications for companies and a higher risk to the stability of the financial system unless the risks are better managed and reduced. Investments in adaptation, therefore, have numerous benefits, including overall financial stability and avoided costs given the UK’s risk exposure as a global financial hub.

While comprehensive and detailed assessments of the UK’s financial sector exposure are missing, there is significant amount of new evidence largely driven by the regulatory efforts of the Bank of England that allows more insights into current and future impacts from climate risks. For instance, there are organisations, such as the Climate Financial Risk Forum (CFRF), co-chaired by the Financial Conduct Authority and the Prudential Regulation Authority (PRA), which are providing UK-specific assessments of financial risks.

In terms of domestic risks, flooding is the most significant risk to the financial system with financial impacts on insurance, mortgages and investment. It is recognised that storms are having a significant impact on businesses through damage and disruption to business infrastructure, which can lead to an immediate financial shock to the business, requiring investment and access to capital. This is seen in the damage to Gatwick Airport’s North Terminal due to multiple storms ([case study 5](#)), which led to £250,000 in direct costs. Estimated pay-outs from the impacts of recent storms Ciara and Dennis are £149 million, with 61,000 domestic property claims, totalling £77 million, 9,000 commercial property claims at £61 million and 3,500 motor claims at £11 million.

Figure 26 below illustrates that windstorm loss projections are region specific, with losses expected to be high in northern England but much lower in the south of England.
Benefits of further adaptation action in the next five years

- Imposing requirements on banks and insurers. Regulators could prescribe additional capital on a case by case basis, for instance if a financial institution does not adequately monitor and manage climate related risks.
- Broadening scope of existing regulations to encourage more scenario-based analysis among financial institutions on a regular basis.
- Insurability: Risk-sharing agreements between private and public financial institutions, similar to that seen in flood insurance, to meet financing gaps.
- Disclosing and reporting: Further standardisation and clarification on scenario analysis models would help so that comparisons can be made.
- Financial and physical risk metrics: Unless physical risk is being reduced through more adaptation investment and action, damages are likely to occur leading to financial implications.
- Incorporating risk reduction and data into insurance requirements.
- Financing adaptation: Further research would be beneficial in new products, such as resilience bonds, which would use premium discounts for long-term planning, such as investment in sustainable infrastructure.
- More collaboration between different parts of the financial system.
- Digital investments: Predictive modelling and decision-making based on algorithms has potential to change the way businesses view, understand and analyse risks, as well as adopt adaptive behaviours.
B5. Reduced employee productivity in businesses

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<tr>
<th>Risk or Opportunity</th>
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<th>Nature of risk/opportunity</th>
<th>England Urgency Score</th>
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<tbody>
<tr>
<td>RISK</td>
<td>B5. Reduced employee productivity in businesses</td>
<td>Infrastructure disruption and higher temperatures in working environments</td>
<td>Further investigation</td>
<td>BEIS</td>
</tr>
</tbody>
</table>

Summary of risk definition and description

A changing climate has the potential to affect productivity, potentially both negatively and positively, as well as indirectly through infrastructure disruption and higher temperatures in working environments. However, there is limited evidence on future risks to productivity. In this risk, employee productivity relates to work output, as opposed to labour productivity which refers more to workplace efficiency, output per worker, per job and per hour. Current magnitude is low but may become medium to high by the end of the century.

There are also risks associated with extreme high temperatures, which can have negative impacts on employees’ health and wellbeing and ability to commute to work. There is some evidence that businesses in England are experiencing these impacts already. The risks are likely to vary widely across business sectors or geographies, with factors such as the type of work, for example construction or industrial processes, whether it takes place indoors or outdoors and the local built environment and infrastructure factors, for example passive ventilation, all playing a role. The COVID-19 related shift to homeworking also creates a new risk, particularly for those employees working from homes prone to overheating.

Workers engaged in certain occupations, for example heavy outdoor manual labour, are likely to be at the greatest risk of heat stress. Recent evidence from the social care sector points to detrimental impact of heat on staff wellbeing. A case study of an older and a modern care home in London reported that staff found the summertime thermal conditions more uncomfortable than the residents did.

However, only a limited number of studies have considered the impacts of higher temperatures on productivity in the UK and there is therefore considerable uncertainty about the magnitude of impacts and the degree of the risk to the UK both now and in the future and differentiating this between nations. One study estimates a 2% reduction in labour productivity by the end of a century.

Business decisions today about design and operation of office buildings and sites, and manufacturing processes with have high capital expenditure will determine future risk levels and are important given the lifetime of these investments. Similarly, the literature has clear thresholds associated with certain types of work, levels of work output (for different types of indoor and outdoor work) and wet bulb temperature, a combined measure of heat and humidity exposure. There are also potentially synergies and trade-offs with Net Zero, particularly through air conditioning as adaptation increases energy use, and the use of refrigerants with high global warming potential which could leak. There is also the potential for feedback loops to be created in urban areas, with heat islands being worsened by the excess heat from air conditioning units.
Benefits of further adaptation action in the next five years

There is some information on various adaptation options to reduce heat in commercial buildings and this links to the information available for domestic buildings (see H1, for example), along with some simple examples of preserving productivity in hot business environments.

Some opportunities for labour productivity adaptation are also identified, such as transition to new ways of working, including remote and flexible working, and low carbon and energy efficiency buildings to maintain employee productivity. These behavioural changes have been tested and employed by various businesses because of the COVID-19 pandemic, but longer-term behavioural change is yet to be seen. Moreover, there are occupational and sectoral differences in the uptake of new ways of working, with some professions lending themselves better to flexible working than others. Better collaboration and stronger governance between business, building owners, Government and infrastructure operators could help to facilitate adaptation and may also deliver benefits in the next five years.
B6. Disruption to business supply chains and distribution networks

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<td>Risk or Opportunity</td>
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<td>RISK</td>
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Summary of risk definition and description

Extreme weather is already a significant cause of supply chain disruption across all sectors with exposure to climate hazards set to increase. A survey by London School of Economics found that, on average, weather-related disruptions caused financial impacts between £12,000 - £250,000 over 2018/19. However, only 9.9% of the respondents were able to quantify these impacts. Climate change is likely to contribute to an increase in exposure to supply chain disruption by driving an increasing frequency of adverse weather events and evolving climate hazards both in England, the rest of the UK and overseas. However, risks specific to England are more difficult to determine.

Some action has been taken by business and there are opportunities from advances in technologies and from the learning and increased focus on supply chain resilience following the COVID-19 pandemic. However, it is unclear if this will keep pace with the increasing risk or how effective it will be specifically in managing climate or weather related disruption. Most of the evidence is skewed towards larger companies, the food sector (case study 13) and self-reporting; for example, industries that are part of the food system rely on agriculture, which is particularly exposed to weather and climate and long distribution networks, with 50% of food consumed in the UK imported from 180 different countries. Overall, more action is needed but with a low certainty at present.

Benefits of further adaptation action in the next five years

Most further actions involve capacity building, institutional changes, or the development of new strategies, technologies, or ways of working, which will take time to develop, test and implement (case study 13). Therefore, there is a benefit to put these in place within the next five years even where the climate-related risks are not immediate. Strategies that businesses can take to build resilience include:

- Product diversification or geographical diversifying.
- Scenario analysis to ensure plans are robust under different plausible outcomes (by explicitly defining and separating external scenarios from internal plans). It is impossible to plan for ‘black swan’ events, which includes some freak weather events, but it is possible to plan and test for generic unpredictable events.
- Ensuring risks are incorporated into risk registers and management programmes so that optimal resources and opportunities to improve corporate performance and earnings can be identified.
- Intensification in the use of storage facilities.
- Making more use of technology to predict, monitor, record, measure, or report supply chain disruption solutions and communicate with suppliers. For example using automated communication and notification systems, Business Continuity Management (BCM) platforms, incident management platforms or social media monitoring (favoured by SMEs).
Expanding firm level insurance coverage of physical risks to supply chains, including by use of new products such as non-damage supply chain insurance plans and parametric insurance (e.g. when pay outs are based on a drought duration index or rainfall data rather than losses) or captive insurance solutions. The latter can improve climate resilience by strategically funding risk exposures preparing for a worst-case scenario in the face of increasing frequencies and by accessing reinsurance markets and alternative capital markets to fund less predictable risks.

There is a role for both the public and private sector in driving resilience through supporting/incentivising their own supply chains to implement adaptation measures by:

- Requiring physical risk disclosures.
- Setting contractual arrangements that take adaptation into account.
- Using resilience criteria with choosing suppliers as part of procurement processes. For public sector procurement, the Public Services (Social Value) Act provides a potential tool by requiring commissioners of public services to think about how they can also secure wider social, economic, and environmental benefits.
- Helping suppliers reduce their own risks. For example, the water stewardship approach provides companies with a means of committing resource and using influence to support good water practices in areas of weak governance.
- Promoting business continuity, with a particular focus on strategies that achieve multiple goals including resilience and sustainability for which there may be market failures. For example, distributed manufacturing, seasonal produce, and local sourcing have a role to play in achieving both sustainability and resilience goals.
- Supporting improved climate and location-based information and integration with other types of information.

Case study 13: Cleone Foods, Birmingham

Cleone Foods, a small Birmingham based food manufacturing business, was recognised for its efforts in implementing an extremely impressive strategy which minimises potential threats to the business. Its comprehensive risk assessment has ensured that whatever the issue, their business is prepared and ready for action. The success of the strategy is highlighted in impressive growth figures and minimal disruption to business practices since its implementation in 2009.

The challenges

- To minimise the possibility of delays in the delivery of its goods as a large proportion of the company’s business is with major supermarket chains and any such delays can result in fixed financial penalties.
- Prolonged disruption is not only a risk to profitability, but a threat to the survival of the company.
- To reduce the impact that extreme weather could potentially bring upon the business.
- To minimise the risk of potential prolonged power failure, as any such event would create major implications for the business, as a large amount of finished stock is on site in chillers and freezers.
- To diminish both the likelihood and the impact of possible IT failure upon the business.

The solutions

- Cleone Foods has a reciprocal agreement with Shire Foods in Warwickshire, which allows emergency production to be easily shifted between sites without affecting production.
- An investment was made into the purchase of specialist equipment, including a forklift snowplough and grit spreader. The company operates as a snow champion, which involves clearing adjacent public roads and the loan of equipment to other local businesses.
- Generators have been put in place which automatically switch on in the event of mains supply loss.
• Managers and other senior staff are enabled to work from home, thanks to facilities which enable access to remote to IT systems. The company also has dual main servers and mirrored hard drives which are protected further by manufacturers 24 hour replacement warranty.

• The company adopts a local employment policy and most staff live near the site.

**The results:** Cleone foods were able to convince a major supermarket chain of their ability to deliver and, as a result, an exclusivity deal was agreed upon. This led to an extremely impressive 11% increase in sales. A major computer failure that took place after adaptation was alleviated within 24 hours, with no significant impact upon the normal operations of the company. Cleone was also the winner of the 2013 Business in the Community Business Resilience Award.

**Learning points:** Excellent planning is essential to maintain a successful and profitable business. A full risk analysis was produced of all possible contingencies along with a rating system which highlighted both the potential impact and possible solutions. Progress of the risk analysis was tracked at monthly managers meetings until its implementation and is now subject to regular review.

Many of the actions implemented by Cleone could be replicated by other businesses and a significant step forward would be to implement a nationwide scale up of resilience measures, especially in SMEs.

*Source: CCRA3 Technical Report Business Technical Chapter, Sustainability West Midlands*
B7. Changes in demand for goods and services

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<th>Nature of risk/opportunity</th>
<th>England Urgency Score</th>
<th>Risk Owner</th>
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<tr>
<td><strong>OPPORTUNITY</strong></td>
<td>B7. Changes in demand for goods and services</td>
<td>Long-term climate change</td>
<td>Further investigation</td>
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</table>

**Summary of risk definition and description**

Climate change will affect the production costs and demand for certain goods and services, increasing the profitability of some and decreasing that of others. The adaptation services sector in the UK is slow growing compared to other countries, but there is an opportunity for the Government to support its accelerated growth. Businesses that anticipate changing markets may be able to gain an advantage, but various barriers exist that could prevent this (e.g. upfront cost barriers to entering new markets, as well as inertia, especially for SMEs) and suggest a role for government intervention. The current magnitude of opportunity is low, rising to medium or high by the end of the century, although there is low confidence in this evidence.

Overall, there appears to be a much better understanding of business opportunities arising from a shift to a low-carbon future and the Net Zero transition than with regards to opportunities arising from adaptation to physical risks as indicate during stakeholder discussions as part of the UKCCRA3 workshops. In a report based on its surveys, CDP reported that 225 companies had identified between them US$236 billion in revenue globally from the provision of adaptation goods and services. As discussed in the different examples below, whilst current opportunities exist, the extent to which these can be capitalised rest on factors such as: demand response, turnover time, adjustment of product lines, alongside quality and design of products/services, retraining and restructuring of the workforce, organisational culture, and agility. Moreover, most opportunities are coupled with risks or threshold effects, with many parallels to be drawn from the COVID-19 crisis and post-recovery opportunities.

A range of UK-wide, sector-specific opportunities are discussed in the literature, including agriculture, forestry, marine, shipping, seafood, construction, retail, tourism, climate advisory, consulting, accounting services finance and heritage. Whilst several possible opportunities for new or expanding sectors are known by stakeholders, there is little or no literature available quantifying the size or potential future for these industries.

Across the UK, there is evidence of further opportunities in the construction industry as businesses change their premises to adapt to climate change. This provides an opportunity for an increase in repairs, maintenance, or clean-up contracts. For the heritage sector particularly, increasing temperatures and extreme weather events intensify the need for repair and maintenance of heritage sites. Therefore, more will need to be spent on the materials industry (sandstone, slate etc) and on sector-specific skills (employees to repair traditional/historic buildings).

There are some lock-in risks, which may prevent realising new opportunities. There are particular risks related to land use change to take advantage of new forms of food production, notably relating to land use change. For retail and consumer spending, there are also risks locking in maladaptive products and services, such as air conditioning. Each potential opportunity also comes with threshold effects, either in terms of biophysical thresholds (e.g. thresholds for suitability for new crops, comfort levels for beach tourism), but also potential investment return thresholds, when it makes sense for the private sector to enter and scale-up.

An example of a potential business opportunity in England due to a changing climate comes from the wine industry, as demonstrated below.
Insight 5: Opportunities for the Wine Sector in England

While there is no specific policy objective for English wine production and this was not identified in the Government’s National Adaptation Programme, in 2016 the English Wine Round Table with the Wine and Spirit Trade Association and Defra made pledges to:

- Increase the number of hectares of vineyards from 2,000 to 3,000 by 2020.
- To increase wine production to reach ten million bottles in 2020.
- Export 25% of the wine produced, generating £30 million in revenues.
- Encourage annual production to reach 40 million bottles by 2040.

Should climate variability be addressed in planning, there could be a potential economic benefit of approximately £50 million per year by the 2050s.

2°C of global warming at 2100 could change England into an ‘intermediate climate’ wine region, which would be a major positive outcome compared to the current climate. 4°C of global warming at 2100 could make England into a ‘warm’ wine region. Therefore, while climate change could open a range of opportunities for growing different varieties of grapes which are currently cultivated in Europe, the level of warming will affect the type of opportunity.

Image: Grapes (Pixabay)

Benefits of further adaptation action in the next five years

Identifying opportunities in increased demand for goods and services, such as climate advisory or adaptation products, would be beneficial in making a business case for climate adaptation in the next five years. This would require greater evidence, such as case-studies, and further investigation into emerging sectors, such as in the retail sector. It would be helpful to assess business capacity post COVID-19 to determine whether these opportunities will be realised and what barriers exist.
8. International dimensions

This section represents the second CCRA analysis of risks and opportunities for the UK from the observed and projected impacts of global climate change. It covers a broad range of initial climate drivers and impacts including food production, violent conflict, human mobility, health and governance.

It includes the risks that climate change impacts overseas present for the UK, and UK interests. Many of these impacts are transmitted through the flow of goods, finance, people and information.Whilst ultimate control of such flows is typically reserved to the UK Government, for example trade agreements, tariffs and border controls, the risks described below have impacts across the UK.

There is little differentiation in how the risks present themselves in England compared to the rest of the UK nations, therefore only a high-level summary of each risk is presented below. For more information on these risks, users should look at the International Dimensions Technical Chapter.
Most of the risks and opportunities arising from international climate change have remained the same, but in some cases their urgency has increased as shown in the table below.

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<th>Urgency Score CCRA3</th>
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<tr>
<td>ID1. Risks to UK food availability, safety, and quality from climate change overseas</td>
<td>Research priority</td>
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<td>ID4. Risks to the UK from international violent conflict resulting from climate change overseas</td>
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<td>ID5. Risks to international law and governance from climate change that will impact the UK</td>
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There follows a summary of all climate risks and opportunities related to the implications of climate change from the rest of the world.
ID1. UK food availability, safety, and quality

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<tr>
<th>International Dimensions</th>
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<tr>
<td>Risk or Opportunity</td>
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<tr>
<td>RISK</td>
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Summary of risk definition and description

Climate change exacerbates disruptive events impacting on agricultural production and food supply chains (from droughts, agricultural pests and diseases, storms), with increased risks of disruption which will increase the likelihood of risk cascades amplifying the impacts. Increasing risks implies a requirement to develop food systems that are resilient to disruption, rather than focusing on supply chain efficiency, which increases fragility.

The absolute availability of food is not likely to be an issue for the UK as a whole because of climate change up to 2100, but, as the international food system becomes more exposed to climate related hazards, food price spikes may become increasingly likely. This, in turn, changes the accessibility to food, particularly for the poorest in society.

Case Study 14: Fresh produce shortages in 2017

An area of concern is the extent to which the UK relies on fruit and vegetable imports as over 80% of fruit and about 50% of vegetables consumed are imported. The vegetable shortages of early 2017 were the result of climatic shocks to the food system.

Poor growing conditions in key sourcing regions, such as Murcia in southern Spain, resulted in rationing and price increases of up to 25-300% across the UK. Shortages were mostly encountered in lettuce, but also courgette, aubergines, tomatoes, peppers, broccoli, cauliflower, onions, carrots and celery. Multiple drivers of shortages were identified, including flooding in south-east Spain and cold temperatures in Italy. In Spain, the highest rainfall in 30 years reduced the area of arable land to only 30% of the area planted. Italy shifted from exporting over the European winter to importing. Traders imported from the US to fill the shortfall, thus increasing cost, emissions and contaminants associated with the produce.

During the vegetable shortages of 2017, some caterers and restaurants were bulk buying from supermarkets instead of wholesale, in response to the shortages and price spikes. Some supermarkets appeared to opt for empty shelves rather than paying the higher price. Shortages appeared to be supermarket dependent, with, for
example, the Co-op not reporting shortages. This suggests that vulnerability may be the result of a high proportion of imports coming from one region. It also suggests that supply chain management might reduce the future impact of events of this kind. Indeed, some companies have since diversified their growers’ networks. For example, Florette have mitigated future risk due to production shortage in southern Spain by moving the grower network of some supply to northern Spain, southern France and northern Africa. Nonetheless, events of this sort continue to occur and interact with UK growing conditions to produce shortages, as in the case of cauliflowers in August 2019.

The socioeconomic and demographic inequalities across the UK result in different exposures and vulnerabilities to the risk of food price spikes. More broadly, environmental hazards exist everywhere and can be related to income, education, employment, age, sex, race/ethnicity and specific locations or settings. In addition to these differences in exposure, inequalities are also caused by social or demographic differences in vulnerability/susceptibility towards certain risks. For example, supermarket shoppers in cities may be exposed to variations in food prices or supply, and they will be differentially vulnerable to price rises, according to their income. Shoppers in rural locations, with access to smaller and more highly dispersed retail outlets, will be exposed to different risks as availability of food will vary more, as well as its price.

Source: CCRA3 Technical Report International Dimensions Technical Chapter
Image: Tomatoes (Pixabay)

Benefits of further adaptation action in the next five years

- That due consideration be given to a range of aspects within emerging Free Trade Agreements, following the UK’s exit from the EU.
- To remove some of the barriers for the private sector to encourage climate change adaptation, as well as ensuring a higher level of resilience along supply chains.
- For a greater focus on adaptive management, research and learning which could also contribute to more resilient food system.
- To address food access inequality, access to fresh produce and informed dietary choices, which will likely have the co-benefit of reducing vulnerability to the risk of decreasing nutritional quality of food produced due to climate change.
### ID2. UK food availability and exports

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<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>UK Urgency Score</th>
<th>Risk Owner</th>
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</thead>
<tbody>
<tr>
<td>OPPORTUNITY</td>
<td>ID2. UK food availability and exports</td>
<td>Increases in productivity and areas suitable for agriculture overseas</td>
<td>Watching brief</td>
<td>Defra</td>
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</table>

#### Summary of risk definition and description

Global patterns of climate change can alter the comparative advantage of the UK in producing and trading in food. Climate change is one of a number of drivers that has an impact on food production patterns, through changes in productivity and/or changes in the land suitable for producing food.

On balance, the lack of evidence of global yield increases in response to climate change, and difficulties in the use of marginal land and in water management suggest that food production opportunities will not be the norm. There are, however, opportunities associated with other drivers of international food systems, not least the ongoing trend towards plant-based meat substitutes and plant-based diets, which have the potential to both mitigate climate change and result in healthier diets.

#### Benefits of further adaptation action in the next five years

Ensuring access to a broad range of international markets would capitalise on any opportunities associated with climate impacts overseas. There is no evidence to suggest further actions that would support such opportunities are currently taking place. Access to markets, which was covered in some detail in Chapter 7 of the CCRA2 evidence review, has the co-benefit of providing some resilience to external shocks, be they climate-induced, or sourced elsewhere (e.g. a global health disruption such as COVID-19). Hence there are multiple lines of reasoning that suggest benefits of access to markets.
ID3. Migration to the UK and effects on the UK’s interests overseas

### International Dimensions

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<tr>
<th>Risk or Opportunity</th>
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<tbody>
<tr>
<td>RISK &amp; OPPORTUNITY</td>
<td>ID3. Migration to the UK and effects on the UK’s interests overseas</td>
<td>Climate-related international human mobility</td>
<td>Watching Brief</td>
<td>Foreign, Commonwealth &amp; Development Office (FCDO)</td>
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</table>

### Summary of risk definition and description

Negative climate change impacts will make some places more difficult to live in and could undermine the development gains overseas in which the UK has invested. One potential adaptation is displacement and migration with affected areas most likely to be in the global south, exposed to frequent climate extremes with high dependence on agriculture and weak social support programmes. Unplanned, unsupported and precarious climate migration presents risks to the human rights of the people on the move, as well as their wider social and economic opportunities. Most climate-related migration in the near future will be domestic, within affected countries or regions. Thus, the UK is unlikely to be a major migrant receiving country and there is weak evidence on any security threat associated with migrants. Where migration to the UK does increase due to change, climate will be one of the many drivers of migration, and it will take place along existing flows. However, increased mobility as a result of climate change is likely. Where people are on the move between regions overseas, there are risks to the wellbeing of those individuals and as such the potential to undermine development gains overseas.

Adaptation involves ensuring pathways for regular migration and altering negative perceptions of migration in receiving countries, as well as supporting development, infrastructure, and strong institutions and transparent decision-making.

### Benefits of further adaptation action in the next five years

In the context of the [Lifetime Skills Guarantee](#), the UK Prime Minster has highlighted skilled labour shortages that could be filled with migration until filled domestically. Thus, there is an opportunity for the UK to set up procedures to ensure that any increases in migration are beneficial to the nation. There are also likely to be ‘win-win’ opportunities ensuring that overseas development and humanitarian response empowers local communities such that they are not forced to migrate but have agency in whether, when and where they chose to move.

During the period immediately following the UK’s exit from the EU, there is a window of opportunity to provide pathways for safe and orderly migration to the UK. The UK can maximise on the benefits that any new migrants bring and thus there are benefits to the UK’s investment in social mechanisms that allow newcomers to integrate effectively into the job market and local society.
### International Dimensions

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<tr>
<th>Risk or Opportunity</th>
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<tr>
<td>RISK</td>
<td>ID4. The UK’s international interests and responsibilities</td>
<td>International violent conflict resulting from climate change overseas</td>
<td>More action needed</td>
<td>FCDO</td>
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</table>

**Summary of risk definition and description**

Recent literature continues debating the role of climate change as a driver of conflict. Nevertheless, there is consensus in the recognition of climate as an amplifier of root causes for conflict, whilst also recognising that a range of other drivers affect the association between climate and conflict. These include, but are not limited to, pre-existing conflict at local and country scales, level of democratisation, post-colonial transformation, economic context and population growth. Overseas conflict can have an indirect impact on the UK through a variety of UK overseas interests, and various aspects such as governance, people (migration), refugees and finance and markets.

**Benefits of further adaptation action in the next five years**

Based on a study in the US, in the context of risks to US international assistance, ‘the impacts of climate change, variability, and extreme events can slow or reverse social and economic progress in developing countries, thus undermining international aid and investments made by the United States and increasing the need for humanitarian assistance and disaster relief.’ A similar observation could be made regarding the overseas aid budget of the UK.

For mitigation of water-based conflict, more cooperative behaviour is associated with transboundary agreements when participating countries are governed by treaties with water allocation mechanisms that allow flexibility and specificity. Therefore, there may also be opportunities to reduce current tensions through appropriately deployed international agreements on shared resources including access to water (where rivers run between countries) or new opportunities in areas such as the Arctic.
ID5. Changes to international governance affecting the UK

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<th>Risk or Opportunity</th>
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<th>Nature of risk/opportunity</th>
<th>UK Urgency Score</th>
<th>Risk Owner</th>
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<tr>
<td>RISK ID5. Changes to international governance affecting the UK</td>
<td>Reduced international collective governance due to climate change and responses to it</td>
<td>More action needed</td>
<td>FCDO</td>
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Summary of risk definition and description

Climate impacts overseas have the potential to threaten and weaken international law and governance but quantifying their effects on UK’s interests and values is difficult. Risks to international law and governance from climate change include human rights violations, contestation of well-established international rules, risks of sovereign defaults in emerging economies and new legal challenges arising from low carbon policies. Such risks have the potential to threaten the UK’s economic, diplomatic and military interests and challenge its foreign policy of strengthening the rule-based international system and promoting human rights.

Benefits of further adaptation action in the next five years

Diplomacy is likely to be the main means of adaptation in relation to this risk. Further engagement with multilateral processes and institutions would have benefits for ensuring that the UK preserves its interests and strengthens its image as a respected multilateral player. This could include engaging constructively with a range of processes and initiatives in the context of climate change, such as by supporting the work of the International Law Commission on sea level rise in relation to international law started in 2019, the work of the UNFCCC on loss and damage and the ongoing modernisation of the Energy Charter Treaty. There would also be benefits from producing a clear plan to meet the challenges posed by a shift in UK relationships with traditional allies and changing dynamics at the United Nations, to coordinate its activities with the EU and to build new partnerships with the Commonwealth. Whilst the short-term benefit of these adaptations is small, it rises on longer timescales, commensurate with the increase in risk magnitude. There is a suggestion, therefore, that it would be beneficial to act now to enable adaptation in the future.
ID6. Increased trade for the UK

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<thead>
<tr>
<th>Risk or Opportunity</th>
<th>Receptor</th>
<th>Nature of risk/opportunity</th>
<th>UK Urgency Score</th>
<th>Risk Owner</th>
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<tbody>
<tr>
<td>OPPORTUNITY</td>
<td>ID6. Increased trade for the UK</td>
<td>Arctic ice melt opening up new trading routes</td>
<td>Watching brief</td>
<td>DIT</td>
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</table>

Summary of risk definition and description

The opportunities from climate change to extend international trade routes are currently limited to potential benefits from increased access to the Arctic and provision of maritime services. However, associated risks coupled with the small magnitude of opportunity lead to the magnitude of this opportunity to be low at present, but longer term, as warming continues, this rises to high. There is no clear need for current action on this issue, as, firstly, the opportunities relating to sea passages opening are being closely monitored by a range of commercial operators in maritime shipping and ancillary industries. Secondly, the UK Government is involved in International Maritime Organisation activities related to the regulation of potential changes in this opportunity.

Benefits of further adaptation action in the next five years

There is some projected analysis which indicates that opportunities from climate change, including Arctic ice melt, on international trade routes could be large, including from the economic effects of trade that is facilitated by a reduction in transport distance between suppliers and consumers. The effect on UK GDP was estimated to be equivalent to an annual increase of 0.24%. There are also potential tourism opportunities that increased access to the Arctic allows, and associated port development in locations that facilitate these trade and tourism opportunities. While these would need to be seen against potentially very large negative impacts from an ice free Arctic for other reasons, they do indicate potential economic benefits. There is an issue whether these benefits will be fully realised by non-Government adaptation alone and it is possible that higher benefits would be achieved for the UK through some enabling actions from Government, which would have likely low costs.
### ID7. International trade routes

#### International Dimensions

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<tr>
<th>Risk or Opportunity</th>
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<th>Nature of risk/opportunity</th>
<th>UK Urgency Score</th>
<th>Risk Owner</th>
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<tr>
<td>RISK</td>
<td>7. International trade routes</td>
<td>Climate hazards affecting supply chains</td>
<td>More action needed</td>
<td>DIT</td>
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#### Summary of risk definition and description

Climate-related disruption to non-food supply chains may occur in production facilities, for example floods affecting factories or mines, but perhaps is more likely to impact on supply-chain logistics, which can be interrupted in multiple ways. COVID-19, for example, disrupted supply chains through the closure of centralised processing facilities, the interruption of transport flows due to grounding of vehicles, lack of labour and delays at borders. With globalised supply chains characterised by ‘just-in-time’ delivery, high efficiency but low redundancy, they can be fragile and lack resilience to disruptions. Given the projected and observed increase in disruptive events, this risk may become more potent in future.

#### Benefits of further adaptation action in the next five years

Given that shocks are likely to increase in future, as climate hazards from extreme events increase, there is benefit from a focus on building further resilience. However, resilience would typically arise from four main properties: building in redundancy (e.g. stocks), diversity (of sourcing, or substitutability), creating modularity or distributed rather than centralised networks, and creating greater flexibility/adaptability. All of these properties have typically been removed to increase efficiency and the leanness of supply chains. Thus, there is a trade-off between fragility (and lower prices) and resilience (and higher prices). As risks increase, the trade-off tips towards resilience providing better returns on average. Resilience as a ‘design feature’ may become a greater focus for investment during post COVID-19 recovery.
ID8. Economic loss to the UK

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<th>International Dimensions</th>
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<td>Risk or Opportunity</td>
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<td>RISK</td>
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Summary of risk definition and description

A significant way that international climate risks impact the UK is through finance. This is separate from the physical impacts within the UK that climate change may have on insurance and investments (risk B4). There may be significant financial exposure to extreme weather (including wildfires), and impacts in other countries especially through the insurance markets and investments. London operates a global insurance market with products covering both direct climate change events such as agriculture insurance as well as indirect impacts such as business interruption. Investment risks are clear where domestic owned assets are exposed to extreme weather events in other regions or supply chains are disrupted. This could have a significant impact on all types of asset classes and potentially put further stress on UK pension funds.

Benefits of further adaptation action in the next five years

Whilst banking and insurance sectors have responded effectively to current extreme weather events, the increase in magnitude and frequency means the likelihood of ‘unhedgeable risk’ is higher, straining the insurance sector. Given that financial risks are still not integrated within firm operating models or in financial markets, there are still significant systematic risks. Whilst companies have started adopting the Task Force on Climate-related Financial Disclosures (TCFD) recommendations, identifying climate risks is only the first step. TCFD’s most recent status update report acknowledges that there needs to be a better understanding of how disclosing climate-related financial information is changing corporate strategies on adaptation, and how investors are using the disclosed information to inform their decisions.
ID9. Introduction of infectious diseases to the UK from abroad

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Summary of risk definition and description

There are two factors that determine climate-induced vector borne disease risk. These are emergent favourability of overseas climate, and prevalence. The risk is high where the vector has been introduced recently and become endemic. There are several examples where UK visitors to popular parts of western Europe now bring the risk of exposure to diseases that until recently were only found in the tropics. The UK climate is also relevant, since it may change enough to allow local transmission of these diseases by vectors which transmit the infection human to human or to a further host from that initially overseas infected person (risk H8).

Of the infectious diseases with known climate drivers, the most likely to impact the UK are those transmitted by animal vectors, such as mosquitoes, midges and ticks, when considering disease of human and domesticated and wild animals (case study 15). In some cases, birds are the possible introducer of the pathogen but the local climatic conditions must allow the transmission of that pathogen by the vectors and to date this has been observed in the UK more for insects than other animals.

Case Study 15: Risks to the UK from competent vectors

The spread of dengue from nine countries a few decades ago, to being endemic for almost half the world’s population today, is highly relevant to ongoing climate-induced risks as people continue to travel and return from these countries. The changes in the distribution of dengue are possibly in part driven by climate change, urbanisation and the ability of mosquitoes to thrive within polluted waters of rapidly expanding urban areas, mostly in the tropics and sub-tropics.

The locally acquired cases of dengue in Spain and France due to Aedes albopictus reported in September 2019, Italy’s first dengue outbreak in August 2020 and the 2017 local outbreak of chikungunya virus in Italy have shown how vulnerable mainland Europe, frequently visited by UK travellers, is to the introduction of what were seen previously as tropical diseases.
Further areas of concern include the spread of other diseases in the UK. For example, *Culex modestus*, a competent vector of *West Nile virus*, has recently found to be well established in the marshland sites of the Thames Estuary and could spread to a wider area. The discovery of the virus that causes *tick-borne encephalitis* was found in two places the UK for the first time in 2019. There has also been a more regular introduction and detection of *Aedes albopictus* in Kent.

Source: CCRA3 Technical Report International Dimensions Technical Chapter
Image: Mosquito (Pixabay)

Benefits of further adaptation action in the next five years

Actions to promote adaptation to emerging diseases include:

- More real-time monitoring of air travel routes, transmission pathways of movement of people and goods.
- Communicate outdoor risks if a vector-borne disease is introduced.
- Improve training and awareness of primary health care practitioners.
- Raise the levels of surveillance programmes and some random screening (for example, part of blood donation screening for antibodies).
- Improvement of public and professional level information, transmission pathway IT/information.

There would also be benefits from increased surveillance of wildlife, people or other imports (e.g. used tyres, the trade of which can aid the spread of mosquitos) coming into the UK, which comes with increased costs. However, if newly arrived infected vectors or animals in combination with more favourable UK climate leads to local transmission, the cost of the impacts may be a lot more. COVID-19 has provided a good example of the scale of impact costs and how this can cascade into other sectors. Therefore, it shows that investments in surveillance can pay off to avoid high impact situations.
ID10. Risk multiplication to the UK

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<th>International Dimensions</th>
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Summary of risk definition and description

There is the potential for hazards to create cascading risks that cross geographies and sectors through infection. COVID-19 is an example, where the emergence of the disease may have an attributable component from climate change, but the spread of the disease and attempts to mitigate it have created disruptions in demand, in trade through supply-chain disruptions from changes in labour availability, through people movement and broader economic impacts. This variety of impacts affecting multiple sectors and all countries are an exemplar of ‘systemic risks’ arising from highly inter-connected sectors and economies. Therefore, the interconnectedness of risks such as those outlined in this section so far suggests it would be beneficial to have a more joined-up assessment of the overall risk of international climate change to the UK, which is more than just a sum of each individual risk.

Benefits of further adaptation action in the next five years

While definitions vary, much of the theoretical literature emphasises transformational adaptation and there is often a focus on changes in governance as well as underlying causes of risk or vulnerability. However, there is very little economic evidence on the costs and benefits of transformational adaptation, reflecting that there is very little evidence on what transformational adaptation looks like in practice. This is an area where further research would be beneficial.
9. Next Steps

The CCRA3 Technical Report assesses the current and future risks to the UK from climate change. It does not recommend the specific adaptation actions that are needed to reduce risk or take advantage of opportunities in the future. The report identifies specific areas where further action is felt to be needed most urgently, based on the available evidence, and it discusses the benefits of taking further action. But an economic appraisal of different actions is out of scope of this assessment.

The task for the UK Government and devolved administrations, following the publication of this third CCRA Assessment, will be to weigh up the costs and benefits of different options and set objectives and actions in the next national adaptation programmes, from 2023 onwards (see page 4). The cycle will then enter a new stage from 2027, when the fourth CCRA will be published (see figure 27).

Further outputs can be read alongside this summary, including a series of 17 briefings that summarise the risks to key sectors (these being Agriculture and food, Business, Cultural heritage, Energy, Flooding and coastal change, Freshwater habitats, Health and social care, High temperatures, Housing, Land use/land use change and forestry, Marine and coastal environment, Telecoms and ICT, Terrestrial biodiversity, Transport, Water availability, Wildfire and Young people).

Other outputs include the Climate Change Committee’s statutory advice to Government on the CCRA, in the form of a separate CCRA3 Advice Report, drawing on the evidence presented in the Technical Report. There are also summaries for the other UK nations and other resources, all of which are available on the UK Climate Risk website.

Figure 27: Summary of the UK adaptation policy cycle (taken from CCRA Technical Report Introduction).

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